UNITED STATES ATOMIC ENERGY COMMISSION

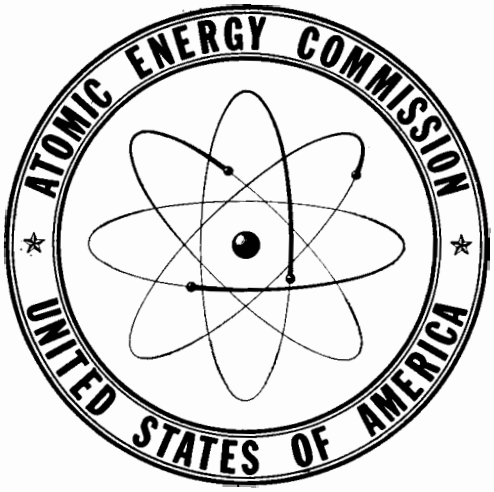
MAJOR ACTIVITIES

IN THE

ATOMIC ENERGY PROGRAMS

January–December 1959

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FOREWORD

The Atomic Energy Commission's Annual Report to Congress for 1959 consists of three parts and an appendix. The parts are:
Part One, The Atomic Energy Industry in 1959 and Related Activities.
Part Two, Major Activities in Atomic Energy Programs.
Part Three, Management of Radioactive Wastes.

Personnel

Commissioner John S. Graham, whose original appointment in 1957 expired June 30, 1959, was renominated by the President and confirmed by the Senate for a 5-year term expiring June 30, 1964.

Commissioner Willard F. Libby resigned effective June 30, 1959, and Dr. John H. Williams, formerly Director, Division of Research, was appointed by the President and confirmed by the Senate to fill the unexpired term, ending June 30, 1961.

Commissioner Vance

Commissioner Harold S. Vance died on August 31, 1959. In commemoration of Commissioner Vance, the Commission adopted the following resolution at its meeting on September 9:

"The Commission notes with sorrow the death of Harold S. Vance, our friend and colleague, on August 31, 1959.

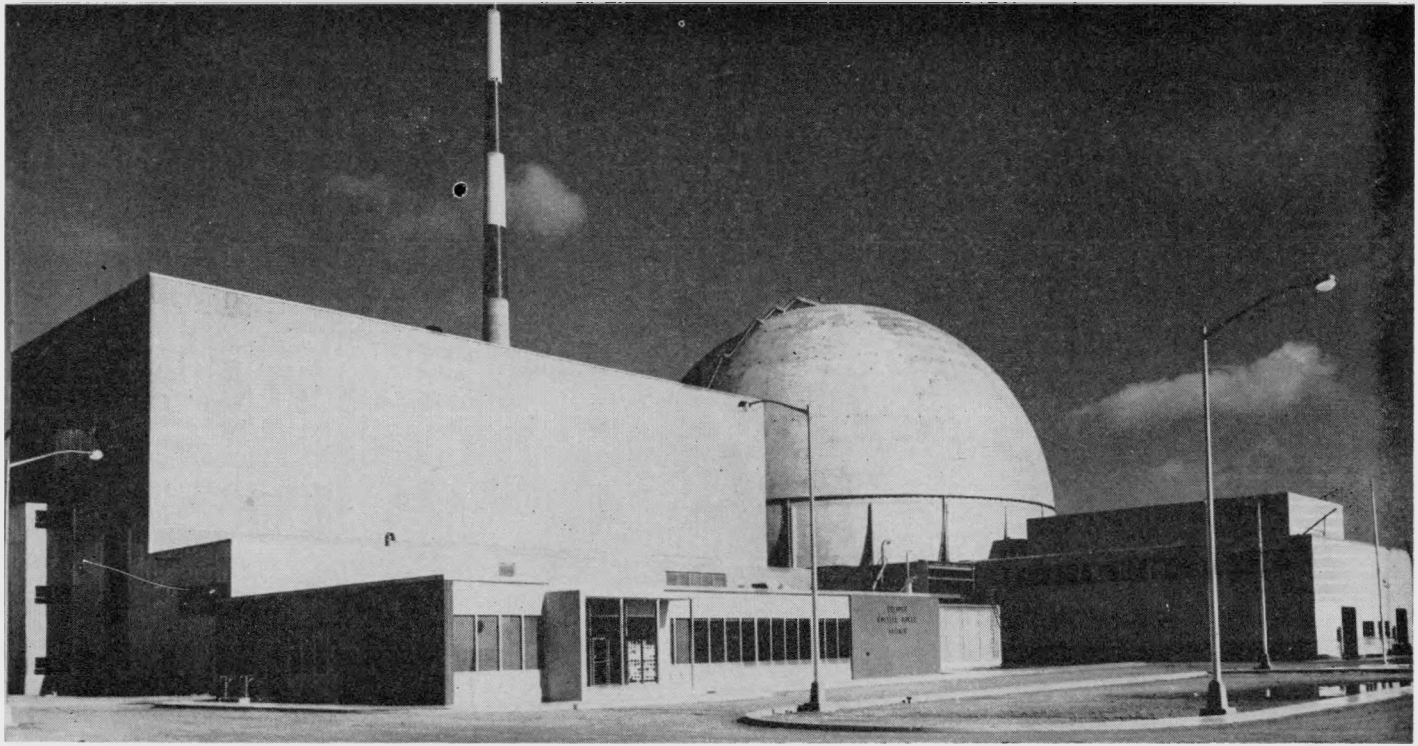
"Appointed in October 1955, Mr. Vance brought to the Commission from a long and distinguished career in American industry, a breadth of experience and depth of knowledge which proved of inestimable value to the Commission in its deliberations, especially at a time when the development of industrial applications of atomic power was receiving ever-increasing attention. The interest and support which Commissioner Vance brought to the Commission's civilian nuclear power program was based on the principle that 'we should move forward with all the vigor at our command in promoting peaceful uses of atomic energy, that we should do so in a manner which does no violence to our normal way of doing business in America.' The rapid growth and extension of atomic energy in industry during the last four years is in many ways a tribute to the work and thought of Commissioner Vance.

"While encouraging at home the participation of both public and private groups in the development of nuclear power, Commissioner Vance was keenly aware of the opportunities and need for United States support of similar programs abroad. His guidance was essential in formulating the basis for United States cooperation with EURATOM. He was likewise instrumental in developing arrangements for assistance to individual nations in the construction of research and power reactors.

"Over the years we have come to rely on Commissioner Vance's experience and wisdom for the incisive observation or enlightening summation which often led to the resolution of conflicting considerations. His friendship, understanding, and ability will be sorely missed by us all."

Part One

The Atomic Energy Industry in 1959 and Related Activities



Dresden Nuclear Power Station. The Nation's first large-scale, privately financed nuclear power station went critical on October 15, shortly after photo was taken. It is expected to achieve its full power generating capacity, 180,000 electrical kilowatts, during 1960. Owned by the Commonwealth Edison Co. of Chicago, it is located 40 miles southwest of that city. The boiling water reactor, which will produce 626 megawatts of heat, was designed by the General Electric Co.

I

INDUSTRY AND COMMISSION ACTIVITIES

Achievement of economically competitive costs for power from nuclear reactors is vital to continued United States leadership in the atomic field. Progress in this effort will pace the development of the atomic energy industry as a whole. In order to advance more rapidly toward competitive power costs, the Atomic Energy Commission will select and emphasize work to promote this progress, even at the expense of some less essential activities.

Plant costs and resultant power costs that could be achieved with present technology, as calculated at the end of 1959, are lower than those estimated as recently as a year ago. These new estimates result both from the further experience of building and operating powerplants, and from increasingly definitive analyses of the potential of various reactor concepts. To realize these potentials, the Commission has pledged itself to continue its cooperation with the atomic energy industry, to support the industry's efforts, and to press forward with effective development of power reactor technology.

An indication of the status of the industry is the fact that 18 civilian power reactors under construction or development as of September 30, 1959, involve industry and Government commitments of more than $717 million, divided about $465 million by industry, and $252 million by Government. Another $300 million similarly is involved in commitments on other civilian reactor projects under construction or development, including $170 million for the New Production Reactor at Hanford and $26 million on a maritime propulsion reactor.[1] On the 18 civil power reactors, about $240 million had been spent, and $477 million remained to be spent, as of September 30, 1959.

Military expenditures for reactors also contribute to industrial activity. In this category, there are commitments of $685.2 million, including nuclear propulsion plants for the Navy, but excluding projects for propulsion of aircraft.

The 180,000-kilowatt Dresden Nuclear Power Station, largest civil plant in the United States thus far, went critical late in 1959. Two

[1] Excluded from these figures are general research and development work not specifically related to a particular reactor, reactors for export, critical experiment facilities, and small training reactors shipped fully assembled. Projects already completed are omitted, as are projects that have not yet reached design stage. Details of these data are given in Part Two of this report, in the section on Programs Supporting Industrial Development.

more large power stations—the Enrico Fermi Atomic Power Plant, and the Yankee Atomic Electric Co. plant—are scheduled to reach criticality in 1960.

The N.S. *Savannah* was launched in July and is scheduled to begin tests in mid-1960 with sea trials to follow—the first nuclear merchant ship in the world.

The Commission in August signed a contract with the Philadelphia Electric Co. and General Dynamics Corp. in support of their proposed 28,500- to 40,000-kilowatt plant. The Consumers Power Co. of Michigan and General Electric Co. jointly proposed a new 50,000-kilowatt nuclear power station in December. Preliminary construction was begun on the Experimental Gas-Cooled Reactor at Oak Ridge, and on the New Production Reactor, at Hanford.

One new small power reactor is planned overseas—a 12,500-kilowatt plant in Japan. Euratom plans still have not crystallized, but one definitive proposal, the 150,000-kilowatt SENN powerplant in Italy, is being evaluated as part of the Euratom program.

Inventories of source and special nuclear material leased by the Commission, as shown by licenses issued during the fiscal year ended June 30, 1959, were up more than 200 percent over the previous year, reflecting in part the fueling of three major power reactors. As of the end of December, 465 reactor operators held licenses, of which 176 were issued during 1959.

Domestic production of uranium continued to increase and, coupled with imports, assured an adequate supply for Government and industry needs. Ore reserves increased.

The atomic energy industry as a whole maintained or increased somewhat its level of operations. One major corporation withdrew from the reactor field, but its staff, activities, and commitments were taken over by another organization. The number of companies supplying and servicing the private and Government industry generally continued at levels adequate to current needs, and some companies have diversified their activities.

The users of radioisotopes, and the volume of material distributed, continued to increase. The number of industrial users was up 16 percent above the previous year—a period when the Commission made some industrial licenses unnecessary by permitting use without a user's license of isotope gages produced and maintained under a specific manufacturer's license.

To plan more effectively the effort for achieving competitive nuclear power, which is a key factor in industry's continued growth, the Commission is evaluating reactor concepts and developing guidelines

for future research, development, and construction of power reactors, with particular emphasis on the period through 1968.

Early in 1959, after a review of studies by industry, by the staff of the Joint Committee on Atomic Energy of the Congress, and by a special ad hoc committee,[2] the Commission presented to the Congress a statement on the outlook for nuclear power. The policies for further power reactor development, presented at that time with a short-term program, have been followed during 1959.

The objectives, as presented to the Joint Committee early in 1959, are to—

- Reduce the cost of nuclear power to levels competitive with power from fossil fuels in high energy cost areas of this country within 10 years (by 1968).

- Assist friendly nations now having high energy costs to achieve competitive levels in about five years. This assistance is to be extended mainly through clearly defined programs of cooperation.

- Support a continuing long range program to further reduce the cost of nuclear power in order to increase the economic benefits and extend these benefits to wider areas.

- Maintain the United States position of leadership in the technology of nuclear power for civilian use.

- Develop breeder type reactors to make full use of the nuclear energy latent in both uranium and thorium, recognizing that uranium 235 alone may not be sufficiently plentiful to meet our needs over the long range.

To devote continuing study to detailed, long-range plans for accomplishing these objectives, the Commission inaugurated a special study in June. Specifically, this study will—

Determine specific technical objectives for each reactor concept being investigated.

Outline a chronological development program for each reactor concept, including research and development, fuel cycle development, plant construction, and operation.

Evaluate the economic potential of each reactor type, taking into consideration the time schedule and the total estimated cost for development and construction required for each reactor type to reach maturity.

[2] See p. 18. Twenty-fifth Semiannual Report to Congress (July–December 1958).

Delineate a program to encourage the development of promising new concepts and reactor types, as well as major modifications of existing concepts.

Establish yardsticks for measuring the rate and degree of development for each reactor type.

The resulting 10-year program will receive continual review as it progresses and will be modified as indicated by developments.

The Commission completed an evaluation of the current technical and economic status of these reactor concepts: pressurized water, boiling water, sodium-graphite, organic-cooled, fast breeder, heavy water-natural uranium, gas-cooled, and aqueous homogeneous thermal breeders.[3]

An analysis also has been made of the technical gains which could be foreseen for each reactor concept over the next several years, the work programs estimated to be required to achieve these gains, and the reductions in cost of power that could result.[4] In these studies, the Commission has had the assistance of industry, and of its contractors.

Preliminary conclusions of these studies, still subject to Commission analysis and review, were that costs of power from reactors built on the basis of today's technology, would range from 9 mills to 13 mills per kilowatt hour. In general, this means that, on the basis of today's technology, no reactor plant of 300,000 electrical kilowatts capacity could be built in the United States to be competitive with a modern conventional plant of equivalent size in which fuel costs were less than 54 cents per million B.t.u. (British thermal units.) Fuel costs as high as these for conventional plants prevail in only a very few isolated areas of the United States.

The studies indicate that, under very optimistic assumptions, it is possible to project development and construction programs which might be expected to bring the cost of power from certain reactors types—light and heavy water reactors, organic-cooled reactors, sodium-cooled reactors including fast reactors and those moderated with graphite—down to a range of 7 to 8.5 mills per kilowatt hour. At these costs, the reactor systems could become competitive with conventional plants using fuel costing from 35 to 40 cents per million B.t.u., which constitute some 20 to 25 percent of existing installed capacity of United States utility systems.

The development programs necessary to attain these ends would vary over a wide range depending on the current state of development

[3] "Summary of Current Status of Reactor Concepts," scheduled for publication February 1960, Superintendent of Documents, Government Printing Office.

[4] "Economic Potential and Development Program," scheduled for publication early in 1960.

of each reactor concept. The time at which commercial reactors could be built, based on each concept, would vary in the same way.

Current development work and accomplishments on civil power reactors is described in the second chapter of this part of the Annual Report.

International Activities

During 1959, the United States continued to broaden its cooperation with other countries in the peaceful uses of atomic energy. The agreement between the United States and the six-nation European Atomic Energy Community, for joint research and development, and for construction of power reactors, went into effect February 18. An Agreement for Cooperation with the International Atomic Energy Agency went into effect August 7. The Inter-American Nuclear Energy Commission was established April 22. The United States increased its participation in the programs of the Organization for European Economic Cooperation. Two new bilateral agreements went into effect this year.

United States industry has continued to expand its commercial arrangements with enterprises in other countries—at least 8 more such arrangements were announced during 1959 in addition to the 30 previously listed—in order to promote the sale of United States research and power reactors, fuel elements and other components, and to provide engineering and consulting services.

Foreign demand for United States research reactors, and for other equipment associated with research and development work continued. The value of research reactors authorized for export during 1959 was estimated at about $5.4 million—up about $2.4 million from 1958. The Commission was informed of new plans of cooperating countries to build 3 reactors in addition to 20 operating and 21 under construction.

Three United States-built power reactors are being constructed and two more are being planned outside the Euratom program, one in Italy and one in Japan; India plans to step up its program. The United Kingdom is continuing its program of constructing reactors to produce 5 million to 6 million kilowatts of nuclear power by 1966. The Soviet Union appears to be stretching out its power reactor construction program.

In some regions, notably in western Europe, economic and political developments lessened the urgency for immediate construction of large-scale nuclear powerplants. Developments included the continuing flow of oil from the Middle East, accumulating surpluses of coal, the beginning of exploitation of oil and natural gas in the Sahara, and a mild slackening in industrial activity. The small num-

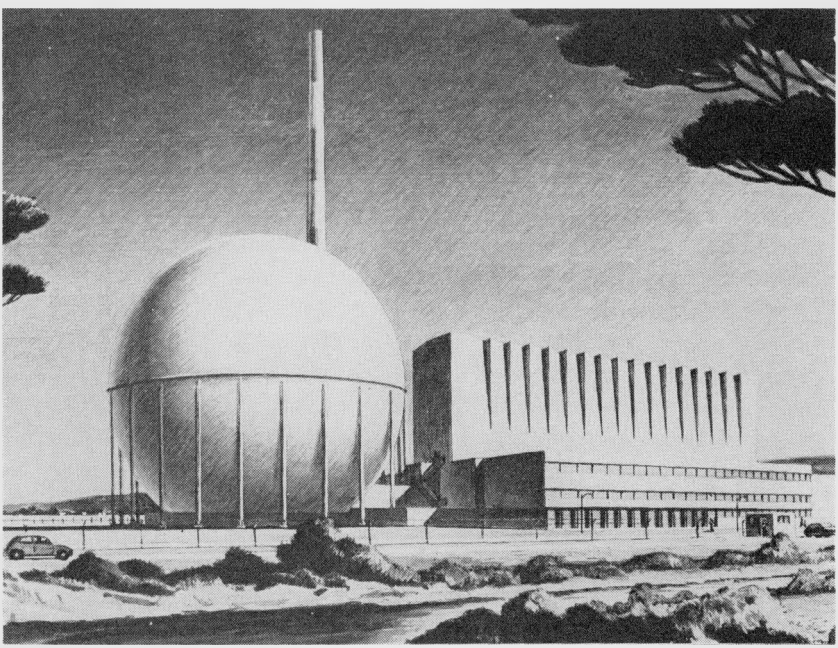
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ber of proposals for construction of power reactors, mostly tentative, in the joint United States-Euratom program reflected these developments. But interest in competitive nuclear power to supplement other European sources continued, a s indicated by the large volume of proposals for research and development work looking toward producing power at competitive costs.

A long-term credit of $135 million was authorized by the Export-Import Bank for Euratom to reloan to participating utilities building power reactors. The International Bank for Reconstruction and Development lent $40 million for the SENN powerplant in Italy.

In February, the Commission announced provision of a deferred payment arrangement for power reactor fuel supplied to non-Euratom countries. This policy, applying to projects whose combined generation capacity does not exceed 500,000 kilowatts, will greatly reduce the initial capital cost of purchasing fuel inventories.

Since world interest appears strong in more intensive development of small and medium power nuclear reactors, the United States has



First Euratom reactor proposal. First definitive proposal for a large-scale nuclear power station under the joint Commission-Euratom program was made by the Societa Elletronnucleare Nazionale (SENN) of Italy. The prime U.S. contractor is International General Electric which is designing a dual-cycle boiling water reactor, somewhat similar to the Dresden Nuclear Power Plant reactor, for the 150,000 electrical kilowatt plant to be built near Naples. Above is artist's conception of plant.

invited the International Atomic Energy Agency to participate in the current Commission program to develop a small power reactor.

Programs Supporting Industrial Growth

The main Commission programs supporting industrial growth are described in other sections of the report—civil power reactor development program, research and development in the entire nuclear field, and the isotopes development program. In other highlights of 1959, the Commission—

Began negotiations with a private company in response to its proposal to build a test reactor, leasing a portion of its space to the Commission for a period of 5 years.

Focused the responsibility for commercial contracts to recover unirradiated scrap from the major Federal reactor development programs.

Undertook further studies looking toward private operation of a fuel element chemical processing plant.

Initiated a study by industry, with Commission cooperation, of the value and cost of production of special nuclear materials to provide industry with assurance on these cost factors essential to its own plans.

Industrial Laboratories' Share of Federal Reactor Work

Reactor development work conducted for the Commission by private industrial organizations, chiefly in their own facilities, amounted to $72.7 million, or about 22.3 percent of the total spent by the Commission for reactor development of this type during the fiscal year that ended June 30, 1959. This represented an increase in dollar volume of 45.1 percent over the level of the previous 12 months; work at Commission laboratories, universities, and other Government nonprofit institutions, increased by 5.5 percent in the same period.

During the fiscal year that will end June 30, 1960, the industrial share of expenditures was expected to increase an additional 38 percent, to about $100 million—nearly 27 percent of the Commission's appropriation for these purposes.

The Commission will continue to place appropriate reactor development contracts with industry in line with its policy of strengthening and broadening private participation in the atomic energy field.

Fuel Supply

United States production and importation of raw materials and production of special nuclear materials continued during 1959 at levels adequate to meet industry and Government requirements, including commitments to foreign countries.

The United States was the free world's leading producer of uranium. The volume of ore mined and milled continued to increase as new mills were brought into operation pursuant to the Commission's public announcement of April 2, 1958.[5] At the same time, efforts were continued to defer delivery of some of the uranium under contract in order to bring supply more nearly in balance with requirements. The Commission notified Canada that it would not be in a position by March 31, 1961, to exercise any of its options to purchase additional uranium concentrates in the period following expiration of the contracts in 1962 and 1963. A stretch-out of current purchases under existing Canadian contracts was announced in November. The Commission a lso discussed with domestic producers the postponement to the 1962–66 period of some contracted-for deliveries.

The amount of ore developed during the year in the United States exceeded the total mined, the net increase as of December 31, 1959, being 4 percent over the previous year, according to preliminary estimates.

At the year's end, the Government closed down the only Federally owned uranium mill. Additional milling capacity in two of the five areas which had developed reserves, but an inadequate market, was assured through the negotiation of new contracts, in accordance with the program announced April 2, 1958. In the remaining three areas, basic terms of contracts involving construction of new milling capacity have been discussed but as yet no agreements have been concluded. Also during the year, modifications of five existing contracts extending the terms into the post-1962 period were executed. Extensions of other contracts are being negotiated.

Production of special nuclear materials continued essentially on schedule. Production of feed materials for the gaseous diffusion plants that concentrate uranium 235 from the natural uranium began in April in a privately owned plant under a fixed-price contract.

Industrial Isotopes

The Commission's program to develop greater public benefits from industrial applications of radioisotopes and high-intensity radiation

[5] See pp. 5–6 and 352–365, Twenty-fourth Semiannual Report to Congress (January–June 1958).

sources got fully underway during 1959. The Commission is issuing a special report, "Radioisotopes in Science and Industry," which will be made available to the Congress and placed on public sale during the first part of 1960. It also has issued a study by the National Industrial Conference Board on the economics of radioisotope applications in industry.[6]

The Commission authorized some 70 contracts for isotopes and radiation investigations, has launched a training program to broaden knowledge of isotope techniques, and has engaged the services of 5 laboratories to perform basic isotopes research. The studies under Commission contracts are developing basic information and techniques which engineers of industrial and other organizations may apply to specific problems.

Industry's interest in further use of isotopes is indicated by a 16-percent increase during 1959 in the number of licenses issued for their use. Wholesaling of isotopes to some 150 processing and retailing firms gives some indication of the extent of use. Quantity of radioactivity per shipment increased some 15 percent during 1959, in spite of the fact that sales of high-activity cobalt 60—widely used in nondestructive radiographic testing in industry—was some 10 percent below the previous year. Total curies sold for all radioisotopes increased at a lower rate than during the previous year—up about 20 percent as contrasted with 37 percent in 1958. If cobalt 60 is excluded from the calculation, the 1959 increase in use of isotopes, as measured by curies, was 110 percent above the previous year.

Information for Industry

The Commission followed through in 1959 with its policy of making promptly available, through sale to the public and to industry, all technical information which can be exempted from the controls necessary for the national defense and security.

Types of information newly declassified include large areas of production information, including production chemistry and technology, and recovery of nuclear materials from reactor fuels. Considerable additional material on military reactors also was made available.

It still was not possible, for reasons of national security, to declassify all information now available to those holding access permits permitting access to certain restricted data. The number of active access permits declined during 1959.

[6] "Radioisotopes in Industry," Office of Technical Services, Department of Commerce, December 1959. $2.75.

In the Commission's programs for review of classified documents in the light of policy changes since 1955, a total of 49,450 items was considered, of which 19,992 were declassified and 10,342 were given lower classification. Review and declassification when possible, of the files of former Commission contractors, was continued.

The Commission carried out a vigorous publication program, not only of recently declassified material, but of the larger volume of newly developed unclassified information. New automatic machine indexing procedures were developed to help make abstracts of scientific and technical documents more readily available. Foreign exchanges have increased sharply, and translation programs correspondingly were expanded. A public document room was established at Hanford to provide access to developing information on the new production reactor being built there with its feature of convertibility to production of electricity. Much of the information is unclassified.

Health and Safety

During 1959, the Commission revised its headquarters administration of key programs for protection of health and safety by establishing the office of Assistant General Manager for Regulation and Safety, with responsibility for regulatory and licensing programs, licensee compliance with safety requirements, health and safety programs in general, and cooperation with the States in this field. An Office of Health and Safety was established to develop and recommend standards and procedures on radiation and to serve as a focal point for State cooperation. The functions involving direct inspection of licensees will be placed under the Assistant General Manager by transfer from the Division of Inspection. The Division of Inspection continues to report directly to the General Manager and has authority to investigate independently all serious incidents, to perform independent inspections of both licensed and Commission activities and to develop Commission policy in these areas.

The Commission inaugurated a policy of providing for hearings on certain Commission reactor projects in procedures that parallel those for licensing of private reactors.

During 1959, the Commission completed the first of its new annual surveys on radiation exposures of workers in its operations, and the results demonstrated again the low levels that are possible with proper planning, procedures and care (Part Two, pp. 270–272).

The Commission continued its policy of issuing to the public as promptly as feasible new information on fallout from weapons ex-

periments. Quarterly reports were published in the current findings on levels of fallout.

Inspections carried out during the last three and a half years found fewer than 2 percent of licensees in noncompliance with standards that involved matters of possible exposures, excessive radiation, or measures to be taken when exposures occurred. In some 43 percent of about 5,500 inspections, items of technical noncompliance were found involving administrative provisions of regulations or conditions of licenses such as labeling and posting requirements. The Commission moved to correct problems arising in release of wastes from uranium mills, and in connection with the unauthorized use of imported strontium 90 in watch and clock dials.

These, and other matters involving health and safety, have been reported to the Joint Committee on Atomic Energy of the Congress. Extensive testimony and reports have been made to special subcommittees on handling of radioactive wastes, and on fallout from weapons tests. A special report on "Radioisotopes in Science and Industry," being issued early in 1960, covers the precautions the Commission enforces in the multiple uses of these products. Other sections of this Annual Report to Congress deal with research and dissemination of information on fallout (pp. 239–266), the management of radioactive wastes (Part Three), and the continuing program of research in the life sciences which supports and guides policies and standards for the protection of public health and safety (pp. 187–239).

Indemnity Activities

During 1959, the Commission published for public comment a revision of its regulation governing Federal indemnity of public liability in the operation of reactors, and undertook a study to determine whether Federal indemnity should be extended to nonreactor licensees using special nuclear materials.

Interim indemnity agreements have been made with 43 reactor licensees, and most major installations operated by Commission contractors now are covered. Transportation of radioactive materials for the Commission is included.

European countries, and the international organizations with which the United States is associated, or which it is assisting, progressed with their discussions and drafting of liability conventions. In the case of the Organization for European Economic Cooperation, a draft convention is scheduled to be submitted to member states during 1960. Methods and procedures for handling public liability problems con-

nected with operation of the N.S. *Savannah* in foreign commerce were studied by the Commission-Maritime Administration team working on problems associated with the *Savannah's* use in world commerce.

Federal-State Cooperation

The Commission took action under Public Law 86–373, effective September 23, 1959, to develop criteria which may be used to determine the adequacy and compatibility of State programs where States wish, under the provisions of this amendment to the Atomic Energy Act of 1954, to take over responsibility for regulating less hazardous uses and quantities of radioactivity. The Commission also prepared to advise States, on request, on types of legislation that would be compatible with Federal responsibility and provide adequate safeguards.

The Commission continued its policy of informing State officials whenever atomic energy licenses were issued or facility licenses applied for, in their States, and of encouraging joint inspection of licensees.

Training programs in radiation control for States' employees with year-long courses at two universities continued during the year. A shorter intensive course is being planned. Instruction of police and fire officials continued during 1959. Through its Radiological Assistance Plan, 35 teams, administered through 8 of the Commission's Operations Offices, are available to provide assistance, when requested, during any civil radiological incident. They cover not only all States, but also Puerto Rico, the Canal Zone, and the Virgin Islands. This is in addition to similar arrangements made by the Department of Defense with reference to any military radiological incidents.

II

PROGRESS IN POWER REACTOR TECHNOLOGY

In the course of the Commission's evaluation and appraisal of its reactor development efforts, certain fundamental emphases were determined. The Commission decided that, as among the three general phases of reactor development—research and development, including reactor experiments; prototype construction; and construction of commercial units—more emphasis should be placed on the construction of prototype reactors. These prototypes can serve the dual purpose of producing power and of furnishing essential technical and economic information. They will be designed to provide data on plant construction costs and statistically significant information on efficiency, performance characteristics, and other operating factors in a manner which will permit reliable projection toward large central station powerplants.

To assure meeting program objectives, the Commission has taken responsibility for leadership in the prototype and research and development phases of the program. It is determining the concepts for which additional prototypes should be constructed, selecting the approximate size and conceptual design best suited to accomplishing basic objectives, establishing schedules for construction and operation, and assuring that the prototypes are operated in the manner most useful to progress in the program.

The Commission is taking into full account the efforts of industry, recognizing that various public and private utility and industrial groups will carry out ever increasing developmental, construction, and operational activities. The utility industry has been encouraged to make unsolicited proposals which could lead to construction of nuclear powerplants. If it is determined that projects proposed under this system may make a significant contribution, Commission research and development assistance and waiver of fuel use charges may be provided.

The civilian power program was enlarged during the year by the authorization (Public Law 86–50, June 23, 1959) of several new reactor projects, including an experimental organic-cooled reactor and an experimental prototype gas-cooled reactor. These two reactors will

be built under the Commission's experimental program. In the cooperative program with industry, research and development assistance was authorized for an advanced high-temperature gas-cooled prototype reactor. The Commission was also authorized to supplement the second and third rounds of its Power Reactor Demonstration program and to consider undertaking as cooperative projects, a boiling water prototype reactor of 50,000 to 100,000 ekw. (electrical kilowatts) capacity, a small-size pressurized water reactor, and two undesignated intermediate-size reactors. If no satisfactory proposals are received from industry for any of these projects, the Commission may then, if the project still is deemed desirable, proceed with the design, construction, and operation of prototypes at its installations.

Provision also was made for construction by the Commission of an experimental low-temperature process heat reactor which could involve participation in a cooperative project, and for a nuclear superheat reactor, either under the Commission's experimental program or under its cooperative program. The Commission will build the process heat reactor in California as a part of a salt-water distillation plant planned by the Department of the Interior.

In addition to providing for these new projects, the Authorization Act provided for alterations to the Shippingport Atomic Power Station which will permit the testing of improved cores, increasing potential electrical output from 60,000 ekw. to 135,000 ekw.

Progress on a new production reactor designed for either plutonium production, or for dual purpose operation—production of plutonium and power—or for conversion to power use, authorized the previous year (Public Law 85–590) is described in a following section of this report on "Production of Special Nuclear Materials." Licensing actions and hearings involving reactors are reported in Appendices 10 and 11.

Summaries of Reactor Project Activities

Pressurized Water Reactors

Shippingport (Pa.) Atomic Power Station. The Shippingport station is the first large-scale (60,000 ekw. net) nuclear power electrical generating station in the United States. The reactor achieved criticality in December 1957, and in the ensuing period demonstrated the operability of such a plant as part of a utility system. Valuable information was obtained on core performance and the effects of extended high-power operation on various plant components.

Alterations to the Shippingport plant to increase the electrical out-

put from 60,000 to about 135,000 kilowatts are under consideration contingent upon increase by Duquesne Light Co. of turbogenerator facilities to handle the additional output.

The Shippingport plant did not operate in the first month of 1959 while repairs to the turbine and turbine moisture separator continued. It was returned to full power on February 4, when it began an extended high-power run. This run was completed on May 21. A total of 2,150 equivalent full-power hours were expended during this period at a load factor of about 85 percent. During June and July, the plant operated to provide power in accordance with the requirements of the Duquesne Light Co. system and for various tests and routine plant maintenance. The plant was operated at full power during the visit of Frol Kozlov, Soviet First Deputy Premier, on July 11.

A full-power run was conducted from August 11 to September 5, before the reactor was shut down for periodic physics tests. It was started up again on September 16 and continued at power until October 7 when the life of the first seed of the first core ended. At that time the reactor had expended 5,800 equivalent full-power hours of operation on the first seed of Pressurized Water Reactor Core 1, compared to a design estimate of about 3,000 full-power hours. The plant produced 388,500,000 gross kilowatt hours of electricity in its first 2 years of operation. Refueling operations began in November and continued through the remainder of the year.

Large reactor stations. Other large-scale pressurized water plants now under construction include the facility being built under the Commission's Government-industry cooperative Power Demonstration Reactor Program by the *Yankee Atomic Electric Co.*[7] at Rowe, Mass., and the privately financed plant of *Consolidated Edison Co.* of New York, at Indian Point, N.Y.

Construction of the Yankee project began in November 1957. The design features of this plant include significant variation from the Shippingport station which will improve the basis for evolution and planning for future development of this type of reactor. As of December 31, plant construction was estimated to be approximately 70 percent complete and on schedule.

Completion of the Consolidated Edison plant, originally scheduled for 1960, has been rescheduled for 1961. Total cost of construction now is estimated at $107.5 million, an increase of $10 million over the estimate a year ago. The increase is due partly to price

[7] Details on this and other reactors are given in Appendix 14.

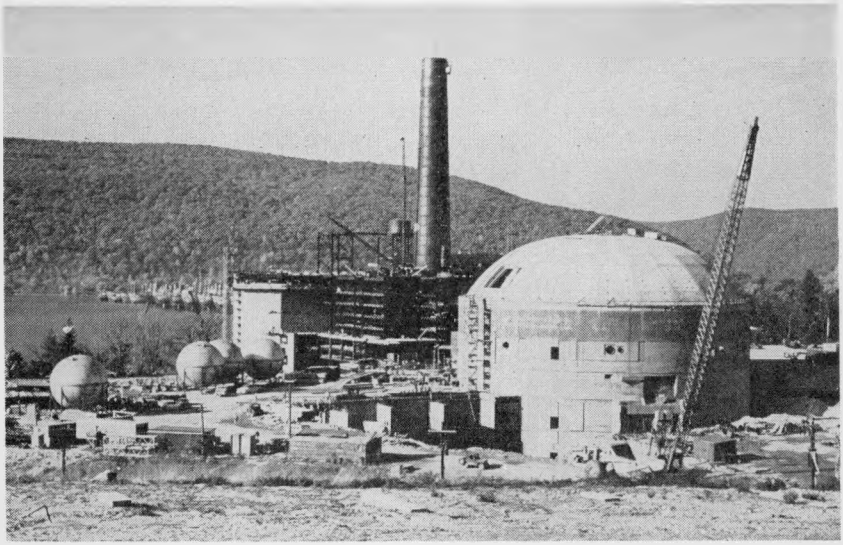


Yankee Atomic Electric power plant. The 110,000-kilowatt (electrical) nuclear power station being built at Rowe, Mass., is more than 70 percent complete and expected to begin operation during 1960. Photo shows plant as of September 30, 1959. The plant, which will use a pressurized water reactor (housed in partially-hidden sphere), is being built by the Yankee Atomic Electric Co. under a cooperative contract with the Commission.

escalation and partly to changes designed to increase plant output.

New private reactor. In January the *General Public Utilities Corp.* announced its plans to build a small developmental pressurized water power reactor at the Saxton, Pa., generating station of its subsidiary, the Pennsylvania Electric Co. The reactor is expected to have a design capacity of about 5,000 ekw, and be capable of being used for testing purposes under limited boiling water conditions. The Westinghouse Electric Corp. will design and build the reactor, furnish fuel loadings, and have primary responsibility for the research and development program. Gilbert Associates, Inc., is Westinghouse's subcontractor to construct the facility and to provide architect-engineer services. Construction is scheduled to start in February 1960, with initial operation planned for early 1962.

Small power reactor. In June, the Oak Ridge Operations Office completed a feasibility study to determine the most promising small reactor type for supplying efficient and reasonably economic power for various isolated areas in this country and abroad. The study recommended a 22,000 ekw. capacity pressurized water reactor utilizing a fossil fuel superheater.



Consolidated Edison reactor plant. Completion of the 255,000-kilowatt (electrical) pressurized water reactor power station (151,000 ekw. nuclear) has been re-scheduled for 1961 by the Consolidated Edison Co. of New York. Photo shows the plant during the summer of 1959. The privately financed generating facility is located at Indian Point, N.Y., on the Hudson River. The reactor will use a fuel composed of highly-enriched uranium mixed with thorium.

While the study showed a small-size boiling water reactor was equally feasible, the Committee felt that the objectives of the study project could be better served by focusing additional effort on the pressurized water concept.

On August 4, the Commission invited proposals from cooperative and public power organizations for participation in such a small size prototype pressurized water reactor project under its Power Demonstration Reactor Program. The small reactor is to have a capacity of 16,500 kilowatts ekw. which could be increased to 22,000 ekw. by the installation of a conventional superheater, under the original invitation, at the option of the proposer. Subsequently, on October 30, the proposal invitation was revised to make the superheater a mandatory feature of the proposed reactor.

The organization selected for the reactor is expected to provide, at a minimum, the plant site, turbogenerator facilities, and associated buildings and services, as well as to assume the responsibility for the operation of the entire plant for the Commission's account, to purchase reactor-produced steam from the Commission, and to participate in the training of operating personnel. Construction of the reactor is scheduled to begin in June 1960 and to be completed 2 years

later. Five proposals had been received by December 21, the closing date under the invitation.

On September 2, the Commission announced that Gibbs & Hill, Inc., of New York City, had been selected, from among 13 organizations which submitted proposals, to provide architect-engineer services for the project. The services will include the conceptual design for the nuclear reactor portion of the plant. The contract also includes an option for titles I and II design.

Boiling Water Reactors

BORAX. The feasibility of boiling water reactors has been demonstrated by the Boiling Reactor Experiments (BORAX 1–4) at the Commission's National Reactor Testing Station in Idaho under the direction of the Argonne National Laboratory. *BORAX-5*, the fifth in this series of experimental reactors, will be constructed primarily to demonstrate the safety aspects and feasibility of an integral nuclear superheat system. The reactor will have a heat capacity of 40 Mwt. (megawatts thermal). An architect-engineering design contract was let with the Norman Engineering Co., Los Angeles, in March. Construction was started in December by Arrington Construction Co., with reactor startup scheduled for October 1960.

Experimental Boiling Water Reactor (EBWR). The Experimental Boiling Water Reactor at Argonne National Laboratory, operating since late 1956 with a rated capacity of 20 Mwt., was being modified during 1959 with the objective of approaching as nearly as possible an output of 100 Mwt. Plant modification is to be completed in September 1960; however, the modification schedule is such that limited power—up to 40 Mwt.—operation can begin in April 1960.

Operation at the higher power level will permit exploration of stability limits of small natural circulation boiling reactor cores at power densities greater than have heretofore been achieved.

Plant modifications also will make it possible to evaluate riser and chimney effects in the coolant-moderator on the natural circulation rate and to evaluate fuel concepts and auxiliary plant problems. The reactor was shut down on July 3 to begin the modification. Sargent and Lundy of Chicago is providing architect-engineer services for the nonnuclear portion of the plant modification.

Vallecitos Boiling Water Reactor (VBWR). The General Electric Co. reactor near Pleasanton, Calif., increased thermal output from 20 to 30 Mwt during 1959 and authorization has been granted for operation at 50 Mwt. During the reporting period, the reactor con-

tinued to supply steam into the Pacific Gas and Electric Co.'s 5,000 ekw. generator.

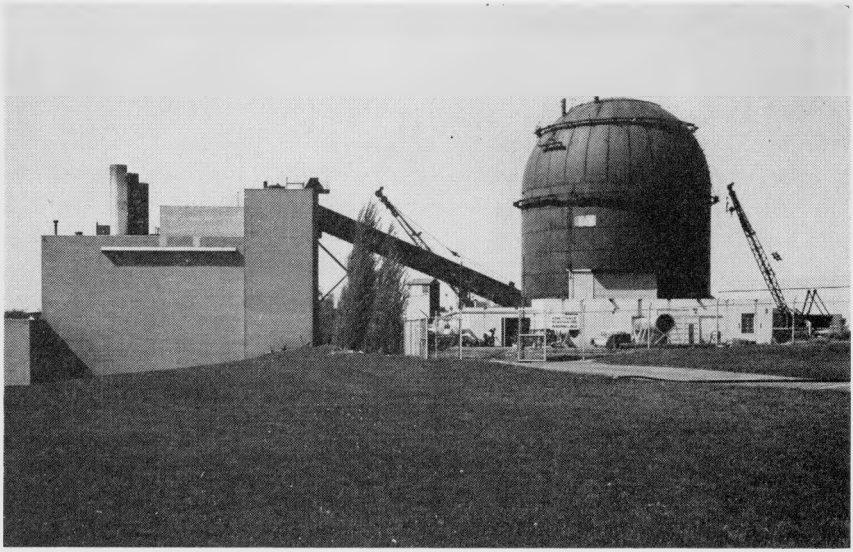
The General Electric Co. announced on May 6 that steam, superheated by atomic power, had been produced in the Vallecitos reactor. In an experiment, saturated steam at 544° F. was fed back into the reactor core in a special loop and superheated to an outlet temperature of 775° F. This initial experiment successfully demonstrated the technical feasibility of nuclear superheat.

Dresden nuclear power station. Engineering data obtained from operation of the Vallecitos reactor are being used in support of the 180,000 ekw. privately financed reactor which General Electric designed for the Commonwealth Edison Co. of Chicago. Bechtel Corp. is providing architect-engineer construction services for the plant. The Dresden nuclear power station, the largest all-nuclear power station so far announced in the United States, was essentially completed in September, several months ahead of schedule. The reactor went critical on October 15, although it was later shut down for modification of control rod drives, and is expected to reach full power in the spring of 1960.

Humboldt Bay plant. Bechtel Corp. and General Electric also are working together on the privately financed 47,000 ekw. plant planned by the Pacific Gas and Electric Co. at Humboldt Bay, Calif. Bechtel is the prime contractor for engineering and construction on a fixed price basis. The reactor, turbine, generator and electrical auxiliaries are to be furnished by General Electric. The preliminary design was completed in June. Construction is scheduled to begin in April 1960, with criticality scheduled in July 1962.

Cooperative projects. Boiling water reactor projects to be built under the Power Demonstration Reactor Program include the 22,000 ekw. plant for the Rural Cooperative Power Association at Elk River, Minn., and the 62,000 ekw. plant for the Northern States Power Co. at Sioux Falls, S. Dak.

The Elk River plant is being designed and manufactured by the Allis-Chalmers Manufacturing Co.; this company having absorbed the nuclear division of ACF Industries, Inc., the former prime contractor. Sargent and Lundy is providing architect-engineer services and Maxon Construction Co. is performing the construction, both under subcontracts to Allis-Chalmers. This reactor will provide physics, heat transfer, irradiation, and performance data on urania-thoria fuel, and cost data on a small plant using an indirect, natural



Elk River plant. The containment vessel for the boiling water reactor of the 22,000 electrical kilowatt power station being built for the Rural Cooperative Power Association at Elk River, Minn., was nearly completed when this photo was taken in May, 1959. The reactor, scheduled to start up in 1961, is being built by the Commission in a cooperative agreement with the Association. On left of photo is a coal-fired steam plant which already is in operation by the Association.

circulation, boiling water reactor coupled with a separate coal-fired superheater. In the first half of 1959, at the request of the Commission, Allis-Chalmers made a study of alternate core designs for this reactor in an effort to incorporate improved control features. As a consequence of the study the control rod blade span was increased, resulting in approximately 42 percent additional control surface in the reactor. This eliminates the need for auxiliary control in the form of boric acid injections into the coolant and results in a core design with potentially lower fuel costs. These design changes were obtained at no additional cost to the Commission.

Field construction was proceeding satisfactorily until the latter part of the year when the strike in the steel industry began to affect equipment deliveries. The supplier of the reactor pressure vessel was shut down by a strike in September. Delayed deliveries and fabrication difficulties may cause the plant construction schedule to be set back by approximately 2 months.

The Northern States Power reactor, known as the *Pathfinder Plant*, is being designed by Allis-Chalmers also, with Pioneer Service and Engineering Co. as the architect-engineer. This project will

provide data on performance and costs for a direct-cycle boiling water reactor with integral nuclear superheat. In April, the Commission modified its contract with Northern States to provide for $2.5 million additional research and development support to incorporate a nuclear superheater into the plant. The contract modification also provides for support of an additional $800,000 by waiver of fuel use charges. The total estimated cost of the project is $33.9 million of which the Commission will provide $10.3 million. Site preparation for the Pathfinder plant began in November.

To obtain physics data relating to design of the reactor, a critical experiment facility was constructed at Greendale, Wis., by Allis-Chalmers. The facility was completed and became critical in November.

A new proposal. On June 19, the Consumers Power Co., of Jackson, Mich., announced plans to construct a high power density boiling water prototype reactor. The Consumers project is to be a 50,000 ekw. direct-cycle, forced-circulation boiling water reactor located at Big Rock Point in northern Michigan. The technical specifications of the project closely parallel those of the high power density reactor planned by the Commission. After preliminary discussions were held by the Commission with Consumers representatives, that company and the General Electric Co. submitted a joint proposal in December requesting Government financial support for research and development and for the waiver of fuel use charges. General Electric would design and supply the nuclear system. This proposal was being evaluated and negotiations were underway at the end of the year.

Improved cycle boiling water reactor. The Commission announced at the end of December that it would extend a proposal in January for proposals to construct and operate a boiling water reactor having an improved steam cycle. The prototype reactor, called the Improved Cycle Boiling Wated Reactor, will have a minimum capacity of 50,000 ekw. The invitation, extended under the Power Demonstration Reactor Program, will be in two parts. First, proposals will be invited from publicly and cooperatively owned utilities to provide the site and the conventional portion of the plant, to operate the entire plant, and to purchase all the steam produced. Second, the Commission will invite industry to submit proposals related to the design, development, and construction of a reactor which will meet required specifications. It is anticipated that the improved design of the plant will eliminate the physical complexity of the indirect cycle system without sacrificing its advantages. If no acceptable proposals are received,

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the Commission intends to proceed with construction of this reactor.

Puerto Rico study. The General Nuclear Engineering Corp. is continuing analytical work on the Boiling Nuclear Superheat Reactor (BONUS) project of the Puerto Rico Water Resources Authority. The purpose of this study is to determine the pertinent problems involved in utilizing nuclear superheat and to generate a preliminary design for a small prototype plant. The company submitted an interim report summarizing the status of the project as of March 1. The Commission forwarded this report to the Joint Committee on Atomic Energy on March 19. The final study report was completed in December 1959, at which time the Commission authorized the negotiation of a contract with the Puerto Rico Water Resources Authority on the basis of a revised proposal which the Authority submitted in October. The contract was signed on January 12, 1960.

Nuclear Superheat Development

The Commission evaluated nine proposals received from industry in April for performance of engineering development work leading to concepts and materials most suitable for power reactors of advanced design capable of nuclear production of superheated steam. In July, cost-plus-fixed-fee type contracts totaling approximately $4.3 million were awarded to two firms, the General Electric Co. and Combustion Engineering-General Nuclear Engineering Corp. The combined effort of these contracts is to develop a nuclear superheat technology for 1,505° F. steam at 1,200 pounds per square inch pressure.

Organic-Cooled Reactors

Work on the organic-cooled reactor program has consisted of the base research and development program, construction and operation of the Organic-Moderated Reactor Experiment, research and development, design and preliminary construction of the Piqua, Ohio, Organic-Moderated Reactor, and a conceptual study and initiation of design on an Experimental Organic-Cooled Reactor.

The base research and development program provides the technology needed to develop organic-cooled power reactors. Work is being performed on forced convection and boiling heat transfer, fuel element development, coolant technology, process system development, and advanced engineering.

Organic-Moderated Reactor Experiment (OMRE). Operation of this reactor experiment, located at the National Reactor Testing Station, and the research and development necessary to analyze and in-

terpret its results, have been under way for 2 years. The OMRE has fulfilled its primary purpose of establishing the feasibility of operating this type of reactor. The reactor has been operated with a number of different concentrations of decomposed organic material in the coolant, and at various outlet temperatures, in order to determine the variations in decomposition of the organic material produced by changes in these conditions and the effect of decomposition product concentration on heat transfer.

While no serious problems have been uncovered as a result of these operations, some difficulty has been caused by rust particles in the circulating coolant. These particles blocked the coolant inlet passage. It is believed that part of this rust was in the system as fabricated and the initial cleanup operation failed to remove it. The remainder was probably introduced with the coolant, for no attempt was made, originally, to purify the coolant before admitting it to the reactor. The reactor was shut down throughout the first part of this reporting period for filtration and purification of the coolant to remove the rust particles and for installation of filtration apparatus. As only 2 months of life then remained in the OMRE first core loading, it was decided to install the second core during the outage.

On May 9, the reactor achieved criticality with the second core loading of 20 fuel elements. In the following weeks, 14 additional fuel elements were loaded, including 3 test elements for the City of Piqua reactor. At a constant flow rate, the installation of the three Piqua test elements resulted in a decrease in coolant velocity through the OMRE fuel elements which, in turn, resulted in a decrease in the operating power of the reactor. Unusual temperature distributions also resulted from the core changes. On August 25, after 442 megawatt days of operation on the second core, the reactor was shut down for nuclear analysis to determine power peaking and correct placement of test elements. While the reactor was shut down a continuous purification system was installed and tested. The reactor was again started up on October 23.

Final design was initiated on modifications to the OMRE to improve its usefulness for experiments. The modifications involve fuel handling, buildings, and support facilities with only minor modification to the reactor vessel itself.

Experimental Organic-Cooled Reactor. Because the Organic-Moderated Reactor Experiment was built as a minimum-cost facility to test the feasibility of the concept, it is lacking in the necessary organic loops needed for investigation of new organic coolants and experimental fuel elements. A facility is planned which can provide power reactor core conditions in full core tests or in loops for investigation

of new organic coolants and experimental fuel elements. This is the Experimental Organic-Cooled Reactor which will test coolants with various inhibitors, different types of reconstituted polymers, a number of bulk coolant temperatures, a number of fuel surface temperatures, various experimental fuel elements, and boiling as well as nonboiling conditions.

This plant, which also will be built at the National Reactor Testing Station, will provide a facility for testing complete cores made up of experimental fuel elements, with the option of various moderator-coolant combinations. The reactor will produce approximately 40 megawatts of heat. No steam generation is planned. The conceptual design of the reactor has been performed by Phillips Petroleum Co., and Fluor Corp. has been selected as architect-engineer for final design.

Piqua Organic-Moderated Reactor. The Piqua reactor is being developed to demonstrate the technical and economic feasibility of an organic-moderated power reactor integrated into an electric utility system. The design of this 11,400 ekw. reactor has been revised by Atomics International, a division of North American Aviation, Inc., to include complete containment of the reactor plant. This was in conformance with the recommendation made in January by the Commission's Advisory Committee on Reactor Safeguards. On June 1, the Commission signed contracts with Atomics International and the city of Piqua for construction of this reactor.

The contract with Atomics International covers fabrication and construction of the reactor and fabrication of the fuel required for operation. Under its contract, Piqua will provide the nuclear plant site and turbine generator, operate the entire plant for 5 years as part of its electric power and industrial steam distribution system, and purchase from the Commission the steam produced by the reactor. Title to the reactor and fuel elements will be retained by the Government.

Groundbreaking for the reactor took place at Piqua on July 6. The reactor building excavation and footings for the reactor containment shell have been completed.

A prototype plant. The Commission announced on December 29, plans to extend an invitation in January under the Power Demonstration Reactor Program for a prototype organic-cooled and -moderated reactor fueled with uranium oxide. The reactor will have a minimum capacity of 50,000 ekw. Utilities submitting proposals for this project will be expected to design, construct, and operate the entire plant. The

Commission will support research and development for the project and will waive fuel use charges during the first 5 years of operation. The proposed prototype plant will operate with nucleate boiling or forced convection cooling and will be designed to produce steam at 600° F. or higher from the organic coolant. If no acceptable proposals are received, the Commission intends to proceed with the construction of this prototype reactor.

Sodium Graphite Reactors

The sodium graphite reactor program is centered around the *Sodium Reactor Experiment* (SRE) at Santa Susana, Calif. The reactor, which is operated for the Commission by Atomics International, went critical in April 1957.

In the 1959 period, the SRE was used extensively as a test facility to irradiate promising new fuels. A new fuel loading of thorium-uranium alloy was fabricated for early installation. Accent was placed on development of uranium carbide fuel, which may combine the good thermal conductivity of metallic fuels with the good radiation and thermal stability of ceramic fuels.

On May 22, after several days of operation with a sodium outlet temperature of 1,010° F., the Sodium Reactor Experiment achieved a maximum steam temperature of 1,000° F. This is believed to be the highest temperature steam ever produced by a nuclear reactor. The reactor was shut down on May 24 to examine visually three fuel elements. This inspection revealed that no significant changes in the condition of the fuel elements occurred during the high temperature run of 150 megawatt days.

The reactor was operated again from May 27 until June 3, when it was shut down because of a tetralin leak into the main primary sodium system from the main primary pump. The pump was removed, repaired, and reinstalled and the reactor was started up again on July 12 and operated at low-power levels while attempts were made to remove impurities from the coolant. The system did not clean up as rapidly as previously experienced, so the reactor again was shut down on July 26 to examine fuel elements.

Initial indications of fuel element damage resulted in a full-scale examination. Inspection showed that 12 fuel elements were parted at the fueled region of the cluster with only the upper half of the elements attached to the hanger rods. The lower portions remained in the core. Forty-one of the 43 elements of the reactor were removed and one of the failed elements was examined in detail. The remaining two elements are securely lodged in channels and will be removed

separately. Preliminary indications were that the damage was triggered by obstruction of coolant passages by a tar-like decomposition product resulting from tetralin leakage. The reduced coolant flow caused overheating of the fuel elements and formation of a low-melting iron-uranium eutectic and subsequent failure of the cladding. When the cladding failed the fuel elements parted. Removal of fuel element debris and remote inspection of the core interior was underway at the end of the year. Rehabilitation of SRE will continue and it is expected that operation of the reactor on its second core (a thorium-uranium core already on hand) will be initiated by late spring of 1960.

Hallam Nuclear Power Facility. Atomics International, design contractor for the 75,000 ekw. Hallam plant, subsequently conducted a thorough review of the design of that sodium-graphite prototype plant in order to incorporate such changes as required to prevent an occurrence similar to the fuel element damage in the Sodium Reactor Experiment. The Hallam reactor is being built on the system of the Consumers Public Power District at Hallam, Nebr. Bechtel Corp. is performing architect-engineer services and Peter Kiewit Sons Co. of Omaha was selected as general contractor for construction of the nuclear portion of the plant. The Hallam project will provide design, construction, and operating experience with a prototype sodium graphite reactor which can be interpreted in terms of a large central station nuclear powerplant. Construction began at the site in April and was about 13 percent complete at the end of December. The Commission had reviewed the project earlier in 1959 and confirmed its decision to proceed with its construction.

In late 1958, a decision was made to use a uranium-molybdenum alloy for the first core loading in the Hallam reactor rather than uranium oxide as previously planned. A new fuel program has been undertaken which will include development of both the uranium-molybdenum alloy and the uranium carbide fuel. Contingent upon continued success in the carbide development program, the replacement fuel for the Hallam reactor will be uranium carbide.

Chugach reactor project. The Commission decided in February to cancel the sodium-cooled, heavy water-moderated reactor project proposed by Nuclear Development Corp. of America and the Chugach Electric Association under the second round of the Power Demonstration Reactor Program. The reactor was to have been constructed at Anchorage, Alaska. The decision was made on the basis that this reactor type was too complex and novel to be built for the first time at such a remote location.

On July 2, the Commission made the additional decision to suspend research and development work on this particular reactor concept. This conclusion was based on a technical and economic study by a task force of reactor engineers and physicists representing the Commission and Commission contractors. The group concluded that the technical feasibility of sodium heavy water reactors is currently in doubt, and even if its feasibility were proved it would not have a potential greater than other concepts which are currently in a more advanced stage of development.

Gas-Cooled Reactors

The Commission is investigating several approaches to the development of gas-cooled power reactors. They include the flexible Experimental Gas-Cooled Reactor designed by Kaiser Engineers and the Allis-Chalmers Manufacturing Co.; the High Temperature Gas-Cooled, Graphite-Moderated Reactor being developed as a cooperative Commission-industry project by the Philadelphia Electric Co. and the General Dynamics Corp; and the Heavy Water Moderated, Gas-Cooled Reactor being developed by the East Central and Florida West Coast Nuclear Groups.

Experimental Gas-Cooled Reactor (EGCR). This reactor, scheduled for completion in 1962, will be the first civilian gas-cooled power reactor in this country. It will use stainless steel clad, slightly enriched uranium oxide fuel in a graphite-moderator core structure and high pressure helium as coolant. The combination of high temperature materials and inert coolant permits relatively high operating temperatures and higher specific power than natural uranium reactors. This reactor will have unusual flexibility for testing advanced fuels and materials in special in-pile loops and will be utilized as an experimental facility for advancing the technology of gas-cooled reactors. It also will have some value as a power-producing prototype for demonstrating the reliability and costs of power reactors of this type.

The reactor, with a net generating capacity of about 22,000 ekw., is being constructed at Oak Ridge, Tenn., where research and development work, especially on the fuel elements and control rods, in support of this reactor has been under way for some time. Preliminary site work began in August upon approval of the specific location by the Advisory Committee on Reactor Safeguards. H. K. Ferguson Co., Cleveland, Ohio, is construction contractor.

High Temperature Gas-Cooled Reactor (HTGR). The Commission announced on August 27 that it had signed contracts with the Phila-

delphia Electric Co. and General Dynamics regarding the High Temperature, Gas-Cooled Reactor which the two companies proposed to build under cooperative arrangement with the Commission at Peach Bottom, Pa. The estimated total cost of the project is approximately $45 million of which the Commission will contribute a maximum of $17 million for research and development and waiver of fuel-use charges.

The General Atomic Division of General Dynamics will conduct the preoperation and post-operation research and development for the advanced type reactor. This work will be supported by the Commission up to a maximum of $14.5 million. The Commission also will waive $500,000 in fuel-use charges for the research and development work, the balance for fueling the reactor.

Philadelphia Electric will design, construct, own, and operate the reactor. The Bechtel Corp., under contract to Philadelphia Electric, will construct the plant on a fixed-price basis. The cost of design and construction of the prototype plant will be shared by Philadelphia Electric and 51 other utilities comprising the High Temperature Reactor Development Associates, Inc. The plant is scheduled for completion in 1963.

This prototype reactor will utilize combined fuel-moderator elements containing enriched uranium and thorium carbide fuel dispersed in a graphite matrix. In the first core, these elements probably will be clad with stainless steel, giving an initial plant capacity of 28,500 ekw. The initial elements will be replaced with impervious graphite-clad elements as soon as they are developed, increasing plant capacity to its designated rating of 40,000 ekw. Combining the fuel and moderator results in a very large heat transfer surface, and the graphite cladding of the fuel permits very high temperature operation. This combination of large heat transfer surface and high temperature capability greatly reduces reactor size in relation to its output.

Heavy Water Moderated, Gas-Cooled Reactor. This reactor is being developed as a cooperative project, the Commission participating with the East Central Nuclear Group in financing the research and development. Construction of the 50,000 ekw. prototype power reactor is being financed entirely by the Florida West Coast Nuclear Group. A contract between the Commission and the two nuclear groups for this project was signed in February.

The plant is to be located at Pierce, Polk County, Fla., about 35 miles east of Tampa. The Florida West Coast Reactor, as it is now called, will use slightly enriched uranium fuel. It will be designed

as a prototype for larger power reactors which may be able to operate on natural uranium.

Fluid Fuel Reactors

Fluid fuel concepts which have been under development include the aqueous homogeneous, which uses a solution or suspension of fuel in heavy water; the liquid metal fuel type, in which uranium dissolved in molten bismuth flows through a graphite matrix; and the molten salt concept, which employs uranium fluoride dissolved in a mixture of lithium and beryllium fluorides.

At the end of 1958, the Commission decided to make a critical evaluation and comparison of these three fluid fuel concepts with the idea that future work should be concentrated on the one that appeared most promising. A technical task force of scientists and engineers from the Commission and industry was convened for this purpose and after two months of deliberation submitted its report on March 2. In summary, the task force concluded that: (*a*) the molten salt concept had the greatest probability of achieving technical feasibility, mainly because of the use of a solution fuel and the availability of a suitable container material; (*b*) the development program for any of the three concepts was estimated to require in excess of $100 million and 10 years of concentrated effort; and (*c*) on the basis of a reasonable extrapolation of current development, only the aqueous homogeneous concept has the possibility of achieving breeding with a reasonably short doubling time (on the order of 15 years).

Utilizing the findings of the task force, the Commission evaluated each of the fluid fuel concepts in terms of their potential for meeting the objectives of the civilian power reactor program. It was concluded that none of the fluid fuel concepts could meet the short-term objectives of achieving early economic nuclear power but that the aqueous homogeneous concept has a strong potential for successful development as a thermal breeder.

Accordingly, the Commission decided in August to initiate a *thermal breeder reactor program* to replace the fluid fuel program. The new program is a long-term effort and has as its objective the development of a thermal breeder reactor capable of converting thorium to fissionable fuel material with a doubling time of not more than 25 years. The Oak Ridge Operations Office was assigned responsibility for this effort and initiated a systematic investigation and evaluation of all reactor types (heterogeneous, as well as fluid fuel) to determine their thermal breeding potential. Following these studies, a

selection will be made of the reactor concept or concepts on which program effort is to be centered.

In the meantime, development work on the liquid metal fuel system at Brookhaven National Laboratory and on the molten salt concept at Oak Ridge National Laboratory will be phased out unless evaluation studies now under way indicate that the breeding potential of either of these concepts is sufficiently strong to warrant continuation on an interim basis.

Aqueous homogeneous reactors. Limited research and development will be continued on the aqueous homogeneous concept at least through final selection of the reactor concept on which thermal breeder program effort is to be centered. Work on this concept has been primarily concerned with the chemical instability problem of the fuel solution encountered in the *Homogeneous Reactor Experiment No. 2* (*HRE–2*), which resulted in severe corrosion in certain areas of the core. Operation of the reactor, as well as studies and experiments in fuel solution chemistry and in the hydrodynamics of core flow, have been directed to a further understanding and solution of this problem. The HRE–2 was operated intermittently during the first half of 1959, and during July and August the reactor was operated without interruption at pressures from 1,150 to 1,750 psig (pounds per square inch gage), at temperatures of 240° and 260° C., and at power levels up to 5,000 thermal kilowatts in order to ascertain the conditions under which operation results in chemical instability of the fuel solution as evidenced by loss of uranium and fluctuations in power level.

The reactor was shut down during September for minor repairs. During the shutdown, the core tank was thoroughly examined for the first time since the hole in the tank was inspected a year before. No new failures in the core tank had occurred. The core tank thickness was remeasured and the reduction in thickness caused by corrosion was accurately established at 10 mills rather than the 40 mills recorded after the 1958 check.

Operation of the reactor was resumed on October 4 for further experiments on the instability problem and continued without interruption through the end of the year. Results of extended operations at full- and near-full power during the last half of 1959 indicate that the fuel solution stability is markedly improved by a reduction in system pressure and an increase in the acidity of the solution. No instabilities were observed during operation with a system pressure of 1,250 psig, even during extensive operation at full power.

Another type of homogeneous reactor experiment operated in 1959 was the *Los Alamos Power Reactor Experiment No. 2* (*LAPRE–2*).

The purpose of this reactor was to determine the feasibility of a reactor concept using a solution of enriched uranium phosphate, phosphoric acid, and water as a fuel, and relying on natural circulation of the solution to carry the heat to the heat exchanger. LAPRE–2 achieved initial criticality on February 26, and operational tests began at the Los Alamos Scientific Laboratory on March 26. From these tests information was obtained on the generation of superheated steam, response of the reactor to power demand, corrosion control through gold cladding of internal components, internal recombination of radiolytic gas, and radiation stability.

The reactor operated satisfactorily at temperatures up to 850° F., and at a power level of 800 thermal kilowatts. It demonstrated extremely stable operation at constant temperature under widely varying power demands without control adjustments. The goals of the experiment having been attained, the reactor was shut down in May and dismantled. The results of the experiment will be used as a basis for evaluation of the potentiality of this fuel system relative to other reactor systems.

Fast Breeder Reactors

Breeder reactors occupy an important place in the nuclear power program because of their ability to produce more fuel than they consume and thereby contribute to the conservation of fissionable material resources. The major projects in the fast reactor program are the Experimental Breeder Reactors No. 1 and 2, both located at the National Reactor Testing Station, and the Enrico Fermi Atomic Power Plant, a cooperative Commission-industry project being constructed in Michigan.

Experimental Breeder Reactor No. 1 (EBR–1). Operation of this Argonne National Laboratory-designed reactor, which began in 1951 at the National Reactor Testing Station, has demonstrated that a nuclear reactor designed to operate in the high energy neutron range is capable of breeding and also has the potential for achieving economically competitive nuclear power. Operating on its third core since late 1957, this reactor was used in 1959 for experiments to determine the effects of fuel element bowing upon operating characteristics. Operation of the reactor through March with a relatively rigid core configuration demonstrated that careful design had eliminated the prompt positive power coefficient of reactivity which with a previous core caused a melt-down of parts of the core.[8] In this

[8] See pp. 45–47, Twentieth Semiannual Report (January–June 1956).



Experimental Breeder Reactor No. 2. The Commission's prototype second fast breeder power plant was approximately 80 percent completed at the year's end at the National Reactor Testing Station in Idaho. Photo above was taken in October. The reactor is expected to achieve criticality toward the end of 1960, and will have a 16,500 electrical kilowatt rating.

situation, a small increase of temperature leads to increased reactivity and a possible power excursion.

In the second phase of the program, the reactor was operated with the core in a position as loose as mechanical design would permit. Sensitive pile oscillator tests did not indicate the presence of instability nor had the coefficient of reactivity changed with the mechanical motion restraints relaxed short of modifying the ribs on the new fuel rods. The reactor was operated under many different combinations of coolant flow, coolant inlet temperatures, and reactor power levels and exhibited good stability throughout. Stability tests are continuing with less rigidity in a successively larger number of elements.

A plutonium alloy core will be fabricated in the Fuels Fabrication Facility at Argonne National Laboratory for this reactor. It is scheduled for installation about mid-1960.

Experimental Breeder Reactor No. 2 (EBR–2). The EBR–2 was designed by Argonne National Laboratory as a prototype fast breeder reactor to demonstrate the engineering feasibility of this concept for

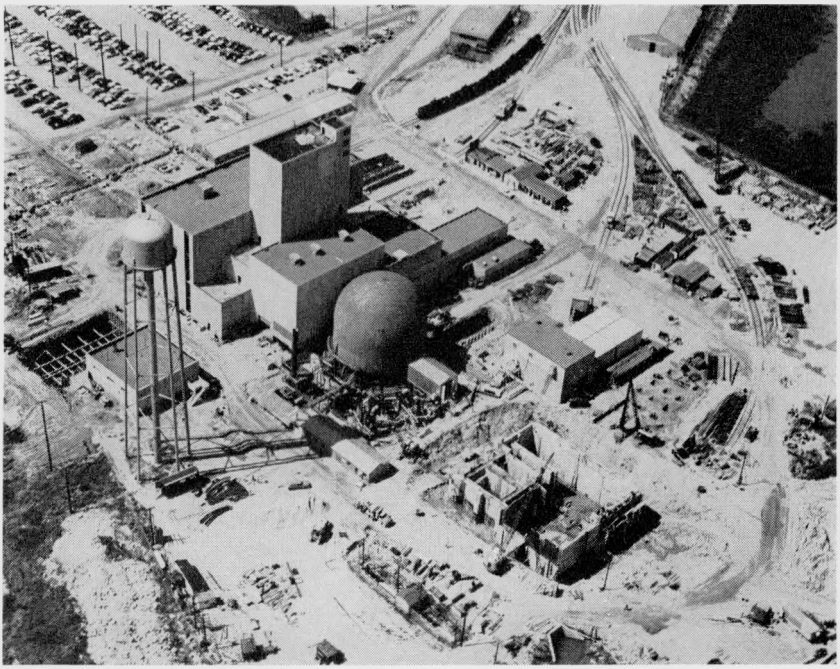
power-generation applications. A major objective will be to demonstrate the feasibility of operation on recycled fuel. The fuel will be processed by a specially developed pyrometallurgical process and then used to refabricate more fuel elements. Both the reprocessing and refabrication will be done by remote control operations. The problems arising from the buildup of heavy isotopes and transuranium elements resulting from the recycling of fissionable and fertile materials will be explored.

The construction schedule of the reactor at the National Reactor Testing Station fell behind substantially in 1959 because of unusually high winds last spring which curtailed the amount of outdoor work that could be done, unforeseen excavating difficulties, and a strike at the plant of a subcontractor fabricating a 140-ton rotary crane. The steel strike also contributed to the delay. The present estimate is that the reactor will achieve initial criticality at the end of 1960 rather than in May.

Enrico Fermi Atomic Power Plant. Operating experience with a large-scale fast reactor is expected to be provided by the 94,000 ekw. Enrico Fermi plant now under construction near Monroe, Mich. The nuclear portion of the plant is being built by the Power Reactor Development Co. under the Power Demonstration Reactor Program. The conventional turbine-generator portion is being built by the Detroit Edison Co. Extensive mechanical testing of reactor and system components was performed. The control, steam generator, and turbine-generator buildings were essentially completed. Overall plant construction was about 40 percent complete at the end of the year. The reactor is scheduled to begin operating late in 1960.

Transient Reactor Test (TREAT). This facility at the National Reactor Testing Station was designed by Argonne National Laboratory to investigate the effect of extreme heat upon fuel elements and other components of fast reactors. The reactor achieved criticality on February 23 and preliminary experiments were run to check out the facility. The reactor can deliver a high-intensity, short-duration surge of nuclear energy without damage to the facility itself. The surge will be useful in simulating abnormal reactor operating conditions and will permit reactor designers to observe, on a small scale, the effect of such conditions on prototype fuel elements planned for fast reactors.

In order to record a fuel melt-down process which will take place in a centrally located test hole, access holes have been provided in the shielding and reflector graphite so that the process can be photo-



Enrico Fermi Atomic Power Plant, near Monroe, Mich., showing progress of construction as of May 1959. This fast reactor is expected to go critical during 1960.

graphed. In September, the first meltdown experiments were conducted on natural uranium fuel pins for Experimental Breeder Reactor No. 2.

Argonne Fast Source Reactor (AFSR). This experimental reactor at the National Reactor Testing Station, which achieved criticality on October 29, was designed as a tool for use in the study of the physics of fast breeder power reactors. The design power is one kilowatt. The reactor will serve essentially as a source of neutrons to be used in the development of improved instruments and improved techniques for making measurements in the neutron energy range characteristic of fast reactors.

Los Alamos Molten Plutonium Reactor Experiment No. 1 (LAMPRE-1). This fast reactor of 1,000 thermal kilowatts will be employed as a short-term experiment primarily to explore the feasibility of using for fuel a molten plutonium alloy containing 10 percent iron. Los Alamos Scientific Laboratory tests have shown that the fuel alloy can be contained in tantalum at temperatures up to 700° C.

A dry critical experiment was conducted on LAMPRE–1 in November. "Hot" critical experiments are scheduled to begin in May 1960.

Information obtained from the LAMPRE–1 tests will permit design of a core for testing a higher power reactor facility. The Commission is proposing a Fast Reactor Core Test Facility in which to conduct a second-stage experiment and related tests. A preliminary design of this facility has been prepared.

Tantalum, the proposed container material for molten plutonium alloy fuels, is a relatively serious fast reactor poison. A calculational study has indicated, however, that potential breeding ratios larger than 1.4 to 1.5 may be achieved with this material in systems offering reasonable specific powers and heat transfer rates. LAMPRE–1, however, will not include a uranium blanket for breeding plutonium.

Design of reactor using oxides. In April, the Commission selected the proposal of the Atomic Power Equipment Dept., of General Electric Co., San Jose, Calif., for performance of research and development and design on a fast breeder reactor using a *plutonium oxide-uranium oxide fuel cycle.* A cost-type contract was awarded on June 30 for this work, which is estimated to require 18 months for completion. The objective of this effort is to lower the cost of electrical power from fast breeder reactors by reduction of fuel cycle costs. General Electric was selected from among eight companies submitting proposals in response to a Commission invitation issued in October 1958.

Heavy Water Reactors

For the past 3 years, the Commission has been conducting a broad program to develop heavy water-moderated power reactors. Commission contractors performed feasibility design studies, basic research and development, a test reactor is being built, and prototype reactor construction is under consideration.

Heavy Water Components Test Reactor (HWCTR). E. I. du Pont de Nemours & Co., operator of the Commission's Savannah River (S.C.) Plant, continued its design of a test reactor for the program, and construction was initiated at Savannah River in April. The test reactor will be a heavy water moderated and cooled, pressure vessel type; the thermal capacity will be about 60 megawatts. It will be used to test various types of fuel elements and reactor components, and will provide means for simultaneous irradiation of up to 12 full-sized natural uranium fuel elements at conditions of temperature, pressure, and power density similar to those encountered in power reactors.

Construction was about 20 percent complete at the end of December. Reactor start-up is scheduled for early 1961.

Carolinas-Virginia Nuclear Power Associates (CVNPA). A contract under the Power Demonstration Reactor Program was signed with the Carolinas-Virginia Group on January 12, 1959, for development, construction, and operation of a 17,000 ekw. heavy water-moderated, pressure-tube reactor at Parr, S.C. Stone & Webster Engineering Corp. is the architect-engineer, and Westinghouse Electric Corp. will develop and furnish plant equipment. This reactor will operate on slightly enriched uranium fuel. It will provide design and operating experience to determine the economic and technical feasibility of a full-scale plant. A larger reactor of this type might be operable on natural uranium. CVNPA will own and operate the prototype plant. Construction is scheduled to begin by March 1960 with reactor operation expected by June 1962. The Commission is supporting research and development up to a maximum of $15.1 million, including $1.2 million waiver of use-charges for fuel during a 5-year operating period.

Cooperative program with Canada. The Commission is expanding its heavy water technology through an extensive cooperative program with Canada. The Canadians, partly because of their reliance upon natural uranium fuel, have a relatively advanced heavy water program. They have in operation two heavy water moderated experimental reactors which have provided extensive irradiation services for some of the United States heavy water activities. Canada also has a 19,000 ekw. heavy water moderated and cooled natural uranium oxide fueled power reactor of the pressure tube type under construction, and is planning to build a 200,000 ekw. reactor which has been authorized.

Plutonium Recycle Program

In the Commission's plutonium recycle program at the Hanford Works in Washington State, a combination of experimental, technical, and analytical investigations is being conducted to obtain basic knowledge on recycling plutonium. The program includes analytical and experimental investigations of the physics, chemistry, metallurgy, engineering, and economic factors basic to plutonium recycle application. Results will be used for determining the best methods of using recycled plutonium as a reactor fuel under a wide variety of technical and economic conditions.

To this end, the Commission planned new facilities at the Hanford Works—the Plutonium Recycle Test Reactor, and a Plutonium Fabrication Pilot Plant laboratory for developing and fabricating plutonium-bearing fuel elements. The test reactor is heavy water-moderated and -cooled, has a rating of 70 Mwt., but has no electric generating facility. The reactor is designed for flexibility in the irradiation of plutonium-bearing fuel and investigation of operating characteristics of recycle systems. Construction of the plant was 55 percent complete on December 31. First occupancy of the laboratory started in September. Construction at the end of the year was about 85 percent complete.

Process Heat Reactor Program

Nuclear reactors are being developed for producing both low-temperature and high-temperature heat for use in various industrial processes.

Market surveys. Two market surveys conducted to determine the size, nature, and needs of industries using process heat, showed that approximately twice as much fossil fuel is used to generate low temperature process heat as is used to generate electricity. However, most of the process heat is consumed in relatively small blocks, 96 percent being less than 75 thermal megawatts and the median being about 10 thermal megawatts.

While industries using process heat have shown considerable interest in nuclear reactors, they have been reluctant to risk depending upon the output of a machine whose development and operation is not part of their main commercial objectives. This feeling was confirmed at a Commission-sponsored symposium on process heat reactors at Commission Headquarters on October 1. Questionnaires were completed by 67 industry representatives and a majority stated the belief that the Government should take the lead in developing economic nuclear process heat.

Low temperature process heat reactor. Earlier in the year the Commission, in an effort to determine the economic attractiveness of nuclear plants for industrial processes, had initiated development of a reactor suitable for process heat production. On the basis of the preliminary work at Argonne National Laboratory on conceptual design and evaluation of reactors for such purposes, the Commission selected a 40,000 thermal kilowatt pressurized water reactor for this project.

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On October 6, the Commission signed an agreement with the Department of the Interior for a cooperative project to develop an experimental plant for conversion of saline water to palatable water by utilizing steam from a reactor. Under the agreement, the Commission will design, construct, and operate a 40,000 thermal kilowatt experimental, low-temperature process heat reactor capable of producing saturated steam at pressures from 5 to 175 pounds per square inch gage. The Department's plant will have its own fossil fuel fired boiler so that the reactor can be operated independently from the rest of the plant when necessary for experimental purposes.

The Department of the Interior will design, construct, and operate the saline water conversion plant, which will use the steam to produce at least 1 million gallons of fresh water per day. The combined facility is to be located on land now owned by the Navy on Point Loma, San Diego, Calif. San Diego is to provide site improvements and facilities for taking the product water from the site to its distribution system. The State of California will contribute funds of approximately $1.5 million for the project. Architect-engineering services for the reactor will be performed by Sargent & Lundy.

High-temperature process heat. High temperature work is being carried on in a joint experimental program between the Commission and the Bureau of Mines, Department of the Interior, at the latter's Appalachian Experiment Station, Morgantown, W. Va. The objective is use of a nuclear reactor as a source of high temperature process heat for gasification of coal. During the past 3 years, the Bureau of Mines built and operated two high temperature helium loops. The first was designed for atmospheric pressure and approximately 2,500° F., and the second for 2,500° F. and 250 psig. As of December 31, the second loop, called the Induction Simulated Reactor Facility, had accumulated approximately 550 hours of operation at helium temperatures above 2,300° F. including approximately 25 hours in the range of 2,500 to 2,650° F.

The Commission has initiated at Los Alamos Scientific Laboratory the preliminary design of a high-temperature gas cooled reactor experiment designated *Turret.* This reactor will have a 3,000 thermal kilowatt capacity, will operate at a temperature of 2,400° F. and a pressure of 500 psig.

This reactor utilizes a simple fuel system consisting of unclad graphite impregnated with uranium and will be cooled with helium. Operation of the experiment will determine the amount of radioactive fission products released from the unclad fuel elements and the possibility of removing contaminants from the coolant stream. The reactor is being developed as a possible source of high temperature

industrial process heat, such as might be used by the Bureau of Mines for coal gasification.

Reactor Design Studies

In accordance with the Congressional Authorization Act for the fiscal year that ended June 30, 1959, design studies were performed by Commission contractors on the three most fully developed power types of reactors—pressurized water, boiling water, and organic cooled—to assess current technology and possible costs for large powerplants. A fourth study was made on heavy water-moderated reactors. The Commission reviewed the design study reports carefully and attempted to place on a comparative basis the many factors that enter into the studies' estimates of economics. It was concluded that none of the specific designs submitted was likely to be competitive with conventional units of the same capacity in any area of the United States where units of the size proposed would be used. A cost differential of one mill or more per kilowatt hour seemed probable. The results of the Commission evaluation, presented in May to the Joint Committee on Atomic Energy, indicated that if the research and development accomplishments deemed necessary to build these design-study plants could be achieved on schedule, and if the technical performance assumed in the studies was attained, the generating costs of very large nuclear powerplants (236,000 to 300,000 ekw.) would be in the range of 8.3 to 9 mills per kilowatt hour. For plants of 150,000 ekw. or smaller, the generating costs would be substantially higher. Evaluation of the design study analysis on the heavy water reactor indicated slightly higher costs.

The Commission concluded further that there was no major difference in the cost of power to be expected among the pressurized water, boiling water, or organic-cooled reactors as designed under the ground rules of the study.

New Reactor Concepts

The Commission is continuing its investigation of new reactor concepts which may have potential advantages in the long-range reduction of power costs. Before these advantages can be demonstrated or disproved, extensive additional technical development will be necessary. Several companies are under contract to the Commission to perform preliminary studies on advanced reactor concepts. The reactor types being investigated include: The *graphite cloud* reactor

concept, a gas-cooled system, by the Babcock & Wilcox Co.; the *pebble bed* concept, a gas-cooled system, by Sanderson and Porter, Inc.; the *fluidized bed*, a water-cooled concept, by The Martin Co.; the *mercury-cooled fast breeder* concept by American Standard Radiator and Sanitary Supply Co.; the *variable moderator* concept, a direct-cycle boiling water system, also by American Standard; the *sodium modulator* concept by the General Electric Co.; and an advanced fluid reactor using *boiling sulfur* as coolant by Aerojet General Nucleonics.

The Aerojet proposal was accepted in July from among 11 received between September 1, 1958, and March 1, 1959, under the Commission's program for making a semiannual evaluation of unsolicited proposals from industry for studies on new reactor concepts.

Advanced Epithermal Thorium Reactor

Late in 1959, work was started on a critical experiment facility at Atomics International's Santa Susana, Calif., site as a part of a privately financed project to develop an Advanced Epithermal Thorium Reactor.

During 1957, a group of privately owned electric companies had banded together to form the Southwest Atomic Energy Associates for the purpose of sponsoring a program to develop an economically competitive nuclear powerplant for the Southwestern area of the United States. Late in 1957, Southwest Atomic Energy Associates engaged Ebasco Services, Inc., to assist in selection of a promising reactor concept. Following evaluation of a number of proposals, a concept proposed by Atomics International was selected and a study was initiated.

The study is based on a reactor using a uranium 233-thorium fuel cycle operated in the high epithermal neutron energy region and cooled with sodium. The immediate objective is to carry out a preliminary research and development program designed to permit a realistic evaluation of the economic characteristics of a full scale AETR plant.

The first phase of the project, covering conceptual design and analytical studies of possible core and blanket configuration, performance requirements, and economic potential of the concept, was completed in June 1959. Phase II of the program, which involves design and construction of a critical experiment and associated facility and thorough investigation of the nuclear characteristics of uranium 233-thorium core configurations, is presently underway. In August, Atomics International applied to the Commission for a license to construct the facility at Santa Susana, Calif. The Fluor Corp. was

engaged to design the facility and at the end of 1959 construction was just starting.

This program was initiated and has been funded entirely by private capital. However, the Commission has agreed to provide 25 kilograms of uranium 233 for use in the critical experiments.

Reactor Safety

Reactor safety research and development continued in three broad areas; reactor kinetic studies; chemical aspects of reactor safety; and containment of reactor systems.

Reactor kinetics. Investigation of transient reactor behavior with the *Special Power Excursion Reactor Test No. 1* (*SPERT–1*) continued at the National Reactor Testing Station with the testing of a stainless steel core from Bulk Shielding Reactor No. 2 at Oak Ridge, and of a fast response control system. The tests were directed toward determining the limit of protection that might reasonably be attained against short period accidents by a quick response and quick insertion control system.

SPERT–2 was to be completed in January 1960. It is a pressurized heterogeneous water reactor designed for operation at 300 psi. and 400° F. The principal objective of this facility is to determine how various moderators and reflectors influence reactor kinetic behavior. Either heavy water or light water may be used as moderator, and provision also is included for controlling reflector thickness and for using solid reflectors such as beryllium. After completion of preoperational tests, the reactor is expected to become critical in March 1960. Transient tests will be initiated after completion of various static measurements.

SPERT–3, which achieved criticality on December 19, 1958, is a light water-moderated reactor for conducting safety tests applicable to boiling water and fully pressurized water reactors. It will provide the widest practicable range of control with varying temperatures, pressures, and coolant flow rates. Transient tests will be initiated by January 1960 after completion of detailed engineering tests and the measurement of static parameters.

Design of *SPERT–4* was initiated in April and construction will begin early in 1960. This will be a pool facility which will permit detailed study of reactor stability based on varying conditions of coolant flow, height of water above the core, and other hydrodynamic effects.

The first phase of the *Kinetic Experiments on Water Boilers* (*KEWB*) was completed in June with tests of a spherical core.

Reactor response to various reactivity additions was studied under many conditions of initial reactor operation. These tests have demonstrated that homogeneous reactors can safely accommodate large reactivity additions. Tests are continuing with a cylindrical core to determine the effects of core geometry and other influences upon the kinetic behavior of homogeneous systems.

Chemical aspects of reactor safety. Experiments aimed both at understanding basic mechanisms of chemical reactions, and at obtaining engineering data concerning the consequences of core accidents, continued at the Argonne, Brookhaven, and Oak Ridge National Laboratories, the National Reactor Testing Station and at private contractor organizations. The Oak Ridge experiments on release of fission products were broadened, late in the year, to include in-pile experiments. The in-pile experiments will permit a more realistic application of laboratory data to the analysis of reactor accidents.

A study was initiated at Brookhaven to determine chemical compositions and physical state of fission products released from various power reactor fuel elements during meltdown. This will complement the Oak Ridge work by providing basic information on retention phenomena. The Argonne studies of the basic mechanisms involved in the combustion of metals continued with the investigation of factors affecting combustion rates. The metal combustion program was expanded during this period by a contract to Stanford Research Institute to study the factors influencing ignition of zirconium.

Studies by the National Reactor Testing Station in Idaho, were aimed at defining the chemical reaction rates of various reactor metals with water. Temperature ranges for these studies were extended upward to include those which might be expected in the event of rather severe reactor accidents.

In September, the first in-pile experiments in the Argonne metal-water reaction studies were performed in the TREAT reactor. They were conducted to study the reaction of enriched uranium fuel pins with water.

A study of the safety problems of the sodium graphite and organic-cooled reactors was begun at Atomics International. Particular emphasis this year was placed on the effect of void formation on stability in these systems.

Reactor containment. Commission research and development includes investigations to assure the integrity of the reactor core vessel and the outer vapor containment shell. Studies are directed to determine the nature of the response to blast and pressure loading of both the pressure vessel and the outer containment structure. Means for

measuring the leak tightness of containment housings are also being investigated. The Commission work is being carried forward under several contracts with governmental, industrial, and university research organizations.

Supporting Engineering and Development

The Commission continued, during 1959, its various programs to advance the technologies necessary to service and support a nuclear power reactor industry. The major support activities were concerned with developing fuels and materials, further studies in reactor physics, and techniques for chemical processing and disposal of radioactive wastes. The work on waste disposal is reported in a special supplement to this report on that subject (part III).

Construction on the *Advanced Reactivity Measurement Facility* (ARMF) at the National Reactor Testing Station was started in September. H. K. Ferguson Co., is the constructor. The $480,000 facility is to be completed in 1960.

It will be the second such facility at the station, and is designed to augment capability for more precise determination of nuclear characteristics of reactor fuels and materials. Such measurements are part of the Commission's program to achieve efficient reactor fuel utilization and to improve the quality of reactor core components.

Fuel Cycle Development Program

The Commission announced in March the selection, as a basis for contract negotiations, of 24 proposals from 18 firms to perform research and development in private facilities under the Commission's fuel cycle development program. These proposals were selected from 111 received from 39 firms in response to an invitation issued late in 1958 for industry and research institutions to participate in a program to improve the fuel cycle for nuclear power reactors. The fuel cycle includes the fabrication and use of fuel elements, their removal when spent, a re-enrichment of the fissionable material in these fuel elements, and re-use of this material in new fuel elements.

Commission experience indicates that a substantial reduction in operating costs of power reactors can be achieved by reducing costs in this area.

The proposals selected will form the basis for contracts for work covering periods of from 1 to 3 years. Total cost to the Commission of the proposals selected is estimated at $25 million. The work will

supplement and accelerate the Commission's existing program which includes substantial fuel cycle development work currently under way in the laboratories of the Commission and private industry.

Fuel Fabrication Facility

The Fuel Fabrication Facility, built and equipped at a cost of $4 million, was dedicated at Argonne National Laboratory on May 14. The facility will make possible developmental research on techniques for fabricating plutonium fuel elements. Completion of this building is part of a long-range program at Argonne. A Fuels Technology Center, in which major emphasis will be placed on metallurgical research, is now under construction at the site. Many of the research efforts to be carried out there will receive practical application at the Fuel Fabrication Facility.

Measurement of Eta for Uranium 233

The ratio of the number of neutrons produced by fissioning of a uranium atom to the number of the thermal neutrons absorbed in the uranium is called *eta*. This ratio for uranium 233 is very important for thorium breeder reactors. It must be appreciably greater than 2.0 in order for breeding to occur; the lower limit for a practical system is somewhere between 2.20 to 2.25. The uncertainty in the value of *eta* for uranium 233 from previous measurements has been fairly large, ranging from 2.18 to 2.32. A study is under way at Oak Ridge National Laboratory and the National Reactor Testing Station to narrow the uncertainty to within one percent of the true value. Experiments completed at Oak Ridge have resulted in a value of *eta* of 2.29, plus or minus 0.02 for uranium 233 atoms fissioned by thermal energy neutrons. Experiments to determine the value of *eta* for epithermal neutrons are now underway.

Chemical Processing Development

Aqueous process development. Development of methods for the chemical reprocessing of zirconium-containing reactor fuels has presented a serious problem from the inception of these fuels. The hydrofluoric-nitric acid process developed for fuels of the type used in the USS *Nautilus* is somewhat limited in application and involves severe corrosion of processing equipment and waste storage tanks. A continuing program of process development is being conducted to develop better methods.

One most promising concept for zirconium-containing fuels, the Zirflex process, is under development at Hanford, the Idaho Chemical Processing Plant, and the Oak Ridge National Laboratory. In this process, zirconium is dissolved in a solution of ammonium fluoride and ammonium nitrate. This process minimizes the volume of high level radioactive waste produced, and the chemicals used are reasonably compatible with available construction materials. A modification of the Zirflex process is under development and gives promise of providing complete dissolution of niobium-containing fuels as well.

The first chemical reprocessing of irradiated highly enriched stainless steel reactor fuels was conducted successfully using the "SIR" process. This process, which was developed by Knolls Atomic Power Laboratory, was installed in the Idaho Chemical Processing Plant several years ago for the recovery of the Submarine Intermediate Reactor (SIR) fuel. The process involves integral dissolution of the stainless steel structural component in sulfuric acid and dissolution of the uranium dioxide component in nitric acid, followed by additional nitric acid dilution to allow use of standard solvent extraction technology. Operation was smooth and without unusual incident. Flowsheet and other minor process modifications were made to allow the successful reprocessing of the first OMRE and APPR–1 (SM–1) cores as well. Although this process has performed successfully, it nevertheless produces undesirably large volumes of highly corrosive radioactive wastes. Consequently, work is being continued to develop and demonstrate a more versatile and efficient process for fuels containing stainless steel.

Maritime Reactors Program

The objective of the maritime reactors program is the development of nuclear-powered merchant ships capable of competitive operation in unrestricted world commerce. The construction of the first nuclear-powered merchant ship and the long-range program for the development of commercially competitive nuclear propulsion are administered jointly by the Commission and the Maritime Administration, Department of Commerce.

N.S. *Savannah*

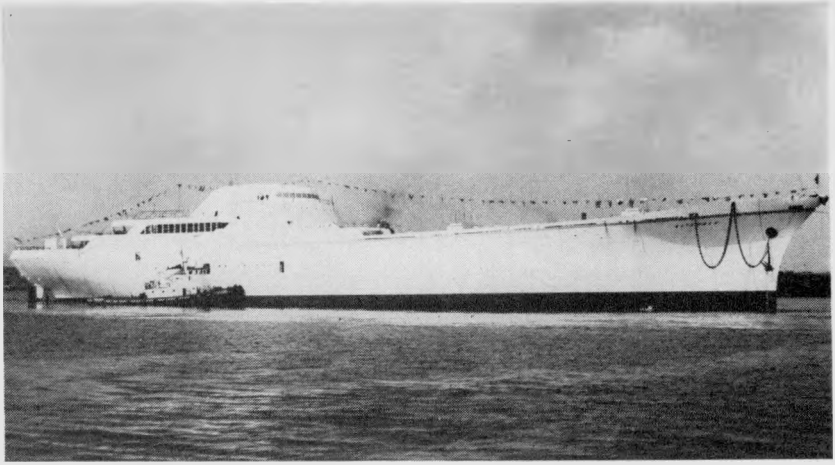
A major milestone reached in the maritime program during 1959 was the launching of the N.S. *Savannah* at the yard of the New York Shipbuilding Corp., Camden, N.J., on July 21. Mrs. Dwight D. Eisenhower was the sponsor.

During the year, the containment vessel for the pressurized water reactor was successfully installed and tested and the nuclear components placed in the pressure vessel. Practically all the conventional propulsion equipment, including turbines, gears, turbogenerators, feed pumps, etc., was installed in the ship. As of December 31, the hull was about 90 percent complete, design and fabrication of the nuclear powerplant was about 80 percent complete, and erection of the nuclear plant in the ship was 40 percent complete. Plans were well underway for the startup, tests, trials, and experimental operation of the *Savannah*, a sequence scheduled to begin in mid-1960.

An extensive program of fuel development for the *Savannah* reactor was carried forward during 1959. A test fuel assembly of the type to be used in the initial core was irradiated in the Vallecitos Boiling Water Reactor for 2,662 megawatt days. Performance was satisfactory in all respects. A second, and somewhat improved, core for the *Savannah* was being designed and developed by General Electric Co. Fabrication of this core was being accomplished on a schedule which permits its delivery for standby purposes shortly after the startup of the ship's reactor, expected in mid-1960.

Consistent with the President's directive that the *Savannah* be used as a "floating laboratory" for development of improved nuclear plant components and operating procedures, plans are being made for a plant improvement and general upgrading program. Ebasco Services, Inc., has been selected to conduct detailed engineering review of the *Savannah* plant. The work involves an independent analysis and evaluation of the nuclear plant and related equipment, followed by recommendations as to plant modifications which would result in improved performance, economics, and reliability.

On March 9, an agreement was executed between the Commission and the Maritime Administration establishing arrangements between the two agencies for the 2–3 year period during which the *Savannah* will be operated as an experimental vessel. This experimental phase will extend from the test and sea trials of the vessel through a period of limited commercial service. Actual operation of the vessel will be augmented by programs aimed at developing improved procedures for operation and maintenance of the nuclear plant and of improved nuclear and conventional components. The vessel will be placed in limited commercial service as early as possible in this period to contribute to the resolution of the many legal, regulatory, and operational problems expected to arise from operation of a nuclear ship in world commerce. The interagency agreement provides that the Maritime Administration, through its general agent, States Marine Lines, will operate the *Savannah's* nuclear plant for the Commission. The Com-



N.S. Savannah launched. The world's first nuclear-powered merchant ship, the N.S. *Savannah* is shown in the Delaware River following her July launching at Camden, N.J. The 595-foot, 22,000-ton vessel is currently being given her final outfitting and will begin tests during 1960. Later she will make a tour of United States Atlantic and Pacific coast ports before embarking on a world tour.

mission will maintain control of the nuclear plant and will be responsible for its safe operation.

Supporting activities. Training of personnel to man the *Savannah* was well underway. The first group of engineering officers completed the academic phase of training at Lynchburg, Va., in a program being carried out by The Babcock & Wilcox Co., under contract with the Maritime Administration. The academic phase, which included intensive training in reactor engineering fundamentals and in the details of the *Savannah's* nuclear propulsion plant, was followed by field training in reactor operation and maintenance at Commission installations. A second group of prospective engineering officers has started the same course. The six prospective deck officers also completed the academic course at Lynchburg, as well as radiological health and damage control courses. Foreign marine and nuclear engineers were given the opportunity to study the construction of the *Savannah.* Engineers from several different maritime nations were at Camden 8 weeks prior to visiting 10 Commission field installations and contractor sites where maritime nuclear propulsion work is underway.

A task force composed of Commission and Maritime Administration personnel went to Europe in September and held discussions of legal and administrative matters relative to the acceptance of the *Savannah* in foreign ports. Meetings were conducted with maritime

nuclear, and public health regulatory officials in Belgium, The Netherlands, Denmark, Norway, Sweden, and France. A discussion with an Euratom nuclear ship study group was held in Brussels, and the United States group met briefly with officials of the British Ministry of Transport in London. In general the reactions were favorable toward receiving the *Savannah* when the ship visits European ports. All groups contacted, however, were awaiting further technical information such as will be incorporated in the "*Savannah* Safety Assessment," a Commission compilation of pertinent construction and operational safety features. Also, several groups expressed a desire to be informed of any special conditions or regulations which are imposed by United States ports during the initial domestic voyage. Public liability matters were of primary interest, and all desired a full explanation of the protection that could be made available under the *Savannah* amendment to the Price-Anderson legislation, providing Federal indemnification in event of nuclear accidents. A number of countries have active committees studying the problem of acceptance of nuclear ships and their operations in commercial ports.

Other Maritime Projects

Gas-cooled propulsion reactor. Work continued in the long-range development leading to the design and construction of a propulsion system for maritime applications combining a gas cooled reactor and a closed-cycle gas turbine. This system offers great potential advantages in economy, weight, compactness, simplicity, and inherent safety.

Development work on the Maritime Gas-Cooled Reactor (MGCR) is being conducted by the General Dynamics Corp. During this period, General Dynamics began utilization of several experimental facilities including: (*a*) an out-of-pile fuel element test loop to evaluate heat transfer and aerodynamics of fuel elements; (*b*) an in-pile loop to evaluate segments of prototype fuel elements under actual operating conditions; (*c*) a bearing and seal test machine; (*d*) a heat exchanger test loop; and (*e*) the construction of turbomachinery test models. The design of a critical experiment was completed and plans were made for construction at the General Atomic Division site in San Diego. Analytical work covering core, containment vessel, and shield, and component design and plant arrangement studies were under way. Experimental development and testing of both fueled and non-fueled materials was progressing.

Engineering studies for a nuclear tanker. Contractors were selected for engineering studies of the most promising reactor concepts for a nuclear tanker in accordance with section 113 of the Atomic Energy

Authorization Act for the fiscal year 1960. Combustion Engineering was selected to prepare a design and engineering study for an advanced type pressurized water reactor system; General Electric for the direct cycle boiling water concept; and Westinghouse Corp. for the indirect cycle boiling water concept. The technical and economic feasibility of installing a developed naval nuclear propulsion plant (A1W) is also being studied. This work is being carried out by the naval architectural firm of Gibbs & Cox of New York. The studies are based upon a criteria of 30,000 maximum shaft horsepower propulsion systems applied to a tanker of about 43,000 deadweight tons. A comparative evaluation of these studies will be made by the Commission and Maritime Administration and a report of this evaluation, together with a recommendation as to the reactor system most suited for further development, will be submitted to the Joint Committee on Atomic Energy by April 1, 1960, as required under the Authorization Act. The firm of George G. Sharp has been engaged by the Maritime Administration to assist in providing naval architectural and marine engineering assistance to the Commission.

Shipside nuclear servicing vessel. A contract was awarded on July 9 to the Todd Shipyards Corp., Houston, Tex., Plant, by the Maritime Administration for design and construction of a non-propelled nuclear servicing vessel. This facility will be a barge-like vessel 129 feet in length with 36-foot beam and will be capable of receiving and processing for disposal, solid and liquid radioactive wastes from nuclear merchant vessels. It also will be used for decontaminating and repairing contaminated components. The design and construction of this vessel will be based upon servicing procedures and preliminary design information developed by Electric Boat Division of General Dynamics under contract with the Commission. Preliminary discussions with several commercial ship repair companies were under way with a view toward entering into contractural arrangements for maintenance and repair of the *Savannah.*

Studies underway. Contracts sponsored by the Maritime Administration include work by Todd Shipyards Corp. to determine the impact and solution of problems related to servicing nuclear merchant ships by commercial shipyards. The work is to include consideration of refueling, maintenance, repair, and drydocking of such vessels. Esso Research and Engineering Co. is carrying out a study of the use of petroleum and petroleum products as shielding, and the effects of radiation on lubricant and organic coolants as related to marine uses. Ford Instrument Co., working with Maryland Shipbuilding Corp., undertook a study of alternate methods of installing a proto-

type nuclear plant in a merchant ship, including the installation of a prototype plant in a pre-assembled hull section. George G. Sharp, Inc., began work on the optimization of containment and shielding design for nuclear merchant ships.

Part Two

Major Activities in Atomic Energy Programs

January-December 1959

Raw Materials

The United States uranium production increased 30.0 percent in 1959 over 1958, and this country was in first place among free world uranium producing countries. Domestic production of uranium plus imports of concentrates continued at levels adequate to meet current requirements.

This was a year of increasing stability for the domestic industry as the Atomic Energy Commission moved forward with its announced program of contracting for purchase of domestic uranium concentrates through 1966. As a result of the discovery in recent years of large, relatively high-grade uranium deposits, coupled with improved mining and milling practices, the domestic industry should be in a favorable position to compete with foreign producers when the industrial market develops.

Domestic ore production reached a total of 6.9 million dry tons during 1959, and production of uranium concentrates (U_3O_8) totaled 16,390 tons.

Private companies continued development of ore bodies at a high level during the year. Preliminary figures indicate that ore reserves increased from 82.5 million tons on December 31, 1958, to 86.0 million tons on December 31, 1959, a net increase of 3.5 million tons during a period when approximately 6.9 million tons were mined.

Uranium concentrate deliveries previously contracted for with Canada and with Combined Development Agency sources—Australia, Belgian Congo, Portugal, and South Africa—were continued at a normal rate during 1959.

The United States reserves, together with the large ore bodies already developed throughout the free world, provide sound support for a broad nuclear power program. Although further discoveries will no doubt be made, exploration activity is expected to be governed largely by the progress made toward competitive nuclear power.

Domestic Activities

12-Year Record of Procurement

The Commission published in September the statistics on U.S. uranium concentrate procurement from domestic and foreign sources

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for the 12 fiscal years 1948–59, and a combined total for the years 1943 through 1947. This action followed the Commission's declassification of all data on uranium ore and concentrate production and procurement before July 1, 1955. Statistics subsequent to that date were declassified in 1956. Procurement statistics in tons of concentrates are as follows:

Fiscal years	*Domestic (tons)*	*Foreign (tons)*	*Total (tons U_3O_8)*
1943–47 inclusive	1,440	10,150	11,590
1948	110	1,960	2,070
1949	120	1,960	2,080
1950	320	2,740	3,060
1951	630	3,050	3,680
1952	830	2,830	3,660
1953	990	1,910	2,900
1954	1,450	3,240	4,690
1955	2,140	3,800	5,940
1956	4,200	6,240	10,440
1957	7,580	8,580	16,160
1958	10,244	16,132	26,376
1959	15,162	18,164	33,326

Receipts of uranium concentrates from domestic sources, which in fiscal year 1959 constituted about 45 percent of the total procurement are expected to exceed those from foreign sources in fiscal year 1961.

Ore Reserves

Preliminary estimates indicate that reserves of uranium ore as of December 31, 1959, were approximately 86.0 million tons containing 0.28 percent U_3O_8. This is an increase of 3.5 million tons over the estimate at the end of 1958. In addition, there were approximately 1.3 million tons of ore in Government and private stockpiles at the end of the year. Final year-end reserve figures by States will be released in March 1960 in the Commission's semiannual announcement of "Domestic Uranium Production Statistics for Last Half of 1959."

Modification of Purchase Program

On November 24, 1958, the Commission announced a modification of the 1962–66 domestic uranium concentrate procurement program,[1]

[1] See p. 8, Twenty-fifth Semiannual Report to Congress (July–Dec. 1958).

whereby the Commission will carry out its commitment of May 24, 1956 [2] to purchase appropriate quantities of U_3O_8 in acceptable concentrates, at the previously established price of $8 per pound, produced and delivered during the period April 1, 1962–December 31, 1966, but with respect only to those ore reserves that were developed prior to November 24, 1958. The Commission will make contracts to purchase concentrates from new ore reserves developed after November 24, 1958, to the extent that requirements dictate and on such terms and conditions and at such prices as the Commission may from time to time agree upon.

Contracts between the Commission and the milling companies covering the purchase of uranium concentrates provide a suitable market for independent ores and, in the period prior to April 1, 1962, require the milling company to pay prices for ore that are no less favorable to the seller than the prices provided for uranium in the Commission's Domestic Uranium Program Circular 5, Revised. New contracts, or renegotiated existing contracts, require that the ore treated shall be produced from specified properties at specified rates.

Pursuant to the modified 1962–66 procurement program, the Commission, on May 18, filed notice with the *Federal Register* fixing August 1, 1959, as the final date for submission of data on ore reserves developed as of November 24, 1958, by those who wished to be considered in negotiations for uranium concentrate procurement for the 1962–66 period. On August 14, the deadline was extended to October 1, 1959, for those who could demonstrate reasonable justification for needing such an extension.

Milling Operations. In keeping with its limited domestic expansion program, announced April 2, 1958,[3] of providing an ore market in certain areas which had developed reserves, but had no market or an inadequate market, the Commission has carried out negotiations for new mills in North Dakota-South Dakota, Nevada, Southeast Texas, Wyoming, and the Colorado Front Range. Agreements were reached for additional milling capacity in Wyoming and for the Colorado

[2] See pp. 1–2, Twentieth Semiannual Report to Congress (Jan.–June 1956).

[3] See p. 5 and Appendix 11, p. 352, Twenty-fourth Semiannual Report to Congress (Jan.–June 1958) and p. 7, Twenty-fifth Semiannual Report to Congress (July–Dec. 1958).

Front Range resulting in contracts for construction of additional milling facilities as follows:

Wyoming	*Former capacity* T/day	*Added capacity* T/day	*New rate* T/day
Lucky Mc Uranium Corp., Fremont County, Wyo	883	147	980
Western Nuclear Corp., Split Rock, Wyo	444	401	845
Federal-Radorock-Cas Hill Partners, Fremont County, Wyo.[a]	0	522	522
Globe Mining Company, Riverton, Wyo.[b]	0	492	492
	1, 297	1, 562	2, 839
Colorado Front Range			
Cotter Corporation, Canon City, Colo	50[c]	150	200

[a] Formerly Federal Uranium Corp.
[b] Subsidiary of Union Carbide Nuclear Co.
[c] Pilot plant.

NOTE: As a result of a reappraisal of the ore supply of the several mills in Wyoming, an adjustment was made in the capacity of the Lucky Mc Mill; and Susquehanna-Western, Inc., Riverton, Wyoming (formerly Fremont Minerals, Inc.) postponed its plans for added capacity.

While the basic terms of proposed contracts have been discussed with companies interested in building mills in Southeast Texas, Nevada, and the North Dakota-South Dakota lignite area, these negotiations have not yet resulted in any agreements involving new mills. Because of the technical and economic problem involved, there was no action during the year to provide milling facilities for Nevada or for the North Dakota-South Dakota area. Negotiations still are continuing with companies interested in the installation of a mill in Southeast Texas.

During the year, the Commission executed modification of existing contracts with the Anaconda Co. Grants, N. Mex., and Uranium Reduction Co., Moab, Utah, extending their terms to December 31, 1966. Contracts with Gunnison Mining Co., Gunnison, Colo., and Kerr-McGee Oil Industries, Inc., Shiprock, N. Mex. also were modified and now extend to December 31, 1962, and June 30, 1965, respectively.

The Commission-owned uranium mill at Monticello, Utah, was shut down in December 1959. Operation of the Commission's ore-buying station at Monticello will continue until satisfactory arrangements are made with private mills in the area to buy the roscoelite and carnotite ores from mine operators desiring to ship such ores to Monticello under the provisions of Circular 5, Revised.

A list of the operating mills and those under construction as of December 31, is given in table I.

TABLE I.—URANIUM PROCESSING PLANTS

Company	Location of mill	Present contract terminates	Tons of ore per day	Estimated cost of mill
1. Anaconda Co	Grants, N. Mex	3/31/66	3,000	$19,358,000
2. Climax Uranium Co	Grand Junction, Colo	7/31/60	330	3,088,000
3. Dawn Mining Co	Ford, Wash	3/31/62	400	3,100,000
4. Federal-Radorock Gas Hills Partners	Fremont Co., Wyo	12/31/66	522	3,370,000
5. Gunnison Mining Co	Gunnison, Colo	3/31/62	200	2,025,000
6. Homestake-New Mexico Partners	Grants, N. Mex	3/31/62	750	5,325,000
7. Homestake-Sapin Partners	Grants, N. Mex	6/30/63	1,500	9,000,000
8. Kermac Nuclear Fuels, Corp	Grants, N. Mex	12/31/66	3,300	16,000,000
9. Kerr-McGee Oil Industries	Shiprock, N. Mex	10/31/59	300	3,161,000
10. Lakeview Mining Co	Lakeview, Ore	11/30/63	210	2,600,000
11. Lucky Mc Uranium Corp	Fremont County, Wyo	12/31/66	980	6,900,000
12. Mines Development, Inc	Edgemont, S. Dak	3/31/62	400	1,900,000
13. Phillips Petroleum Co	Grants, N. Mex	12/31/66	1,725	9,500,000
14. Rare Metals Corp. of America	Tuba City, Ariz	3/31/62	300	3,600,000
15. Susquehanna-Western, Inc.[a]	Riverton, Wyo	10/31/63	500	3,500,000
16. Texas-Zinc Minerals Corp	Mexican Hat, Utah	12/31/66	1,000	7,000,000
17. Trace Elements Co	Maybell, Colo	3/31/62	300	2,208,000
18. Union Carbide Nuclear Co	Rifle, Colo.[b]	3/31/62	1,000	8,500,000
19. Union Carbide Nuclear Co	Uravan, Colo	3/31/62	1,000	5,000,000
20. Uranium Reduction Co	Moab, Utah	12/31/66	1,500	11,172,000
21. Vanadium Corp of America	Durango, Colo	3/31/62	750	813,000
22. Vitro Chemical Co.[c]	Salt Lake City, Utah	3/31/62	600	5,500,000
23. Western Nuclear Corp	Jeffrey City, Wyo	12/31/66	845	4,300,000
	Subtotal		21,412	136,920,000
Mills Under Construction: (To be revised)				
1. Cotter Corp	Canon City, Colo	2/28/65	200	1,800,000
2. Globe Mining Co	Natrona County, Wyo	12/31/66	492	3,100,000
	Subtotal		692	4,900,000
	GRAND TOTAL		22,104	141,820,000

[a] Formerly Fremont Minerals, Inc.

[b] Union Carbide Nuclear Co. also buys ore at Slick Rock, Colo., and Greenriver, Utah, as feed for the Rifle, Colo. mill.

[c] Formerly Vitro Uranium Co.

NOTE: The above listed mills are privately-owned and operated, and all are licensed to buy uranium ores from producers. The USAEC buys the concentrate product under the terms of contracts with each mill operator.

Bonus Payments

Bonus payments paid to mine operators on initial production from mining properties from inception of the program in March 1951 totaled $15.8 million through December 31, 1959. On May 14, the Commission filed with the *Federal Register* a notice of modification of Domestic Uranium Program Circular 6 (F.R., title 10, part 60, section 60.6) designed to permit orderly termination of the initial production program on March 31, 1960, its expiration date. Although no bonus will

be paid on ores delivered after March 31, 1960, additional time is given uranium producers for filing applications for certification and applications for bonus payments on prior deliveries.

Radioactivity Hazards in Uranium Mines and Mills

The Commission has had a strong and continuing interest regarding possible methods for controlling radiological hazards associated with mill operations. In August 1957, the Commission instructed its Process Development Laboratory at Winchester, Mass. (operated under contract by the National Lead Co., Inc.), to extend its research and development activities to include the development of procedures for reducing radiological hazards associated with mill operations. The precision of measurements and basic studies of the chemical behavior of radium and thorium at extremely low concentrations constitute a major part of this program. Information developed by the Winchester Laboratory on measurement techniques and processing methods to control radioactive substances in the mill workers' environment and in the mill effluent have been tested in the Commission's Monticello mill. Technical meetings have been held this year in which information obtained by these two organizations has been reported to the private mill operators, the Public Health Service, and published for distribution to the general public.

Actions taken by the Commission concerning uranium mill operations are reported in the section on "Licensing, Regulation, and Indemnification."

The states exercise regulatory authority over uranium mines, but the Commission has participated in and financed a number of pertinent activities in studying the radiological problems of the industry. Arrangements were concluded during the summer with the Bureau of Mines which provide for health and safety inspections including radiation surveys by the Bureau of 14 Commission-controlled uranium properties being privately operated under leasing agreements. The Bureau of Mines also has undertaken inspection of the uranium mines on Indian reservations under the control of the Bureau of Indian Affairs. Preliminary results show that most of the mines have areas where the radon concentration is well above the standards established by the uranium mining states. These inspections have been restricted to "spot checks" and are not, therefore, conclusive. They do, however, indicate a need for continuing inspections and precautions to make sure that the uranium miners are not subject to excessive exposure. The Bureau of Mines reports the results of their inspections with recommendations directly to the mine operators with copies to the

Commission. The Commission's Grand Junction Operations Office has advised the lease operators that they must improve substandard operations to comply with standard regulations governing health and safety in mining operations. Commission mining engineers from Grand Junction regularly inspect the leased mines and give technical advice and assistance to help the operators control the hazards.

In addition, an arrangement was made with the Colorado State Health Department under which the Commission will furnish assistance to mine survey parties in that state in exchange for survey reports.

The question of Federal versus State responsibility for regulating radioactivity hazards in uranium mines was discussed at a meeting held in May at the Department of Health, Education, and Welfare headquarters in Washington. (See section of this report on Health and Safety for other aspects of Federal-State cooperation.)

Foreign Activities

Deliveries of foreign uranium concentrates to the United States during 1959 totaled 18,120 tons of contained U_3O_8 with 13,680 tons coming from Canada and the rest coming from Australia, Belgian Congo, Portugal, and South Africa under contracts of the Combined Development Agency.

Canada

In accordance with a long-standing agreement with Eldorado Mining and Refining, Ltd., the Commission amended its contracts with Eldorado to procure additional amounts of U_3O_8 in concentrates prior to March 31, 1962, from certain Canadian producers. These amendments, which do not represent new commitments to procure uranium concentrates from Canada, provide for the following amounts from the producers listed below:

Producer	*Pounds U_3O_8*	*Price per pound U_3O_8*
Gunnar Mines, Ltd	4, 500, 000	$8.75 (Canadian)
Pronto Uranium Mines, Ltd	1, 508, 000	8.00 (United States)
Algom Uranium Mines, Ltd	2, 456, 000	8.00 (United States)
Bicroft Uranium Mines, Ltd	260, 000	8.00 (United States)

Deferral of deliveries. The Commission announced in November that it will not be in a position to exercise the options it holds to purchase additional Canadian uranium concentrate in the post-1962 period. It also was announced that the Commission and Eldorado

had reached agreement on an arrangement that would permit the Canadian companies to defer part of the deliveries, which would have been made over the next 3 years, into the period March 31, 1962, through December 31, 1966. Under this stretch-out arrangement, which was announced to the Canadian industry by the Canadian Government, the Commission's total Canadian uranium commitment remains unchanged with respect to pounds to be delivered and the prices to be paid under existing contracts. Because the product to be delivered had been counted upon by the Canadian companies to provide amortization payments due in the pre-1962 period, an advance payment of $2.50 per pound of U_3O_8 will be made by the Commission with respect to each pound now deferred which would have been delivered under the previous agreement. These payments will be made at approximately the same time as the deliveries of these pounds would have been made had there been no deferment.

Combined Development Agency

Deliveries under Combined Development Agency contracts with Australia, Portugal, and South Africa were normal. Monthly shipments of Belgian UO_3 product continued as scheduled.

Assistance to Foreign Countries

Limited technical assistance in uranium exploration in Australia was completed in June of 1959. Assistance programs in Brazil, Chile, and Peru continued through 1959; these are scheduled to terminate at the end of December 1960.

During the period June to September, 1959, a 14-week program of training in uranium geology, exploration, and mining was completed by 16 foreign geologists and engineers from 10 countries. This program included visits to principal uranium districts in this country for observation and study of the various types of uranium ore deposits and mining methods and equipments. Special techniques and methods for the discovery, delineation, and evaluation of uranium ores were also studied. Included in the program were inspections of uranium ore processing mills. Four participants sponsored by the International Cooperation Administration are continuing their studies by undertaking specialized field investigations.

Production of Special Nuclear Materials

During calendar year 1959, special nuclear materials production was essentially in accordance with schedules and proceeded without unusual incident. Some schedules were revised during the year to comply with revised demands.

Plant Construction

The Allied Chemical Corp.'s uranium hexafluoride plant at Metropolis, Ill., began operation in April 1959. The plant is privately owned and, under a fixed-price contract, converts the uranium oxide in Commission-furnished concentrates to UF_6 feed material for the gaseous diffusion plants which concentrate the 235 uranium isotope. In contrast to the processes employed in the Commission's feed materials plants, the Allied plant uses a direct fluorination process which grew out of basic development work performed at several Commission installations. The most significant work on the use of fluid bed equipment in the uranium feed materials program was performed by the Argonne National Laboratory, which also performed pilot studies helpful to Allied in designing its facility. Some startup difficulties were encountered, but at year-end plant operation was in accordance with the contractual agreement.

Disposition of Facilities

In view of the existing and reserve capacity of other Commission facilities, the uranium processing plant located at Destrehan Street, St. Louis, Mo., which was placed in standby condition in June 1958, is now being dismantled.

The Dana Heavy Water Plant, in standby condition since June 1957, was transferred to the Army Chemical Corps on July 29, 1959 for other process use.

Nuclear Fuel Processing

In line with its announced policy of accepting from reactor operators irradiated fuels in unprocessed form and of making financial

settlements which provide for reprocessing of the spent fuels until such services become available commercially, the Commission announced October 16 that the irradiated fuels will be received for processing at the following facilities: Chemical Processing Plant, National Reactor Testing Station, Idaho; Oak Ridge National Laboratory, Oak Ridge, Tenn.; Savannah River Plant, Aiken, S.C.; and the Hanford Works, Richland, Wash.

Assignments of fuel elements from specific reactors to these sites have been made according to the process involved in each case (see the special section of this report on Management of Radioactive Wastes). Representatives of the Commission's reprocessing organizations and private industry took part in a symposium at Richland, Wash., on October 20–21, 1959, to review the reprocessing technology to be employed at each site. Mechanical handling methods, chemical processes, materials of construction for processing equipment, and specific site plans were presented and discussed.

Production Reactor With Power Convertibility

Kaiser Engineers of Oakland, Calif., was awarded a cost-plus-fixed fee contract on May 13 for construction of the New Production Reactor (NPR) at Hanford, Wash. Construction of access roads and temporary facilities has begun and contracts have been placed for procurement equipment requiring long-term delivery.

In contrast to the existing Hanford reactors, the new reactor will employ secondary cooling in which the cooling water is converted to steam. Although most of this steam will be condensed by river water, power facilities will be installed later if power recovery is undertaken; plant design is quite flexible, providing for the recovery of electric power over a wide range.

A study of the economics of adding electric generating facilities to the reactor was undertaken for the Commission by the Bureau of Power of the Federal Power Commission. Both architect-engineers, Burns & Roe for the heat dissipation system and General Electric Co. for the reactor design, are working with the Atomic Energy Commission to establish operating and maintenance labor requirements for the alternate operational plans. These estimates will be made both for dual-purpose and power-only operation.

Because of the NPR's power convertibility features, a technical information program has been established so that interested individuals and groups are able to obtain information on design and construction of the reactor, partly on an unclassified basis and partly, through the Commission's Access Permit Program, as confidential-

restricted data. A portion of this information now is available in the form of reports and engineering drawings, announced and sold through the usual channels. A reading room has been established at the Hanford Office where information and technical data are available for inspection.

Military Application

During 1959 emphasis continued on research and development activities designed to improve and increase the United States' arsenal of nuclear weapons. Research and development efforts continue along the same general lines reported previously [4] with special emphasis on smaller, immediately-ready, and more rugged weapons for use in advanced weapons systems. Some Commission laboratory effort is being devoted to the problems of detection of nuclear explosions in outer space and underground.

Production of nuclear weapons continued as authorized by Presidential direction.

Since the President's announcement that the United States would suspend nuclear testing beginning November 1, 1958, the Commission has placed the facilities at Eniwetok Proving Ground on a minimum maintenance basis. The Nevada Test Site has been kept in standby readiness by maintaining the buildings and equipment and repairing, or preparing, certain tunnels.

The first of a series of high explosive, nonnuclear, tests was detonated on December 17, 1959, in the Carey Co. Salt Mine near Winnfield, La. The tests are a part of the program on detection of the seismic effects resulting from underground explosions. Special nuclear materials will not be used in these tests.

Radiation Accident at Los Alamos

On January 1, 1959 at the Los Alamos Scientific Laboratory, a chemical operator died as the result of a massive overexposure to radiation. The cause of the accident was a critical excursion in a plutonium recovery operation. The man involved was standing less than 2 feet from the critical excursion; he received an average whole-body exposure in excess of 5,000 rads and died 35 hours after the accident.

Details of the accident itself were published in an unclassified document, LAMS 2293, "Nuclear Critical Accident at the Los Alamos Scientific Laboratory on December 30, 1958."

[4] See p. 11, Twenty-fourth Semiannual Report to Congress (January–June 1958).

Weapons Facilities

A new facility was completed at Livermore, Calif., for the Sandia Corp. to provide support for the weapons function of the E. O. Lawrence Radiation Laboratory (Livermore Branch). The $5.9 million facility was occupied in February of 1959.

The facility, located on a 75-acre site near the University of California's laboratory, consists of some 200,000 square feet of floor space in six structures.

Construction was also completed on the new Sigma Building at Los Alamos. The building is the last of the major technical area structures constructed to replace the temporary, wartime technical buildings located in the townsite area. Demolition of the original technical area is continuing.

Mutual Defense Agreements

Agreements for Cooperation with other nations for mutual defense purposes may provide for the exchange of certain classified information concerning nuclear weapons and military reactors and for the transfer of the less sensitive nonnuclear parts of atomic weapons systems necessary to improve the training and operational readiness of Armed Forces. Under certain conditions, these agreements may also provide for the transfer of military reactors, nonnuclear parts of weapons, and nuclear material for military purposes.

Six Agreements for Cooperation for mutual defense purposes became effective during 1959. These include a revised agreement with Canada, and new agreements with France, the Federal Republic of Germany, Greece, The Netherlands, and Turkey.

The United States-United Kingdom Agreement for Cooperation on the uses of atomic energy for mutual defense purposes is considerably broader than the other agreements. Under this agreement, a program for the exchange of more detailed atomic weapon information and the sale of a submarine propulsion reactor was begun during the latter part of 1958. During 1959, this program was further expanded and the Agreement for Cooperation was amended to provide for transfer of certain materials and nonnuclear components of weapons to the United Kingdom. A number of technical conferences on problems of mutual interest were also held.

On September 30, 1959, the President, by Executive Order 10841 delegated to the Commission and Department of Defense, acting jointly, the authority to make the determination required by Sections 91c, 144b and 144c of the Atomic Energy Act that proposed coopera-

tion and proposed communications or transfers under Agreements for Cooperation for mutual defense purposes will promote and will not constitute an unreasonable risk to the common defense and security.

Military Reactor Development

Work continued on the development of compact, lightweight, power and heat reactors capable of being set up rapidly and at minimum costs at remote military installations; the development of a group of nuclear propulsion plants to meet specific naval applications established by the Department of Defense; and the development of nuclear propulsion systems for manned aircraft, missiles, and space vehicles, and nuclear sources of auxiliary electric power for space applications.

Army Reactors Program

Stationary Medium Powerplant 1 (SM–1). Alco Products, Inc., continued operating the SM–1 (formerly the APPR–1, see Table II) at Fort Belvoir, Va., under a contract jointly funded by the Commission and the Army. The plant was used for training military operators, for research and development, and for production of electrical power to supply in part the requirements of the U.S. Army Engineer Research and Development Laboratories.

As of December 31 the plant had operated for 12,040 equivalent full-power hours, or 13.7 megawatt years of its now expected 15 megawatt-year core life. It had generated 23,188,000 kilowatt-hours of electrical power.

The SM–1 was shut down early in March to permit removal of the pressure vessel head for visual inspection and subsequent metallurgical examination of selected core components. This was the first time the pressure vessel head had been removed since the plant began operation in April 1957. The shutdown was scheduled to determine the effects of long-term irradiation at operating temperature and pressure on control rods and fuel elements. Certain core components were selected for removal and sent to the Oak Ridge National Laboratory for detailed metallurgical examination. The results of the analysis will be of value in the development of the SM–2 (formerly the APPR–1B) core, and in the SM–1A (APPR–1A) and PM–2A programs. The selected core components were replaced with available spares and the plant resumed operation on May 22.

Tests in support of continuing research and development programs on activity buildup, fission product activity and core physics measure-

ments were performed at intervals, but emphasis was placed on operating crew training for the SM–1A and PM–2A plants.

TABLE II.—CHANGES IN REACTOR DESIGNATIONS

The designations for projects under the Army Reactors Program have been changed to make them more descriptive of the projects and to indicate (*a*) mobility characteristics; (*b*) power range; (*c*) development sequence; and (*d*) field plant sequence. The old and new designations of active projects, together with their meanings, are as follows:

Atomic Energy Commission Projects

Former Designation	*Present Designation*
APPR–1—Army Package Power Reactor 1	SM–1—Stationary Medium-Powerplant–1
APPR–1B—Army Package Power Reactor 1B or "High Power APPR" (core)	SM–2—Stationary Medium-Powerplant–2
APPR–2—Army Package Power Reactor 2 or "Modular Prepackaged Plant"	PM–1—Portable Medium-Powerplant–1
ALPR—Argonne Low Power Reactor	SL–1—Stationary Low-Powerplant–1
PGCR—Portable Gas-Cooled Reactor	ML–1—Mobile Low-Powerplant–1
GCRE—Gas-Cooled Reactor Experiment	No change

Department of Defense Projects

Former Designation	*Present Designation*
APPR–1A—Army Package Power Reactor 1A	SM–1A—Stationary Medium-Powerplant–1A
None	PM–2A—Portable Medium Powerplant–2A

The suitability of this reactor concept for military powerplants has been proved by successful operation of the SM–1 for nearly 32 months under conditions of rigorous testing and frequent load cycling with no major failure of equipment or components. Experience with this plant has developed a firm basis for improved nuclear powerplants to meet military requirements.

Stationary Medium Powerplant–2 (SM–2). Alco Products, Inc., undertook, under a Commission contract, the design and development of a higher power core of the SM–1 type. This project was initiated in response to a Department of Defense requirement for a 6,000 ekw. (electrical kilowatts) core of the same overall size as the SM–1 core and with a minimum life of 1 year. Preliminary results of an intensive program to develop a technique for welding fuel elements of the flat plate, dispersion type have been encouraging. Capsule irradiation studies have been initiated in the Commission's test reactors.

To check the effects of high heat flux conditions in the SM–2, several two-plate assemblies were tested in the Vallecitos Boiling Water Reactor. The results of these tests indicated a need for continuing these experiments. Equipment for conducting hydraulic tests on the fuel elements was built by the Alco laboratories and these tests are underway.

Preliminary designs of other components are undergoing evaluation prior to writing specifications for the final design. Under an Army contract, Alco also continued the design of a plant to utilize the higher power core. Target date for completion of core design is July 1, 1960, and of final design and specifications for the SM–2 plant December 31, 1960.

Portable Medium Powerplant–1 (PM–1). The PM–1 (formerly APPR–2) is a factory-assembled, modular, air-transportable, nuclear powerplant being designed, developed, and constructed to meet a Department of Defense requirement. This project is being accomplished under a cost-plus-fixed-fee contract signed in April with The Martin Co. and funded jointly by the Commission and the Air Force. The estimated cost of the project is $6 million.

The PM–1 will produce 1,000 ekw. net plus 2,000 kilowatts of space heat and will be installed at Sundance Air Force Station, Wyo., during the summer of 1961. It will be designed to provide maximum ease of operation and maintenance, reduced transport and erection efforts, increased reliability, reduced installation and operation costs, and a capability for relocation after operation.

The objective of core design and development is a compact reactor with a minimum operating life of 2 years. It is estimated that the entire PM–1 plant will be capable of being shipped by 15 cargo aircraft and erected within a 90-day period.

Stationary Low Power Reactor (SL–1). Operating responsibility for SL–1 (formerly ALPR) was transferred February 5 from Argonne National Laboratory, which designed and initially operated the plant, to Combustion Engineering, Inc. Combustion Engineering was selected as operating contractor from among 13 firms submitting contract proposals.

The plant is being operated to obtain operating and performance data, to train military operators, to determine the limits of plant performance, and to obtain design information for small, boiling water plants. A recently completed conceptual design of a portable plant based on SL–1 indicates such a plant could be built and installed at a remote site for about $2 million.

During July and August a sustained power run was made of SL–1 to obtain data on operational reliability. The plant operated at power for 995 out of 1,000 hours of elapsed time. The air-cooled condenser did not maintain design performance. The cause has been determined to be an insufficient condensing surface area.

Preliminary studies during the year indicated that the aluminum core may not attain its design life of three calendar years. Tests have been conducted to evaluate the core further and to establish parameters and materials for future cores.

SL–1 operation in 1959 and the plant evaluation has shown the suitability and feasibility of boiling water field plants, and indicated the increased potential of such plants with further development. As of December 31, the plant had operated for 3,969 equivalent full-power hours, or 1 megawatt year of its expected 6 megawatt year core life. It had generated 806,100 kilowatt-hours of electric power.

Nuclear Test Plant (NTP). Combustion Engineering, Inc., began preparation of the conceptual design of the Nuclear Test Plant on September 14. The NTP will be a power reactor intended to test water-moderated reactor cores under operating conditions up to power levels of 60 tMw (thermal megawatts). This installation will have no electrical generating capacity. The facility, to be located at the Army Reactor Experimental Area, National Reactor Testing Station, will permit full-scale test operation of new reactor core designs prior to application in remote military nuclear powerplants.

The architect-engineer firm of C. F. Braun and Co. was selected to provide the detailed design of the NTP. Completion of the NTP is scheduled for August 1961. The first reactor core to be tested will be the prototype SM–2 core. NTP cost is estimated at $5 million.

Pressurized water reactor core development. The Martin Co. began a program to develop improved methods of nuclear analysis for pressurized water reactors in the Army program. These improved techniques will be used to obtain more economical cores with longer life, improved power distribution, reduced coolant flow and pressure requirements, and refined methods of reactor control. Experimental data and reactor operating experience will be used to verify the accuracy of these methods.

Gas-cooled reactor systems. Fabrication of the Gas-Cooled Reactor Experiment (GCRE) was completed in October. Component and precritical system testing is being completed and reactor criticality will be attained in February 1960. This plant will develop engineer-

ing data and experience for the design and construction of mobile powerplants for military use.

Aerojet-General Corp., contractor for the design, fabrication, and operation of the GCRE also is completing the final design of the Mobile Low Powerplant No. 1 (ML–1) (formerly PGCR). To meet a Department of Defense requirement, the plant will have a net electrical output of 400 kw, be readily transportable by land, sea, and air vehicles, and be able to operate under extreme environmental conditions. Construction of the facility is scheduled to start in May 1960. The ML–1 will be the first closed-cycle gas-turbine powerplant to be operated from a nuclear reactor heat source.

Military Compact Reactor Program. The goal of the Military Compact Reactor Program is the development for the Department of Defense of a mobile, light weight, extremely compact nuclear powerplant of moderate power level. Staff action leading to the selection of a prime contractor to perform the work is now nearing completion.

The Commission's evaluation of the three studies of compact reactors performed by the Curtiss-Wright Corp., General Electric Co., and the Nuclear Development Corp. of America, and of the compact shielding study conducted by the Convair Division of General Dynamics Corp. was completed earlier in the year. These classified studies have provided valuable information on the technical feasibility of a compact reactor system, and have indicated that the attainment of objectives of this program will require a significant development effort.

Army Reactor Experimental Area (AREA). A portion of the National Reactor Testing Station has been designated as the Army Reactor Experimental Area (AREA). Reactors in the Army Program and facilities necessary for their support will be located within AREA.

Construction of support facilities, including hot cells, a shop and maintenance building, and necessary utilities, was authorized in the fiscal year ended June 30, 1959. Design was completed in January by the Norman Engineering Co., Hollywood, Calif., and a construction contract was awarded to Teller Construction Co., Idaho Falls, Idaho, on March 25. Construction is scheduled to be completed in April 1960.

Remote Military Power Applications study (RMPA). In response to a Congressional directive to perform design and engineering studies on reactors for remote overseas installations, a study contract

was awarded to Kaiser Engineers, Division of Henry J. Kaiser, Oakland, Calif.

The Department of Defense will furnish a list of power applications for remote locations in the range of 5,000 to 40,000 electrical kilowatts. From this list Kaiser will develop designs of plants for those 10 applications in which nuclear power is most nearly competitive with conventional power. Although the contractor will judge only on the basis of economics, the Commission reserves the right to have included among the final 10 applications selected by the contractor any particular location, type of plant, or method of installation where it is necessary to derive the maximum possible benefit to the reactor development program as a whole or to accommodate a particular interest of the Department of Defense.

For example, a barge-mounted plant and a plant having a core of low enrichment may be included not necessarily because of economics, but because of Department of Defense interest in the former, and of civilian power program interest in the latter.

The contractor's final report is due by February 1, 1960, and the Commission's report to the Joint Committee on Atomic Energy is to be submitted by April 1, 1960.

Naval Reactors Program

The Navy now has 37 nuclear submarines and 3 nuclear surface ships operating, under construction, or authorized by Congress. (Table III summarizes the types and status of the 40 nuclear ships.)

Submarine Reactors

The USS *Nautilus*, the Nation's first nuclear-powered submarine, entered the Portsmouth, N.H., Naval Shipyard in May to undergo her second refueling and to receive the first regular overhaul of a nuclear-powered ship. When the second reactor core was shut down for the last time, the *Nautilus* had traveled a total of 153,886 miles, of which 115,383 were fully submerged.

Submarine Fleet Reactor—(S3W/S4W). On January 9, the nuclear-powered submarine *Halibut* (SSG(N) 587) was launched at Mare Island Naval Shipyard, Vallejo, Calif. *Halibut* is powered by a *Skate*-type reactor plant. The ship is designed to be armed with the currently operational air-breathing surface-to-surface missile, Regulus. The submarine was commissioned on December 30, 1959.

In March the USS *Skate* (SSN 578) made the first extensive trip in winter under the polar ice cap. During this trip *Skate* traveled

11,495 miles, 11,220 of which were fully submerged, and 3,090 of which were under the Polar ice cap. She punched her way through the ice to surface 10 times.

The USS *Sargo* (SSN 583) departed in early January on extensive operations in the Pacific and returned to Pearl Harbor in late March. During this period she traveled 19,000 miles, of which 18,880 were fully submerged. This is the longest period of sustained under water operation recorded by any submarine.

High Speed Submarine Reactor—(S5W). During March, USS *Skipjack* (SSN 585), the first of the high-speed nuclear-powered attack submarines, completed her first sea trials satisfactorily. *Skipjack* attained the highest speed known to have been made by any submarine. This submarine was commissioned on April 15, at Electric Boat Division of the General Dynamics Corp., Groton, Conn.

Submarine Advanced Reactor—(S3G). The S3G land prototype reactor plant at West Milton, N.Y., was operated during this report period to test the propulsion plant and to train Naval submarine crews.

The nuclear-powered radar picket submarine, the *Triton*, was commissioned on November 10 at Groton, Conn. This submarine, largest one ever built for the United States Navy, is powered by two reactors of the S3G type.

Small Submarine Reactor—(S1C). Construction of the Small Submarine Reactor prototype plant was completed at Windsor, Conn., and the plant achieved full-power operation on December 19.

The *Tullibee* (SSN 597), a hunter-killer nuclear submarine which will embody an S1G type of reactor plant, is under construction at Electric Boat Division in Groton, Conn.

Surface Ship Reactors

Destroyer Reactor Prototype—(D1G). The hull for the destroyer reactor prototype at West Milton, N.Y., was completed in January. Work on the in-hull foundation installation and installation of in-hull components was under way. Construction of off-hull facilities, such as the cooling water towers and connecting piping, continued.

The keel of the nuclear-powered guided missile destroyer *Bainbridge* (DLGN-25), which will utilize two D1G-type reactors, was laid on May 15 at Bethlehem Steel Co., Shipbuilding Division, Quincy, Mass.

Large Ship Reactor—(A1W). Initial full-power operation of the first reactor plant of the A1W prototype plant was achieved in Janu-

TABLE III.—NUCLEAR POWERED NAVAL SHIPS

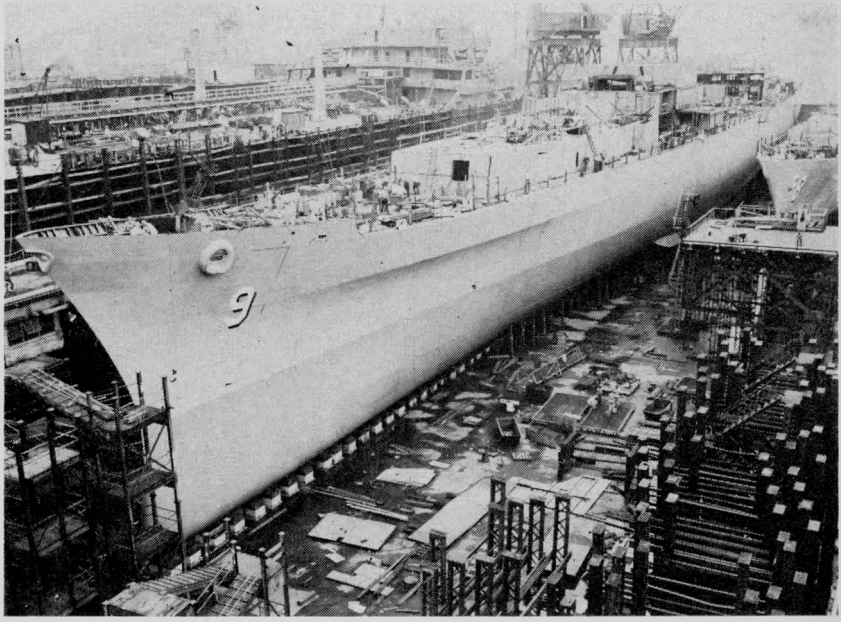
Submarines and surface ships	Type	Status	Shipbuilder [a]	Reactor designer
SSN571 Nautilus	Attack	Operating	EB Division	Westinghouse.
SSN575 Seawolf	do	Being converted	do	Do.
SSN578 Skate	Small attack	Operating	do	Do.
SSN579 Swordfish	do	do	Portsmouth	Do.
SSN583 Sargo	do	do	Mare Island	Do.
SSN584 Seadragon	do	do	Portsmouth	Do.
SSG(N)587 Halibut	Regulus missile	do	Mare Island	Do.
SSN585 Skipjack	Fast attack	do	EB Division	Do.
SSN588 Scamp	do	Under construction.	Mare Island	Do.
SSN589 Scorpion	do	Launched (Dec. 19, 1959).	EB Division	Do.
SSN590 Sculpin	do	Under construction.	Ingalls	Do.
SSN591 Shark	do	do	Newport News	Do.
SSN592 Snook	do	do	Ingalls	Do.
SSN593 Thresher	do	do	Portsmouth	Do.
SSN603 Pollack	do	do	New York	Do.
SSN604 Haddo	do	do	do	Do.
SSN605 Jack	do	do	Portsmouth	Do.
SSN606 Tinosa	do	do	do	Do.
SSN594 Permit	do	do	Mare Island	Do.
SSN595 Plunger	do	do	do	Do.
SSN596 Barb	do	do	Ingalls	Do.
SSN607 Dace	do	do	do	Do.
SSR(N)586 Triton	Radar picket	Operating	EB Division	General Electric.
SSN597 Tullibee	Hunter-killer attack.	Under construction.	do	Combustion Eng
SSN612	Attack	Authorized	Not Assigned	Westinghouse.
SSN613	do	do	do	Do.
SSN614	do	do	do	Do.
SSN615	do	do	do	Do.
SSB(N)598 George Washington.	Polaris missile	Operating	EB Division	Do.
SSB(N)599 Patrick Henry.	do	Launched (Sept. 22, 1959).	do	Do.
SSB(N)600 Theodore Roosevelt.	do	Launched (Oct. 3, 1959).	Mare Island	Do.
SSB(N)601 Robert E. Lee.	do	Launched (Dec. 18, 1959).	Newport News	Do.
SSB(N)602 Abraham Lincoln.	do	Under construction.	Portsmouth	Do.
SSB(N)608 Ethan Allen	do	do	EB Division	Do.
SSB(N)609 Sam Houston.	do	do	Newport News	Do.
SSB(N)610 Thos. A. Edison.	do	do	EB Division	Do.
SSB(N)611 John Marshall.	do	do	Newport News	Do.
CG(N)9 Long Beach	Guided missile cruiser.	Launched (July 14, 1959).	Bethlehem	Do.
CVA(N)65 Enterprise	Aircraft carrier	Under construction.	Newport News	Do.
DLG(N)25 Bainbridge	Guided missile destroyer.	do	Bethlehem	General Electric.

[a] EB Division—Electric Boat Division of General Dynamics Corp., Groton, Conn.;
Portsmouth—Portsmouth Naval Shipyard, Portsmouth, N.H.;
Mare Island—Mare Island Naval Shipyard, Vallejo, Calif.;
Ingalls—Ingalls Shipbuilding Corp., Pascagoula, Miss.
Newport News—Newport News Shipbuilding and Dry Dock Co., Newport News, Va.
Bethlehem—Bethlehem Steel Co., Shipbuilding Division, Quincy, Mass.

ary. The pre-core installation test program on the second A1W reactor plant was completed in February. Installation of the core for the second reactor plant began late in March and pre-critical tests prior to final assembly began in June. Initial criticality was achieved in July and on September 15, both reactor plants operated at full power for the first time. The plant continued operation utilizing both reactors to develop data on dual plant performance. This is the first nuclear plant to have two reactors powering one ship propeller shaft.

The aircraft carrier, *Enterprise*, under construction at Newport News Shipbuilding and Dry Dock Co., will be powered by eight A1W type reactor plants. The cruiser, *Long Beach*, being built by Bethlehem Steel Co., Shipbuilding Division, Quincy, Mass., will utilize two A1W type reactors. The *Long Beach* was launched at Quincy on July 14.

Natural Circulation Reactor. In September the Commission assigned responsibility for design, development, and prototype construction of a natural circulation, pressurized water reactor plant for naval ship application to the Commission's Knolls Atomic Power Laboratory at



Nuclear-powered cruiser. The Navy's guided missile cruiser *Long Beach* was launched at Quincy, Mass., during July. Above photo shows the ship just prior to launching. The *Long Beach* will be the Navy's first nuclear-powered surface vessel. She will use two pressurized water reactors.

Schenectady, N.Y., which is operated by the General Electric Co. The natural circulation reactor plant offers promise of an improvement in the field of pressurized water reactors for ship propulsion through plant simplification and increased operating reliability. This reactor concept eliminates the need for large circulating pumps and associated control equipment by using natural convection to circulate the reactor cooling water. The construction of this plant, authorized in the program for the fiscal year that will end June 30, 1960, is estimated to cost $18.5 million.

Aircraft Reactors Program

Nuclear propulsion for manned aircraft. The Commission's work on nuclear powerplants for manned aircraft was continued on two approaches—the direct cycle and indirect cycle. In July, both cycles were oriented toward a common objective based on guidance from the Department of Defense. Increased emphasis was placed on the development of materials and reactor systems compatible with militarily useful nuclear propulsion systems of high performance and long life.

The *direct cycle* approach is being developed by the General Electric Co., under Commission contract, at Evendale, Ohio, and at the National Reactor Testing Station in Idaho. Much of the basic research and development work has been in reactor materials development and in the operation of reactor experiments.

The first aircraft reactors experiment, Heat Transfer Reactor Experiment No. 1 (HTRE–1), was modified to HTRE–2 for use as a test reactor for investigations on high temperature fuel elements and moderators. The HTRE–3, which is the first aircraft type reactor of horizontal configuration, entered a series of power tests in late 1959.

The overall program orientation, noted previously, will involve some modification of projects, but will not materially affect the general scope and goal of the direct cycle program. Increased promise of advanced fuel elements makes it possible to set as a goal of the reoriented program, the development of an advanced powerplant with higher performance than previously planned.

Construction of two new facilities for use in the direct cycle program—the Flight Engine Test Facility and the Shield Test Pool Facility—was essentially completed at the National Reactor Testing Station in June.

Development of the *indirect cycle* approach is being carried out under Commission contract by the Pratt & Whitney Aircraft Division of the United Aircraft Corp. at the Connecticut Aircraft Nuclear

Engine Laboratory (CANEL), Middletown, Conn. This program is directed toward developing high temperature materials and reactor technology for ultimate application to high performance systems. Encouraging progress is being made in the areas of high temperature fuel element development, liquid metal components developments, and high temperature compatibility of liquid metal coolants with their containing materials.

In March, the construction was initiated on a Hot Laboratory Facility at CANEL.

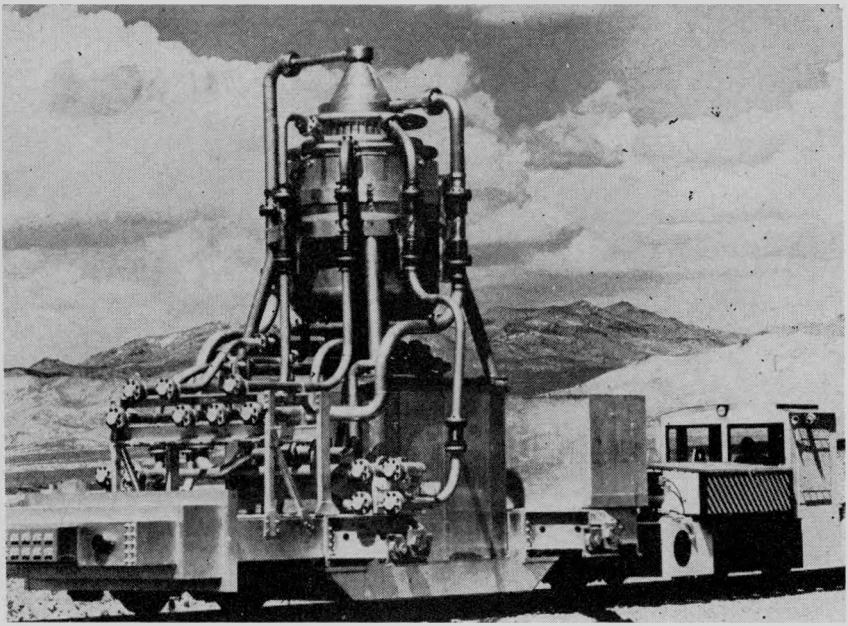
In March, the Air Force announced the selection of the General Dynamics Corp. Convair-Division, Fort Worth, Tex., to work on the initial design of a nuclear powered aircraft. Convair will work closely with the General Electric Co. and Pratt & Whitney on this project.

The Oak Ridge National Laboratory is providing general support in research, applied development, and testing in both the direct and indirect cycle programs. Also in general support the Sylvania Corning Nuclear Corp. is carrying out investigations on high temperature materials.

Nuclear propulsion for unmanned vehicles. Work on application of nuclear energy to unmanned vehicles is carried on in three programs: nuclear rocket propulsion (Project ROVER); nuclear ramjet propulsion (Project PLUTO); and systems for nuclear auxiliary power (SNAP).

Technical work on *Rover* is centered at the Commission's Los Alamos Scientific Laboratory. The first objectives are to develop special test reactors to explore the problems involved in achieving high-power density, to develop reactor materials capable of withstanding high temperatures, and to investigate new concepts for conversion of nuclear energy into useful propulsion forms. The work at Los Alamos is leading to a series of test reactors which will be operated in the Commission's Propulsion Reactor Test Area at the Nevada Test Site. The initial facilities were completed and the first test reactor, KIWI–A, was successfully tested at full power on July 1. KIWI–A is a heat exchanger device in which the propellant, heated in the reactor core, is expended to the atmosphere through a nozzle. The run was made according to plan. The knowledge gained will be applied to the design of future test reactors.

Project *Pluto* is pointed toward demonstration of the feasibility of using a nuclear reactor as the heat source in a ramjet engine. Reactor work is under the direction of the Commission's Lawrence Radiation Laboratory at Livermore, Calif., with support on materials



Space propulsion reactor mockup. Work in the Commission's program for nuclear propulsion of unmanned space vehicles includes studies in the field of nuclear rockets. The first experimental reactor, the *Kiwi-A*, was tested in July. It is a heat exchanger device in which the propellant, heated within the reactor, is expended to the atmosphere through a nozzle. Above is a mockup of the *Kiwi-A*, a nonflying proof-of-principle reactor named after the earth-bound Australian bird.

research supplied by the Atomics International Division of North American Aviation, Inc. The Air Force has the Marquardt Co. under contract to provide engineering assistance to the laboratory and to develop certain non-nuclear components associated with the tests of the Livermore experimental reactors. Construction of special facilities are nearing completion at the Nevada Test Site for testing experimental reactor cores. The design and fabrication of the first test reactor, Tory II, is proceeding according to schedule and testing is expected to be initiated in 1960. Critical experiments at elevated temperatures are continuing in the Hot Box facility in Nevada.

In the Commission's SNAP (Systems for Nuclear Auxiliary Power) program for developing compact, lightweight nuclear-electric auxiliary power units for use in space vehicles, two approaches have been followed: one, the development of radioisotope-heated units such as in SNAP–1 and SNAP–3, and, two, the development of small reactor-heated units such as SNAP–2. The radioistope units have

been under development by the Nuclear Division of The Martin Co., Baltimore, Md. The reactor-heated units have been developed by Atomics International, Canoga Park, Calif.

SNAP–3, the first complete unit delivered by The Martin Co., was publicly demonstrated by President Eisenhower on January 16, 1959. This radioisotope fueled thermoelectric generator weighed 5 pounds, had no moving parts, and produced 2.5 watts of electricity. The polonium 210 fuel for the unit was provided by the Commission's Mound Laboratory, Miamisburg, Ohio. Other radioisotope fueled SNAP units will be suited for a wide range of remotely located devices such as radiobeacons, fallout and fire warning alarms, and meteorological stations.

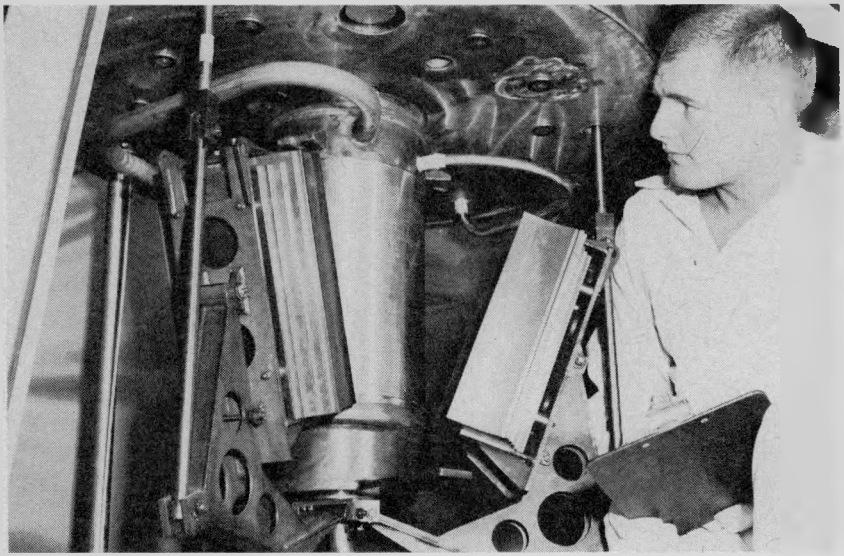
It was announced in November that the prototype of a lightweight, high-temperature nuclear reactor had been test-operated at design power and temperature. The reactor, developed in the SNAP–2 program and designated the SNAP Experimental Reactor, is comparable in size to a 5-gallon can and weighs approximately 220 pounds without shielding.

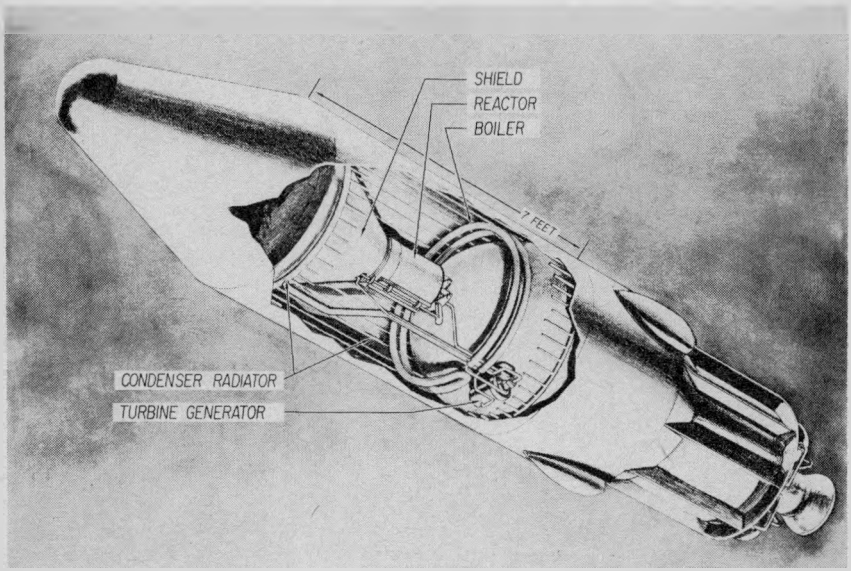
In an operational device, heat from the reactor would be transferred by a liquid sodium coolant to a boiler containing mercury. Mercury vapor would be directed into a miniature turbine so that the system would operate on the same principle as ordinary steam-electric generators except that the mercury vapor would be used to drive the turbine. Such a conversion system has been developed and successfully operated at design conditions with an electrical heat source.

The SNAP–2 space power system, weighing about 600 pounds will provide 3 kilowatts of electricity for a period of at least 1 year operating unattended in the weightless vacuum environment of outer space. Development work was recently initiated on a higher-power verison (designated SNAP–8) of the SNAP–2 reactor for use in satellite and space missions of the National Aeronautics and Space Administration.

The SNAP program also sponsors work in the development of compact means of converting heat into electricity. Companies that have been participating in developing advanced power conversion devices are Thompson-Ramo-Wooldridge, Inc., of Cleveland, Ohio; the Minnesota Mining and Manufacturing Co., St. Paul, Minn.; United Electronics Co., Newark, N.J.; Westinghouse Research Laboratories, Pittsburgh, Pa.; and Thermo Electron Engineering Corp., Cambridge, Mass.

A method of directly converting nuclear energy to electrical energy was demonstrated in April at the Los Alamos Scientific Laboratory.





SNAP 2 space vehicle. Development of a lightweight, high-temperature reactor to power instruments and radios in space satellites was announced by the Commission during November. The prototype reactor was developed by Atomics International under the Commission's SNAP (Systems for Nuclear Auxiliary Power) program and weighs, without shielding, about 220 pounds. (Upper photo) The core of the reactor (cylindrical container in center of photo) will produce 50,000 watts of heat. The heat will enter the boiler (top of photo) to vaporize mercury which, in turn, will drive a miniature turbine supplying the needed electricity. The reactor will be externally-controlled through the arc-shaped plates which are shown in a fully-open position. (Lower photo) Artist's conception of a SNAP 2 reactor placed in a space vehicle. The reactor can operate continuously and unattended for a full year.

The experimental device consisted of a "pin" of uranium carbide—zirconium carbide solid solution surrounded by a collector of stainless steel with separate electrical connections made to the emitter and collector. The space between these electrodes was filled with partially-ionized cesium vapor. The device was immersed in the center of the Omega West research reactor, and the neutron flux from the reactor caused fissioning of the uranium in the pin. The fission energy released caused the temperature of the pin to rise to about 1,900° C. The partially-ionized cesium vapor neutralized the space charge between the electrodes with a resulting short-circuit current of about 30 amperes. The open-circuit voltage was about 3.8 volts.

Although the work on this device, called the "plasma thermocouple," is in the early experimental phase, the experiment demonstrated a potentially valuable means of producing direct electric power for space vehicles and for possible use in small mobile nuclear power plants in remote areas.

In the latter part of 1959, an *Aerospace Nuclear Safety Board* was established within the Commission to: (*a*) analyze and project the effect of nuclear space devices upon the health of the people of the world; (*b*) analyze and maintain cognizance over present and future radiation from space nuclear power sources on earth and in those outer space regions of special interest to the United States; (*c*) recommend standards of safe practice for the employment of nuclear powered space devices by the United States; and (*d*) recommend policy and procedures to be followed in regulating the use of nuclear energy for devices in space vehicles and satellites proposed for use by the United States.

Work was begun on such initial task assignments as indoctrination of members in technology and problems of aerospace nuclear safety, selection and appointment of expert consultants, and development of operating procedures within the Commission. The Board has jurisdiction over the entire Commission aerospace nuclear safety program.

Programs Supporting Industrial Growth

The Commission continued during 1959 to encourage the growth of privately owned industrial capability to support the nuclear power industry. Commercial services, if available at reasonable price, are used by the Commission for processing and fabricating of unirradiated nuclear materials for power and test reactors, and for the shipment of radioactive wastes. In meeting its own needs for test irradiation services, the Commission encourages private industry to build and operate the required test reactors. Discussions are con-

tinuing with industry to develop a long-range program through which special nuclear material for privately owned reactors can be sold instead of leased. Development studies are going forward directed toward the chemical processing of irradiated fuels by private industry.

Training and educational assistance activities, reported in a succeeding section of this report, are directed toward broadening the base of nuclear knowledge and technology at home and abroad, and increasing the capability of the educational system for training qualified scientific personnel.

Industrial Testing Reactors

The Commission believes that a certain part of its requirements for test reactor facilities can be met with private reactors based on proved designs and technology. The Commission accordingly announced in 1956 that it would construct additional test reactors only if its needs for irradiation space could not be met by other sources.

Late in 1958 the Commission invited proposals from industry for irradiation services in reactors specifically designed for testing purposes. Eleven proposals were submitted and the Commission selected, in July, the proposal of The Babcock and Wilcox Co. as the basis for negotiation of a contract to provide the Commission with test irradiation services in a 60 thermal megawatt test reactor the company would build in Lynchburg, Va. The required services are in addition to those available in the Commission's Materials Testing Reactor and Engineering Test Reactor in Idaho. The Babcock and Wilcox reactor would be used primarily to meet Commission test needs for neutrons in the low- and mid-flux ranges. The Commission is also negotiating contracts with Westinghouse and General Electric for irradiation test space in their general test reactors at Waltz Mill, Pa., and Pleasanton, Calif., respectively.

In August, the Commission assigned to Phillips Petroleum Co. the task of performing a conceptual design study of a high-flux test reactor incorporating the most advanced technology available. The study was submitted to the Commission on October 1.

During August and September the Commission made a survey of industry's own requirements for irradiation space in test reactors in the period 1960 through 1965. Of 185 companies sent a questionnaire on this subject, 110 responded. Twenty-eight indicated requirements.

Commercial Processing and Fabrication

The Commission, in 1958, directed its field operations offices to procure from commercial sources, if available at reasonable prices, processing and fabricating services for unirradiated nuclear materials to be used in power and test reactors. During 1959, this directive resulted in 25 companies receiving 99 Commission procurement awards totaling $28 million. Fuel fabrication services—routinely supplied by industry prior to the 1958 directive—continued to be procured commercially, and comprised 34 contract awards to 14 companies for a total of $37.1 million.

In November 1959, the New York Operations Office was assigned responsibility for developing an unirradiated scrap industry by acting as a central point for placement and administration of this kind of contracts for civilian, Army, Navy, aircraft and maritime reactor development programs. Only the New York, Chicago, Pittsburgh, and Schenectady Operations Offices were included initially, but the arrangement may be extended.

Chemical Processing of Irradiated Fuels

The Commission held a meeting at Hanford in October to review Commission plans for processing irradiated fuels from private reactors and the necessary modification of its facilities. The Commission, in a cooperative program with major reactor owners, expanded its studies on feasibility and design of relatively small chemical processing facilities which could be owned and operated privately. It postponed for a period of 6 months modifications to Commission plants under the interim processing program to give further assurance to private processors that it will not compete in processing nonweapon fuels if industry does go forward with private plants.

Plutonium and Uranium 233 for Noncommercial Purposes

Late in 1958, the Commission established base charges of $12 per gram of plutonium and $15 per gram of uranium 233 made available to licensees for research and development uses of the type set forth in section 31 of the Atomic Energy Act of 1954, as amended, including critical experiments, but excluding fueling of nuclear reactors.

Distribution of uranium 233. In accordance with Commission policy to distribute uranium 233 to licensees for the purpose of carrying out research and development activities, the Commission authorized supply of 25 kilograms of uranium 233 to Southwest Atomic Energy Associates. This material will be used in a critical facility to determine the nuclear parameters of an epithermal thorium-uranium 233 breeder.

Irradiated fuel shipping containers. In line with the Commission's intention that shipments of radioactive material from private reactors to Federal processing plants be handled entirely by private firms according to appropriate Government regulations, the Commission furnished private companies with information on the technical requirements for such shipping. More than a dozen companies expressed interest in providing this service and some are actively developing procedures and designing the large, heavily-shielded containers needed to ship the radioactive fuel.

Companies licensed to perform these and other atomic energy services are listed in the section of this report on Licensing, Regulation, and Indemnification.

Availability of Lithium 7

Increased availability and decreased prices for enriched lithium 7 were announced by the Commission in September. The material, lithium hydroxide monohydrate, is available in kilogram quantities at the following prices:

99.99 atom percent Li 7	$120 per kg. contained lithium
99.98 atom percent Li 7	$107 per kg. contained lithium
99.97 atom percent Li 7	$100 per kg. contained lithium

No commercial source of this material exists. The Commission's production takes place at its Oak Ridge facility.

Nonnuclear Uses of Depleted Uranium

The Commission sponsored a study by the Battelle Memorial Institute regarding uses of depleted uranium other than in nuclear reactors or as a radiation shield. A report [5] by Battelle "Potential Nonnuclear Uses for Depleted Uranium" describes a wide variety of potential applications, for consideration by private firms.

[5] Office of Technical Services, Department of Commerce, Washington 25, D.C., $0.75.

Revision in Special Nuclear Material Lease Agreement

Improvements in the leasing program of special nuclear material were undertaken by the Commission, and include: (*a*) instituting a single, comprehensive lease agreement with each licensee to cover all his receipts and deliveries of special nuclear material, rather than the present system of lease contracts for each batch of material; and (*b*) centralizing the leasing function within the Commission at the Oak Ridge Operations Office, for all domestic special nuclear material leased. The change-over to these new methods is expected to take place early in 1960.

Sale of Special Nuclear Material

Under the Atomic Energy Act of 1954, all special nuclear material located in the United States is the property of the Federal Government. Special nuclear material is leased to licensees, who must pay the current 4 percent annual use-charge. This leasing system has several disadvantages for the Government, including the fact that it delays the recapture of money invested in production of the materials. The leasing system also requires the Government to buy special nuclear material produced in private reactors, even though its value can be established only in the market place.

A meeting was held with industry in February to discuss the problems which would result if special nuclear materials were sold instead of being leased to domestic licensees. Most representatives of industry believed that eventually domestic licensees should be permitted to own special nuclear material, subject to regulatory control, but that the time was not yet appropriate to change from lease to sale.

The Commission has under consideration the entire subject of a possible change from lease to sale of special nuclear material. Discussions with industry are continuing.

In order that industry may determine for itself the fact that the price of enriched uranium fuel does not represent a Government subsidy but is based on the full cost of production, the Commission invited [6] a committee sponsored by the Atomic Industrial Forum, Inc., to examine the facts.

The Committee,[7] after reviewing data furnished by the Commission as requested, reported in part as follows:

[6] Chairman John A. McCone in remarks at the Atomic Industrial Forum-American Nuclear Society meeting, Washington, D.C., Nov. 3, 1959.

[7] K. D. Nichols, consultant; Percival F. Brundage, retired partner, Price, Waterhouse and Co.; and William Webster, president, New England Electric System.

". . . A review of these data indicates that the published prices of U 235 do not include any Government subsidy. Further, as a result of technical advances and economies accomplished since the U 235 prices were established in 1955 and with due consideration to additional economies and technical advances anticipated, it is our opinion that in the future the price of U 235 in terms of 1959 dollars should not increase and a decrease might be warranted.

We should point out, however, that interest rates have risen rapidly during the past four years and at the present level of interest rates, the use charge to the industry of 4 percent per annum does contain an element of subsidy. It is our opinion that this factor would have to receive consideration in any contemplated future reduction in the price of U 235.

A review of anticipated U 235 requirements, both military and commercial, and a review of ore reserves, United States refining capacity, and the United States U 235 separation capacity indicate that there can be U 235 supply available to support both the inventories required and the continuing burnup requirements for a commercial atomic power capacity of at least 40 million kilowatts. For the purpose of estimating, it was assumed that the capacity of 40 million kilowatts does not, however, include the additional atomic power capacity that might be supported by the use of plutonium or natural uranium as a fuel."

Statistical Surveys

Joint Census-Commission survey. A joint survey by the Bureau of Census, Department of Commerce, and the Commission indicates that shipments of key atomic energy products from private manufacturing establishments were 55 percent greater in 1958 than in 1957. The total for 1958 was about $150 million as against the $96 million in 1957. (See table IV.)

This survey does not cover the entire field. Excluded are construction expenditures, engineering and design costs, research and development expenditures, except for products listed here, as well as products and materials used in atomic energy work which are not specifically designed for nuclear use. For some reactors, items not included in the survey have contributed from 70 to 80 percent of the total reactor cost. More than 200 firms returned reports showing some shipments of the products listed

TABLE IV.—FACTORY SHIPMENTS OF KEY ATOMIC ENERGY PRODUCTS: 1958 AND 1957

(Value—Thousands of Dollars)

Product	1958	1957
Nuclear Reactors (includes only those assembled at place of manufacture)	1, 156	2, 997
Accelerators and Accelerator Parts	45	[a]
Reactor Components and Equipment:		
Vessels and tanks	17, 099	11, 145
Control Rod Drive Mechanisms	7, 481	1, 263
Accessory Control Instrumentation	15, 284	9, 953
Heat Exchangers	13, 799	8, 284
Pressurizers	1, 758	[a]
Pumps	9, 516	6, 291
Valves	11, 401	7, 876
Complete Fuel Elements	23, 873	11, 057
Partially Fabricated Fuel Materials	5, 742	4, 985
Core Structurals (barrels, cans, etc.)	3, 908	1, 185
Hot Laboratory Equipment	3, 886	4, 761
Radiation Survey, Monitoring and Control Devices	13, 846	17, 471
Radiation Counting Equipment	10, 387	
Radioactive Isotopes Shipped from Plants Producing the Isotopes	171	73
Radiation Sources Produced From Purchased Isotopes	3, 071	2, 722
Control and Measuring Devices Containing Radioactive Isotopes	4, 909	6, 007
Commercial Irradiation Service	97	[a]
Enriched Uranium Metal and Compounds	1, 503	[a]
Total	148, 932	96, 070

[a] Not available.

Commission survey of reactor expenditures. Data based on a Commission survey indicate that nuclear reactor projects under construction or development as of September 30, 1959, will cost about $1,700 million when completed. About $320 million of this will be for research and development, $4 million for land specially acquired for the projects, the remaining $1,376 million for plant and equipment, including fabrication of fuel. (Project list in Appendix 14.)

Civilian power projects and propulsion plants for naval vessels account for the bulk of the costs, the distribution being as follows:

Purpose	Number of projects	Total cost (millions)
Civilian power experiments and prototypes	18	$717.2
Propulsion plants for naval vessels	[a] 32	468.5
Military prototypes, experiments, and field plants [b]	9	189.2
Materials production [c]	1	170.4
Civilian testing	8	75.4
Military testing	5	27.5
Propulsion plant for merchant ship [d]	1	26.3
Civilian research	19	28.2
Total	93	1,702.7

[a] A total of 41 reactors is to be installed in the 32 propulsion plants.
[b] Excluding projects in aircraft nuclear propulsion programs.
[c] The New Production Reactor at Hanford, designed with a power convertibility feature.
[d] N.S. Savannah.

Of the total costs represented by the projects, about 40 percent will be borne by the Commission, 30 percent by the Department of Defense, 30 percent by utilities, manufacturers, and universities. The distribution is as follows:

	Millions	Percent
AEC	$687.6	40.4
Department of Defense	509.8	30.0
Other Federal Government	14.2	.8
State and municipal utilities	22.0	1.3
Rural electric cooperatives	3.4	.2
Private industry-utilities	439.6	25.8
Private industry-manufacturers Universities	[a] 26.1	[a] 1.5
Total	1,702.7	100.0

[a] These two categories combined to avoid disclosure of costs for an individual project.

For all categories but the naval propulsion plants, data also were collected on expenditures already made from the inception of the projects through September 30 and on expenditures made during the 3 months ended September 30. These indicate that about $425 million, or about 35 percent, of the total cost of the projects, other than naval propulsion plants had been expended by September 30, and that about $57 million was spent in the 3 months ended September 30.

The distribution by type of project was as follows (in millions):

Purpose	Total cost of projects	Through Sept. 30, 1959	Quarter ended Sept. 30, 1959
Civilian power experiments and prototypes	$717. 2	$240. 1	$36. 7
Military prototypes, experiments, and field plants	189. 2	98. 4	10. 4
Materials production	170. 4	13. 4	2. 5
Civilian testing	75. 4	46. 0	4. 2
Military testing	27. 5	12. 8	. 6
Propulsion plant for merchant ship	26. 3	9. 5	1. 2
Civilian research	28. 2	5. 1	1. 4
Total	1, 234. 2	425. 3	57. 0

Of the amounts spent through September 30, again excluding expenditures for naval propulsion plants, about half was spent by the Commission. This was true also of expenditures in the 3 months ended September 30. The distribution was as follows (in millions):

	Total cost of projects	Through Sept. 30, 1959	Quarter ended Sept. 30, 1959
AEC	$687. 6	$210. 9	$29. 9
Department of Defense [a]	[a] 41. 3	[a] 21. 2	[a]. 8
Other Federal Government	14. 2	11. 8	. 5
State and municipal utilities	22. 0	4. 8	3. 8
Rural electric cooperatives	3. 4	2. 8	. 1
Private industry-utilities	439. 6	158. 9	20. 7
Private industry-manufacturers	[b] 26. 1	[b] 14. 9	. 3
Universities			. 9
Total	1, 234. 2	425. 3	57. 0

[a] Department of Defense figures exclude naval propulsion plants.
[b] These categories combined to avoid disclosure of costs for an individual project.

Of the $717 million estimated total cost for 18 *civilian power projects*[8] about $477 million will be for plant and equipment, $192 million for research and development, $45 million for fuel fabrication and $3 million for land.

[8] The 18 reactors included are BORAX–5, Carolinas Virginia Nuclear Power Associates Plant, Consolidated Edison Thorium Reactor, Dresden Nuclear Power Station, East Central and Florida West Coast Nuclear Groups Plant, Enrico Fermi Atomic Powerplant, Experimental Breeder Reactor No. 2, Experimental Gas-Cooled Reactor, Hallam Nuclear Power Facility, High Temperature Gas-Cooled Reactor Experiment, Humboldt Bay Powerplant, Unit No. 3, Los Alamos Molten Plutonium Reactor Experiment, Northern States Power Co. Pathfinder Plant, Philadelphia Electric Co. Reactor, City of Piqua (Ohio) Plant, Saxton Nuclear Experimental Reactor Project, Rural Cooperative Power Association Plant, Yankee Atomic Electric Co. Plant.

About $240 million, one third of the total cost of these projects, had been expended by September 30, of which $37 million was spent in the 3 months ended September 30.

The Commission's share of the cost of civilian power projects was estimated at $252 million. The remaining $465 million was distributed among segments of the electric utility industry as follows (in millions):

Investor financed utilities	$439.6
State and municipal utilities	22.0
Rural electric cooperatives	3.4

About half the Commission's costs for the civilian power projects will be for research and development. Through September 30, research and development accounted for nearly three-fourths of the Commission's costs. The distribution was as follows (in millions):

	Total cost	Costs through Sept. 30, 1959
Research and development	$131.7	$53.9
Plant and equipment	105.9	18.5
Fuel fabrication	14.6	1.3
Total	252.2	73.7

The electric utility industry's outlays for the projects are primarily for plant and equipment, as the following distribution shows (in millions):

	Total cost	Costs through Sept. 30, 1959
Research and development	$60.1	$36.8
Plant and equipment	371.2	116.7
Fuel fabrication	30.6	10.8
Land	3.0	2.3
Total	464.9	166.6

Of the $37 million spent for the civilian power projects during the 3 months ended September 30, $12 million was spent by the Commission, $25 million by the various utilities. Plant and equipment expenditures accounted for $26 million of the total spent during the 3-month period. Of this $26 million, $22 million was incurred by the utilities, $4 million by the Commission.

Prototype reactors jointly financed by industry and Government are the most numerous class among the civilian power reactors and account for the largest share of the costs, as follows:

	Number of projects	Total cost (millions)	Costs through Sept. 30, 1959 (millions)
AEC financed reactor projects	5	$123.2	$41.4
Cooperatively financed projects	9	398.0	103.2
Industry financed projects	4	196.0	95.5
Total	18	717.2	240.1

Costs of cooperatively financed prototypes are distributed between the Commission and industry as follows (in millions):

	Total cost of projects	*Costs through Sept. 30, 1959*
AEC	$129.1	$32.2
Industry	268.9	71.0
Total	398.0	103.2

The civilian power projects will have a total net generating capacity of more than a million electrical kilowatts. They are estimated to achieve design power operation according to the following schedule:

	Electrical kilowatts
1960	290,000
1961	402,450
1962	229,750
Unscheduled	90,200
Total	1,012,400

The projects included in the survey were those under construction or development. Completed projects were not included, nor were those so early in the planning stage that preliminary design had not begun. In this context a completed plant was taken to be one which had achieved operation at design power. Thus, the Dresden Nuclear Power Station was included since it achieved criticality but not design power shortly after the period covered by the survey; Shippingport Atomic Power Station was not included. In the case of naval propulsion plants, those included were all those for ships which have been authorized but not commissioned.

Commission costs, as calculated here, do not include the dollar value of waiver of use charges for fuels and materials.

Research and development costs included are only those specifically allocable to the reactor projects in the survey. It therefore omits a

considerable amount of more general research and development work not linked entirely to specific projects. The great preponderance of this has been financed by the Commission. Post-construction research and development also is excluded.

Also omitted are the costs of reactors for export, of work in the programs for nuclear propulson of both manned and unmanned aircraft, of critical experiment facilities, and of small training reactors shipped fully assembled by the manufacturer. Data in the joint Commission-Bureau of Census survey given previously indicate that the value of such training reactors shipped during 1958 was $1.2 million.

Access Permit Program

Under the Access Permit Program, individuals and concerns obtain access to Restricted Data which is of value for private business and research uses. As of December 31, there were 1,268 permits in effect; 462 for access to confidential information, and 806 for access to one or more categories of secret information. The distribution of permits by geographic area, industry, and field of interest is given in Appendix 10.

The total number of permits in effect is showing a downward trend. One year ago, active permits totaled 1,402, with the peak number of permits, 1,432, having been reached in August 1958. Two major factors in the decline probably are the continued increase in the scope of information available on an unclassified basis, and the Commission decision that after December 31, 1958,[9] it would no longer provide up to 25 free investigations for personal security clearances requested by permit holders, with the single exception of employees of nonprofit educational institutions. At the close of the reporting period the investigation fees were $15 for one "L" clearance giving access to confidential data, and $385 for one "Q" clearance giving access to both secret and confidential data.

Civil Uses of Nuclear Explosives

Studies in connection with the Plowshare program, to investigate possible civil uses of nuclear explosives, continued during 1959. These studies have included theoretical analyses, field surveys and preliminary planning related to several possible uses, progress on which is described in the following sections.

[9] See p. 58, Twenty-fifth Semiannual Report to Congress (July–December 1958).

Engineering

The available information has encouraged the study of the application of nuclear explosives to excavation. During the period of this report theoretical studies have been considered on the relation of depth of burial to the amount of material removed and the depth of excavation produced as well as of the control of radioactivity. Project CHARIOT is a study to determine the feasibility of a possible excavation experiment in Northwest Alaska between Cape Thompson and Cape Seppings. This project is designed to provide additional basic data on use of nuclear explosives in civil engineering projects. Field studies conducted during the summer consisted of on-site bioenvironmental and engineering surveys to determine the experiment's feasibility. Survey teams included personnel from the University of Washington, the University of Alaska, the Fish and Wildlife Service, the Weather Bureau, the Public Health Service, the Geological Survey, and the Army Corps of Engineers, the Commission staff and laboratory personnel. Reports are being prepared which will evaluate the health, safety, and technical feasibility, and conservation aspects of this experiment.

Power and Isotope Production

The study of the production and recovery of heat and isotopes produced by a contained underground explosion was continued. A part of this study includes planning for a possible full-scale nuclear experiment in the Salado Salt basin, 25 miles southeast of Carlsbad, N. Mex. During 1959, three nonnuclear high explosive shots were detonated at the site to assist in determining whether the proposed nuclear explosives could be detonated without damage to nearby facilities. Outstanding seismologists and other experts reviewed the resulting data and other pertinent information and concluded that the possibility of seismic damage to nearby facilities is remote enough so that the project could safely be carried out as planned. It is estimated that about one year would be required to prepare the site and execute the experiment if a decision were made to proceed.

Exploitation of Natural Resources

Theoretical analyses have been made on the feasibility of using nuclear explosives to aid in recovery of natural resources, such as oil from oil-bearing shales and from tar sands.

With regard to oil-bearing shales, these analyses indicate that nuclear explosives might be used to fracture large masses of shale so that in-place thermal oil separation might be achieved. Plans for an experiment in oil shales are being investigated in conjunction with the United States Bureau of Mines, Department of the Interior.

The Richfield Oil Co. has approached the Canadian Government concerning a possible experiment to utilize the heat from nuclear explosives to lower the viscosity of the oil in the Athabaska tar sands in Alberta, Canada, so that this oil can be recovered. The Canadian Government has established a technical committee to study the feasibility of conducting such an experiment. The Commission is providing technical advice and assistance.

Other Applications [10]

Theoretical studies also were made on use of nuclear explosives to provide basic data for seismology, geology, and chemistry studies where conventional high explosives and laboratory techniques cannot provide the necessary data, and the use of nuclear explosives to control surface and underground water resources.

Plowshare Symposium

The second unclassified Plowshare Symposium on industrial and scientific uses of nuclear devices was held in San Francisco, on May 13–15, 1959, by the Lawrence Radiation Laboratory and the Commission's San Francisco Operations Office. Representatives from government laboratories, universities, research institutions, the petroleum and chemical industries, and engineering and construction companies attended. Papers presented are being edited for publication.

Plowshare Advisory Committee

The Commission established a Plowshare Advisory Committee to advise the Commission on the relative merits, feasibility and safety aspects of the program. (See appendix 2)

International Activities

Achievements during 1959 in the international atomic energy program of this country can be measured most readily by the contributions

[10] See pp. 51–53, Twenty-fifth Semiannual Report to Congress (July–December 1958).

made to fulfillment of goals of United States foreign policy. Development of peaceful uses of atomic energy is an aspect of the national policy directed toward strengthening economies and enhancing human welfare throughout the free world. Mutual defense, disarmament, and extension of areas of contact with the Union of Soviet Socialist Republics, are other important international aspects of atomic energy activities.

Major objectives of atomic energy policy in the international field may be summarized as (*a*) expanding and improving the capabilities of this country in the application of atomic energy to peaceful and beneficial uses in all nations; (*b*) fostering cooperation with other countries so that information and benefits of atomic energy may be shared freely with other nations; and (*c*) providing certain mutual defense assistance to strengthen the security of the free world while working for a relaxation of cold war tensions and for disarmament.

The Program

To achieve these objectives, the Commission has developed, in unison with the Department of State and the Department of Defense, a broad program in atomic energy fields for promoting international cooperation and assisting development in individual countries.

During 1959, the Commission moved toward foreign policy objectives through programs which have the following aims:

To foster the exchange of scientific and technical personnel, and of information pertinent to the development of peaceful uses of atomic energy.

To assist in training foreign nationals in nuclear science and technology through courses, research, and work assignments in this country's universities, Commission-owned laboratories, and other facilities.

To encourage and assist installation and use of nuclear research and power reactors abroad by: (*a*) providing financial assistance to cooperative countries in the form of direct grants in support of the costs of nuclear research reactor projects; (*b*) making special nuclear materials available through sale and lease arrangements; (*c*) offering chemical reprocessing services to foreign reactor operators at specified charges; (*d*) providing a market for plutonium produced in foreign reactors fueled with materials from the United States; and (*e*) assisting in evaluation of Export-Import Bank loans which are made available under criteria similar to those for financing conventional powerplants.

To assist in the acquisition of equipment for use in the development and application of nuclear energy in the physical and life sciences, medicine, agriculture, and industry.

To cooperate with other countries in establishing international guidelines concerning such aspects of the peaceful uses of atomic energy as health and safety and public liability.

To encourage the development and acceptance of an international system of safeguards to prevent the diversion of special nuclear materials to military purposes.

In a broad sense, all development of atomic energy contributes to the international program. The domestic program, in turn, benefits from the increased volume and variety of research and applications throughout the world. Similarly, industry in the United States contributes its capacities to international developments and is strengthened through sales of equipment, research and power reactors, and through forming cooperative commercial arrangements with foreign corporations.

Highlights of 1959

Five developments stand out in a review of the program for international cooperation in atomic energy during 1959.

The exchange of visits between leading figures in atomic energy activities of the Union of Soviet Socialist Republics and the United States. Further exchanges of information between the two countries on peaceful uses of atomic energy were arranged pursuant to the memorandum signed by Chairman John A. McCone and Professor Vasily S. Emelyanov during November 1959. The results will be made available to all nations through the International Atomic Energy Agency.

The continuation of discussions between the United Kingdom, the United States, and the Union of Soviet Socialist Republics looking toward cessation of nuclear weapons tests, and the unilateral continuation by the United States of the period during which it would not conduct further tests. At the expiration, December 31, of the period of cessation, the United States announced that it was no longer committed to a cessation of tests, but would give notice before any resumption of testing.

The progress of the International Atomic Energy Agency toward carrying out its function of: serving as a center for distributing special nuclear materials and research information; providing technical assistance; promoting education in nuclear science and tech-

nology; taking the lead in developing international agreement on norms for dealing with problems of health and safety, and administering safeguards against diversion of special nuclear materials.

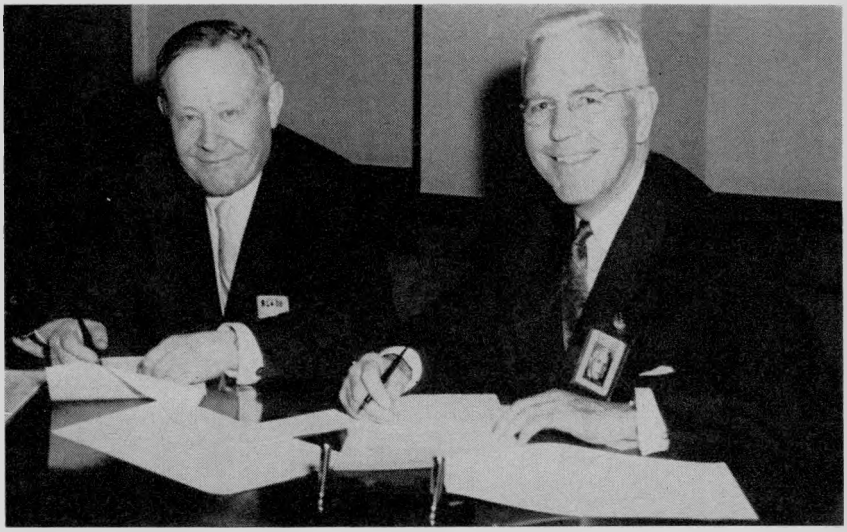
Completion of the United States accord with the European Atomic Energy Community, and progress of the joint United States-Euratom program for research and development and construction of nuclear power reactors.

The establishment of closer United States ties with the Organization for European Economic Cooperation, and the formal inauguration of the Inter-American Nuclear Energy Commission.

Atomic Relations With the Soviet Union

U.S.–U.S.S.R. Exchange Agreement

On November 24, 1959, a Memorandum of Cooperation was signed by Chairman John A. McCone of the Atomic Energy Commission and Professor Vasily S. Emelyanov, Head of the USSR Main Administration for Utilization of Atomic Energy, and member of the USSR Academy of Sciences. The Memorandum will be implemented



U.S.–U.S.S.R. exchange agreement. Commission Chairman John A. McCone (right) and Professor Vasily S. Emelyanov, Head of the U.S.S.R. Main Administration for Utilization of Atomic Energy, sign a Memorandum of Cooperation providing for reciprocal exchange of unclassified information relating to peaceful uses of atomic energy and certain nuclear physics research. The historic agreement was signed in Washington, D.C., during November.

within the framework of the US–USSR Scientific, Technical, Educational, and Cultural Exchange Agreement for 1960–61.

The agreement provides for reciprocal exchanges of unclassified information, of visits by scientists, for exploration of the desirability of engaging in unclassified joint projects in the peaceful uses of atomic energy, and for making available new scientific instruments on a reciprocal basis and as permissible under the laws and policies of the two countries. Initially, visits will be exchanged by groups of three to five scientists to facilities interested in work on controlled thermonuclear research, nuclear power reactors, high energy physics, nuclear physics, neutron physics, and structures of nucleons. The visits will be for periods of from 10 to 15 days. The arrangement does not preclude the addition at a later date of other areas of exchange.

The International Atomic Energy Agency and its members will benefit from this exchange since the Agency will be given all reports and the results of the exchanges. To the extent possible, the Agency will be asked to assist in the consideration of possible joint projects by sponsoring meetings, symposia or studies considered necessary for such planning.

At Chairman McCone's request United States interest in the possibilities of cooperation in the peaceful uses of atomic energy were first presented informally to Professor Emelyanov during discussions in Vienna in June 1959 between him and John A. Hall, the Commission's Assistant General Manager for International Activities, and Professor Isador I. Rabi, United States member on the IAEA Scientific Advisory Committee. Further consideration was given to the subject during the visit of Vice President Nixon to the USSR in July for the opening of the American Exhibit in Moscow. Subsequently, more definitive discussions of the proposed exchange were held between Chairman McCone and Professor Emelyanov during the latter's visit to the United States in September with Premier Khrushchev. Agreement was reached on an initial exchange of visits to unclassified facilities in the respective countries.

The first visit under the preliminary agreement was made to the USSR October 8–19 by a U.S. delegation headed by Chairman John A. McCone. The delegation included Commissioner John H. Williams; Dr. Frank K. Pittman, Director, Division of Reactor Development; Dr. Alvin Weinberg, Director, Oak Ridge National Laboratory; Dr. Lyman Spitzer, Jr., Director of Thermonuclear Research, Princeton University; and Dr. Kenneth Pitzer, member of the General Advisory Committee and Dean of the College of Chemistry of the University of California.

The Soviet facilities visited included the Leningrad Scientific Research Institute of Electro-Physical Apparatus, Leningrad Physico-Technical Institute, the Moscow Institute of Theoretical and Experimental Physics, Dubna Joint Institute for Nuclear Research, the first Soviet nuclear power station at Obninsk, and civilian power reactor sites at Voronezh and Byeloyarsk. Also included was a cruise on the nuclear powered icebreaker, *Lenin*, and a tour of a uranium mine in the Krivoi Rog area of the Ukraine.

The conclusion of the U.S. delegation was that the USSR's activities which they had seen were generally parallel to similar activities in the United States in program scope and development.

The initial exchange was completed with the visit to the United States by a Soviet delegation. The group comprised Professor Vasily Emelyanov, Yuri Emelyanov, Anatoliy P. Aleksandrov, Doctor of Physico-Mathematical Sciences and member of the USSR Academy of Sciences, Andrey A. Bochvar, Metallurgist, Doctor of Chemical Sciences, and member of the USSR Academy of Sciences, Vladimir I. Veksler, Nuclear Physicist, Doctor of Physico-Mathematical Sciences, and member of the USSR Academy of Sciences, Igor N. Golovin, Nuclear Physicist, Doctor of Physico-Mathematical Sciences, and member of the USSR Academy of Sciences, Nikoley A. Dollezhal, Power and Construction Engineer, Doctor of Technical Sciences and corresponding member of the USSR Academy of Sciences, Gennadi L. Konstantinov, Engineer in the Main Administration for Utilization of Atomic Energy, Aleksandr I. Leipunsky, Doctor of Physico-Mathematical Sciences and member of the Ukraine Academy of Sciences, E. V. Piskarev, Engineer and Nuclear Physicist and Doctor of Physico-Mathematical Sciences, and V. D. Pavlo, Third Secretary of the USSR Embassy, Washington.

Included in the tour by the Soviet delegation were the unclassified areas of: N.S. *Savannah* (Camden, N.J.), Shippingport Atomic Station (Shippingport, Pa.), Enrico Fermi Atomic Power Plant (Lagoona Beach, Mich.), Argonne National Laboratory (Lemont, Ill.), Dresden Nuclear Power Station (Morris, Ill.), National Reactor Testing Station (Idaho Falls, Idaho), Lawrence Radiation Laboratory (Berkeley and Livermore, Calif.), Rio d'Oro and Jackpile uranium mines and Kermac Uranium Mill (near Grants, N. Mex.), Los Alamos Scientific Laboratory (Los Alamos, N. Mex.), Oak Ridge National Laboratory (Oak Ridge, Tenn.), Princeton Controlled Thermonuclear Research Laboratory (Princeton, N.J.), and Brookhaven National Laboratory (Upton, L.I., N.Y.).

Further joint discussions will be held to implement the arrangements provided in the Memorandum of Cooperation.

Negotiations on Nuclear Weapons Tests

The cessation of nuclear weapons tests has been the subject of intense international discussion during the last year. On the initiative of President Eisenhower, technical talks between Western and Soviet bloc scientists on the feasibility of inspecting a cessation of nuclear weapons testing took place in Geneva from July 1 to August 22, 1958.

The report produced by atomic scientists, which pointed out the capabilities and limitations of a control system for testing, served as a basis for political negotiations among representatives of the United States, the United Kingdom and the Soviet Union. These negotiations began on October 31, 1958, and were continuing as of the date of the report. A second technical conference, which met from June 22 to July 10, 1959, produced a report which described a control system for monitoring nuclear explosions at very high altitudes and in outer space.

On November 25, another technical working group of scientists from the United States, the United Kingdom, and the Soviet Union began consideration of underground detection and identification problems. The group considered the question of the use of objective instrument readings in connection with on-site inspection of unidentified seismic events.

The terms of reference of the group called for it to "consider all data and studies relevant to the detection and identification of seismic events . . . and possible improvements of the techniques and instrumentation." The meeting was of considerable importance because the group considered the new seismic data from the HARDTACK II series of nuclear detonations conducted in Nevada during September and October, 1958. Although the new data, which cast doubt on the capabilities of the control system recommended by the scientists who had met in Geneva in 1958, were made available to the USSR delegation in January 1959, this was the first time USSR representatives agreed to consider and discuss the results of the HARDTACK II series in a formal conference.

The technical working group filed its report on December 18, 1959. All three delegations to the technical conference agreed on the advisability of improvements of seismic techniques and instrumentation. The three technical delegations were unable, however, to reach agreement on the interpretation of HARDTACK II data as it affected the capability of the control system. As a result, the three delegations submitted individual reports in the form of separate annexes, even though the UK report generally supported the conclusions in the U.S. annex. The annex submitted by the U.S. delegation indicated

that the capabilities of the system were reduced below those thought to be obtainable in the report of the 1958 conference of experts. In addition, the U.S. report showed that it is theoretically possible to decouple and thereby substantially reduce the strength of seismic signals by conducting nuclear tests in large underground cavities in salt or hard rock.

Commission and Commission-contractor personnel participated in the international technical discussions and served as technical advisors to the United States representative in the political negotiations.

International and Regional Cooperation

International Atomic Energy Agency (IAEA)

Three and a half years after President Eisenhower placed his proposal for world-wide cooperation before the United Nations in December 1953, the International Atomic Energy Agency was established at Vienna. Since its inception, the Agency has made steady progress in assisting member states in the development and application of the peaceful uses of atomic energy.

To enable the Agency to assist atomic research and power programs in member countries without delay, the United States in 1956 offered to supply 5,000 kilograms of uranium 235 and to match such offers of special nuclear material to the Agency by other member states as were made from June 1957 through July 1, 1960.[11] Later, this offer was formalized in a provision of the United States Agreement for Cooperation with IAEA which became effective on August 7, 1959. The agreement also provides that the United States will make available to the Agency, source material and reactor materials if these are not available from commercial sources.

During 1959, the number of member states increased from 69 to 70 and pledges to the operational fund for calendar 1959 rose to nearly $1.160 million. The United States pledged $500,000 unconditionally, plus $250,000 on a matching basis after a total of $1 million had been reached. The payment by the United States under this arrangement was $561,000. This pledge was renewed for the 1960 calendar year. In addition, the United States contributed $600,000 toward the cost of building and equipping a central analytical laboratory for the Agency to be located at the site of Austria's research reactor near Vienna.

[11] As of December 31, 1959, the total amount of special nuclear material offered by other countries was 70 kilograms of uranium 235.

The Agency continued to shift emphasis from organizational to programmatic work. The Commission has been active in varying degrees in each of the Agency's 1959 activities, as described in this section of the report.

Supply of nuclear materials. Agreements between the International Agency and three member states—the United States, United Kingdom, and Union of Soviet Socialist Republics—came into effect, providing the basis for transfer to the Agency of quantities of nuclear materials for use in meeting requests from member states. In agreements with Canada and Japan, the Agency completed its first fuel transaction by which Canada donated about 3 tons of natural uranium to the Agency for sale to Japan at $35.50 per kilogram.

During the General Conference in September, Austria became the second country to request that the Agency furnish fuel for its research reactor. Tunisia announced its intention of requesting the Agency to provide enriched uranium for Tunisia's atomic energy program. Also Finland has requested supply of enriched uranium for a TRIGA Mark II reactor and a critical assembly.

Safeguards. Interim safeguards against diversion of special nuclear materials from civil uses, to be applied in connection with the sale of natural uranium to Japan were agreed on in March and will apply up to the point of reactor operation. Safeguards procedures for continued operation are being developed.

In September, the Board of Governors approved provisionally a set of general principles for application of Agency safeguards. This approval was conditional upon further consideration of these principles by the Board in developing detailed procedures for their application. The Commission provided technical advice during the drafting and consideration of the safeguards principles.

Training. Progress in training has been the International Agency's most outstanding achievement. Over one-half the Agency's calendar 1959 operating funds were obligated to its fellowship program for nuclear training in various member countries. By December 31, the number of applications for the 1959 program was 575 of which 367 had been selected for awards. Approximately 25 percent of the awards were for training in the United States.

Conferences. In promoting the exchange of information, the Agency sponsored two major international conferences, "Application of Large Radiation Sources in Industry" conference in Warsaw, Poland, September 8–12, and "Disposal of Radioactive Wastes" conference in

Monaco, November 16–21. A 3-day seminar was held in Vienna, Austria, during October on meteorology of radionuclides.

A panel was convened in Vienna to prepare a draft of an international convention on public liability and state responsibility in connection with nuclear accidents. Educational problems related to the development of the peaceful uses of atomic energy were considered by a seminar at Saclay, France, in cooperation with the United Nations Education, Scientific, and Cultural Organization.

The United Nations Food and Agriculture Organization, the IAEA, and the United States, joined in offering a training course on radioisotope techniques in agricultural research at Cornell University, Ithaca, N.Y. The Commission also served as co-host with the Agency for a Conference on Preservation of Food by Ionizing Radiations, held at the Massachusetts Institute of Technology, Cambridge, Mass., in July.

Technical experts. The agency received 74 requests for technical assistance from 24 countries, and sent approximately 30 experts to member states for periods ranging from 3 months to 1 year.

The Agency sent survey missions to Southeast Asia (Burma, Ceylon, Indonesia, and Thailand) in January and February and to the Far East (Japan, Korea, Philippines, Formosa, and Viet-Nam) in May and June. Other missions went to Latin America (Argentina, Brazil, and Venezuela) in July, and the Near East (Iran, Iraq, and Turkey), and to Yugoslavia in October, to determine the extent of future Agency assistance to countries in those areas.

A re-evaluation team sponsored by the Agency visited the Boris Kidric Institute in Yugoslavia for a detailed investigation of the radiation hazards resulting from the critical assembly accident at the Institute in 1958. The international team included several United States experts on neutron dosimetry. Although a preliminary study has been completed by an agency team, planning for the reevaluation of the accident is temporarily in abeyance in view of unexpected costs involved in conducting the experiment and other problems.

A United States-donated mobile radioisotope laboratory was used for training purposes in Austria, Greece, Yugoslavia, and Germany during this period. The United States delivered to the agency in December a second mobile radioisotope laboratory. It will be used initially in training programs in Latin America.

Publications. The Agency published several reports of special interest to member states, including the "Directory of Nuclear Reactors" (Volume I—Power Reactors), an "International Directory of Radioisotopes," and a manual on the "Safe Handling of Radioisotopes."

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Publication of the "IAEA Bulletin," a periodical describing Agency activities, was begun during 1959. In preparation are further volumes of the reactor directory and a medical addendum to the radioisotopes manual.

Research. The Agency promoted research activities during 1959 by sponsoring approximately 45 research contracts, by providing technical assistance for the development of member states' programs, and by sponsoring scientific meetings for discussing and identifying research problems. The United States placed one contract through the Agency for research in other countries, and seven others were being negotiated. The results of this research will be made available to all member states.

Third IAEA General Conference. The third session of the IAEA General Conference was held in Vienna, September 22–October 2. The following conclusions regarding this country's support of the Agency and estimate of the Agency's progress were set forth in a statement presented on behalf of the United States by Atomic Energy Commissioner John F. Floberg:

The Agency now is ready and able to become a principal channel through which the more advanced nations can pool their efforts most effectively to provide expert advice, materials, and equipment to the peaceful uses programs of underdeveloped areas.

The Agency should embrace the opportunities to expand its programs that contribute to this goal, including nuclear power studies, into a major coordinated effort based on the proposals which the member states put forth during the Conference.

The Agency now has the competence to assume vital responsibilities in the areas of safeguards and in health and safety, especially in the urgent problem of waste disposal.

The Agency has a continuing and important role as a supplier of source and special nuclear materials.

The Agency is achieving its objective of accelerating the peaceful applications of nuclear energy throughout the world, is indispensable in the nuclear age, and deserves increased support from the member states.

During the Conference, the United States: (*a*) committed itself—to the extent of available funds and through the Agency—to supplement Agency efforts to meet as many as possible of the current requests of member states for equipment; (*b*) invited participation by Agency

personnel in the United States program for development of small and medium size power reactors, especially in the construction of a small pressurized water prototype reactor; and (*c*) announced its donation to the Agency for calendar 1960 of enriched uranium valued at $50,000 for use in Agency-sponsored research projects, including research reactors.

European Atomic Energy Community (Euratom)

An Agreement for Cooperation between the United States and the European Atomic Energy Community (Euratom) went into effect February 18, 1959. Euratom was officially established January 1, 1958, and its members are Belgium, France, the Federal Republic of Germany, Italy, Luxembourg, and The Netherlands. It is one of the three institutions of the European Community and is responsible for encouraging and undertaking development within Community nations of the peaceful uses of atomic energy, including the production of power.

The United States-Euratom Agreement provides for cooperation in a joint nuclear power program, and was authorized in the United States by the Euratom Cooperation Act of 1958. The major objective is installation in Euratom countries within the next 3 to 5 years of approximately 1 million kilowatts of nuclear electric power using reactor types carried to an advanced stage of development within the United States. Related to this is a joint research and development program aimed at improving the performance of reactor systems and lowering fuel cycle costs.

Reactor program. In response to an invitation for proposals to construct power reactors under the joint program, issued April 13, Euratom announced October 20 it had received a definitive proposal from the Italian utility, Societa Elletronucleare Nazionale (SENN). The proposal provides for construction of a 50,000 ekw. boiling water reactor at Punta Fiume, Italy. The prime United States contractor is International General Electric.

Euratom also announced two expressions of interest in participating in the joint program:

The German group, Arbeitsgemeinschaft Kernkraftwerkes Stuttgart, submitted technical and economic portions of a proposal it expects to submit after completion of a contract with its proposed United States associate.

A Franco-Belgian group, Societe Franco-Belge de la Centrales des Ardennes, expressed its intention to submit a firm proposal including

bids from American manufacturers for participation in a reactor project.

In addition, letters indicating general continued interest in the joint program were received from a group in The Netherlands and one in West Berlin.

A Joint Reactor Board was established to evaluate proposals, to make recommendations to the Euratom Commission and the Atomic Energy Commission, and to coordinate execution of the joint reactor program. Both Euratom and the United States are represented on the Board.

At least one manufacturer from the United States and one from Euratom must play an important role in each proposed project.

Research and development program. A Joint Research and Development Board has been established to review and select research and development projects submitted as a result of an invitation for proposals issued on December 23, 1958. The Board had received by the year's end, 276 definitive proposals for research and development work. Of these, 79 were from the United States, 115 from Euratom countries, and 82 were joint proposals by firms in the United States and Euratom countries. A substantial proportion of the proposed work was in the field of metallurgy and technology of fuel element fabrication. Seven contracts have been executed, four of them in the last 3 months of the year. Of these, four went to United States firms, and three to foreign organizations.

Safeguards. Euratom has initiated safeguards activities against the diversion of nuclear materials to nonpeaceful uses by issuing and putting into effect two regulations. These relate to the reporting of information concerning nuclear facilities and source and special nuclear materials within Euratom countries. A safeguards staff and appropriate procedures are also being established.

Supply agency. Euratom members participated in extensive discussions on the establishment of a Euratom Supply Agency. This Agency, which is expected to be formally established in early 1960, will have as a primary task the administration of transactions involving exchange of nuclear materials between Euratom members and other countries. These transactions will be based on policies and prices presently being established for the use of enriched uranium and for the purchase of plutonium.

Organization for European Economic Cooperation (OEEC)

Although not a member, the United States has expanded its participation in programs of the Organization for European Economic Cooperation.

Reactors. Of special interest is the OEEC "Dragon" project for construction between 1960 and 1962, at Winfrith Heath, England, of a high-temperature, gas-cooled reactor estimated to cost $38 million. Participants include the Euratom countries, Austria, Denmark, Norway, Sweden, Switzerland, and the United Kingdom.

The Commission provided technical advice and assistance for a joint small-scale plant for chemical processing of fuel elements which is being built at Mol, Belgium. This project is directed by the European Nuclear Energy Agency (ENEA) of OEEC.

The Commission provided reactor experts and exchanged information related to the Halden reactor project, a boiling heavy water plant constructed in Norway by Norway and The Netherlands—the first of its type in the world. Under an agreement signed in June 1958, a Halden research and experimental program under OEEC auspices will be conducted for three years. Members of OEEC participating in the program are the Euratom countries, Austria, Denmark, Norway, Sweden, Switzerland, and the United Kingdom.

Public liability. As a supplement to the efforts of individual countries, the International Atomic Energy Agency, and Euratom to develop satisfactory public liability arrangements for nuclear activities, the OEEC sponsored numerous conferences during 1959 devoted to drafting a convention concerning financial protection against nuclear risks. The draft convention is expected to be submitted to member states in 1960 for final approval.

Safeguards. OEEC members adopted a "Convention on the Establishment of a Security Control in the Field of Nuclear Energy." This Convention will apply to OEEC projects, and operation of the OEEC safeguards and control system will be a responsibility of the European Nuclear Energy Agency.

Inter-American Nuclear Energy Commission (IANEC)

The Inter-American Nuclear Energy Commission, of which the United States is a member, was established on April 22 as the nuclear energy arm of the Organization of American States (OAS). Major responsibilities are: assisting member republics in developing a co-

ordinated plan for research and training; furthering the exchange of scientific and technical information; organizing conferences and other meetings; recommending public health safeguards; requesting, when deemed advisable, the cooperation of public and private institutions in contributing to nuclear development programs in member countries; undertaking studies within its sphere of responsibility, and advising member states, when requested, on formulating administrative provisions to facilitate inter-American cooperation.

The first meeting, at which 15 of the 21 members of the OAS, including the United States, were represented, was held in Washington, October 20–24. The delegates established an ad hoc advisory committee to formulate a coordinated plan for development of training, education, and research. They also recommended holding in Brazil a Third Inter-American Symposium on the Peaceful Applications of Nuclear Energy, and accepted the United States' offer of financial support for the symposium.

U.N. Committee on Atomic Radiation

The United Nations Scientific Committee on the Effects of Atomic Radiation held its Sixth Session from March 23 through April 1—essentially an organizational session in preparation for the next phase of work. The Committee recommended further study on various specific problems of radiation and asked that members of the United Nations continue sending the Committee data on radiation and its biological effects. The next meeting will be held in January 1960.

Other Cooperative Activities

Bilateral Agreements for Cooperation

New agreements. Two new bilateral Agreements for Cooperation in the civil uses of atomic energy came into effect during 1959 with Iran and Viet-Nam.

To date, 44 agreements are in force with 42 countries (Switzerland has 2) and the City of West Berlin—13 for power reactor cooperation and 31 for research. Eight other agreements are awaiting final action by their respective governments and the United States, including power accords with Austria, Brazil, Cuba, Peru, and Venezuela, as well as research accords with Costa Rica, Iraq, and Panama. (See Appendix 17.)

A protocol to the comprehensive power and research agreement with Japan came into force during the year. Amendments which

became effective will extend or modify power agreements with Belgium, France, the Federal Republic of Germany, The Netherlands and Switzerland and research agreements with Brazil, and the Republic of China.

In general, bilateral negotiations now in progress involve amendments to extend or modify the terms of existing agreements.

Mutual defense agreements. Six Agreements for Cooperation for mutual defense purposes became effective during 1959, with Canada, France, the Federal Republic of Germany, Greece, The Netherlands, and Turkey. An amendment to the mutal defense agreement with the United Kingdom came into force during the year (see Appendix 17).

Reactor Activities

Fuel assistance. During this year, 102 kilograms of uranium 235 for use in reactors and research and development programs were shipped to cooperating countries under sale or lease arrangements, including substantial shipments to Australia, Canada, France, and Italy. A total of 108 tons of heavy water also was transferred in this period to Canada and India.

These shipments bring the total transferred abroad since the beginning of the program in September 1955 to 309 kilograms of uranium 235 and 406 tons of heavy water. In addition, many small quantities of other materials were shipped (see Appendix 18).

Lease or sale of materials. On May 27, the Commission established a policy of leasing nuclear material to foreign countries either through the International Atomic Energy Agency or through bilateral agreements for use in exponential and subcritical assemblies and in defined reactor experiments. This represents a clarification of previous policies under which material has been leased for research reactors. Material for power reactors continues to be available only on a sale basis.

The Commission also made available to foreign countries, on a sale or lease arrangement, uranium enriched up to 90 percent for use as fuel in subcritical assemblies, research and materials-testing reactors, and reactor experiments.

Deferred payment plan. The Commission announced, on February 2, a limited program under which enriched power fuel will be made available on a deferred payment plan. Euratom has a similar pay-

ment plan with the United States. Countries and international organizations are eligible if they have agreements for cooperation with the United States providing for the supply of such fuel.

The plan is limited to nuclear power projects with a combined electrical generating capacity of up to 500,000 kilowatts. Plants must be scheduled for operation before June 30, 1964, and use United States designs and components. The plan is designed to ease the initial heavy capital cost of purchasing fuel inventories by postponing payment for these inventories for 10 years. The nuclear power reactor being built by Societa Elettronucleare Italiana (SELNI) in Italy has been approved by the United States as the first participant under the deferred payment plan. Inquiries have been received from two other foreign companies, but no other applications have been made to date.

Safeguards. The Commission has established a staff to handle safeguards activities under United States Agreements for Cooperation, and to assist in establishment of an effective world-wide system through the International Atomic Energy Agency. Negotiations of new United States bilateral agreements, as well as major amendments to existing agreements, provide for inclusion of a clause looking to the transfer to the International Agency of safeguards activities.

In consultation with the Department of State, the Commission has defined the policies and procedures which will be followed in bilateral arrangements. The policies provide that (*a*) the United States will give assistance and advice to the recipient country in the establishment of a national system of control over the materials and equipment, which includes adequate materials accountability and physical control measures; (*b*) this system then will be subject to audit, appraisal, and verification by United States personnel under the authority of the rights accorded in the Agreements for Cooperation; and (*c*) the specific measures applied in auditing and verifying the system will depend upon the type and complexity of the facilities involved and the type and quantity of the materials involved, to the extent that these factors determine the risk of the materials and equipment being diverted to military use.

Specific procedures are being developed, first for research, test, and small power reactors.

The Commission staff has provided assistance and guidance to cooperating countries and has undertaken programs to develop more economical and simpler execution of safeguards.

Public liability. A major problem in nuclear power development is the lack of effective international agreement concerning the extent of

liability that should be applicable to suppliers of nuclear facilities in the event of harmful effects on persons and property, and the extent of protection that should be provided. The United States has participated in extensive discussions of this subject by the OEEC, Euratom, and the IAEA.

The Commission and the Maritime Administration are studying special problems related to foreign visits of the N.S. *Savannah*, as described in chapter II, Part One, of this report.

Research Reactor and Equipment Grants

Reactors. During 1959, the Commission approved three research reactor project grants of $350,000 each to Korea, Thailand, and Viet-Nam. Requests for grants from three other countries were under consideration.

A total of 19 commitments have been made for $6.650 million. The grants are limited to one-half the cost of the reactor project, but not to exceed $350,000, and are paid on completion of the project. To date, grants have been paid to Brazil, the Federal Republic of Germany, Italy, and Spain (see Appendix 16).

A commitment of $500,000 was made by the United States to the Philippine Government in June for a research reactor being acquired by the Philippines under a contract with International General Electric. This is pursuant to a special offer made by the United States in 1955 to the Philippines.

Equipment. Twelve grants for the acquisition of nuclear research and training equipment were approved during 1959 for 10 countries: From the beginning of the equipment grant program (June 1958), 15 equipment grants have been approved to 13 countries, in addition to the donation of 2 mobile radioisotope laboratories to the International Atomic Energy Agency.

Eleven additional requests for equipment grants were under consideration at the end of the year.

Progress in Foreign Reactor Projects

As of December 31, United States manufacturers had built or were building 38 research reactors for foreign countries. Of these, 20 already were in operation. In addition, 3 power reactors were being constructed in foreign locations by United States manufacturers, 1 each in Belgium, the Federal Republic of Germany, and Italy.

Plans for construction of at least 3 more power reactors and negotiations of contracts for export of 8 additional research reactors were under way (see table E, Appendix 14).

Education and Training

During 1959, the Commission continued to expand training opportunities for foreign personel at United States colleges and universities, the Government's national laboratories, and other facilities.

Approximately 273 persons from 45 countries participated in formal training courses during the year. An additional 654 foreign nationals from 52 countries received individual on-the-job training assignments at Commission facilities.

Approximately 100 foreign students seeking training in nuclear science and technology in United States colleges and universities, private industries, and institutions, were given guidance on available educational opportunities and financial assistance.

The eighth and ninth sessions of the *International School of Nuclear Science and Engineering* were completed this year at the Commission's Argonne National Laboratory. Enrolled in the eighth session, completed June 13, were 50 foreign students representing 17 foreign countries, plus 7 students from the United States. Ten of the foreign participants received fellowships from the International Atomic Energy Agency. The ninth session of the school ended December 14, with 44 participants. Of these, 5 were from the United States and 39 foreign students were from 21 countries. Twelve of the foreign students were IAEA fellows. Since establishment of the school 416 foreign nationals from 45 countries and 106 United States citizens have attended the courses offered.

Effective with the term beginning February 3, 1960, the name of the school will be changed to the International Institute of Nuclear Science and Engineering. The program is being altered to meet the growing need for highly advanced and specialized training in nuclear science and engineering. This objective is in line with the increased capacity of universities to provide basic training.

A 9-month *reactor operations supervision course* was offered for the first time on February 2, 1959, at the Commission's Oak Ridge National Laboratory. It is designed to prepare engineers and scientists to superintend operation of power or research reactors. Ten foreign nationals representing 10 countries completed this course on October 30. The second course began November 2 with 10 foreign nationals from 9 foreign countries, and one United States citizen enrolled.

A 12-month *reactor hazards evaluation course* was inaugurated at Oak Ridge National Laboratory on February 2, 1959. Sixteen foreign nationals representing 12 countries will complete the first course on January 29, 1960. The second course began November 2 with 12 foreign nationals from 9 countries and 2 students from the United States.

At the year's end, 10 foreign nationals from 6 countries had attended the *radiochemical and counting procedures courses* conducted at the Commission's New York Health and Safety Laboratory.

In September, the Oak Ridge Institute of Nuclear Studies completed the 71st session of the 4-week basic *radioisotope techniques course.* During this year, five sessions were attended by 59 foreign nationals from 28 countries enrolled, making the all-time total 363 foreign nationals from 54 countries and 2,082 United States citizens. Also, during 1959, seven foreign nationals representing Argentina, Indonesia, Ireland, Peru, and Venezuela attended the *industrial radioisotopes teaching courses.*

Nuclear power merchant ship training courses were offered for the first time during 1959 under the N.S. *Savannah* Observation Program at Camden, N.J., and at the Reactor Engineer Officers Training Course at Lynchburg, Va. Enrolled in the program were 26 foreign nationals representing Denmark, France, the Federal Republic of Germany, Italy, Japan, Norway, Sweden, The Netherlands, and the United Kingdom.

A *nuclear power station training program* at the Shippingport Atomic Power Station was established in 1959 and two courses were held with nine foreign nationals enrolled from Belgium, the Republic of China, India, Italy, and Japan.

Beginning in June, the Commission offered a 14-week program of *training in uranium geology, exploration, and mining.* As part of the program, 17 foreign nationals from 10 countries participated in field trips to various uranium ore deposits and processing plants.

Approximately 20 students were enrolled in 1959 for instruction in nuclear science and technology, radioisotope techniques, radiological physics, and nuclear medicine at the *Puerto Rico Nuclear Center.* The Center is operated for the Commission under contract with the University of Puerto Rico and offers courses taught in the Spanish language at a graduate-level primarily for students from Latin American countries. A 10-watt training reactor built by Atomics International, went into operation at the Center in August. A large research reactor and related laboratory facilities are scheduled for completion in 1960 and will make it possible to bring the curriculum up to its

planned level and to attract an increased number of foreign students to the Center.

Exchange of Information

With the rapid accumulation of technical information in the atomic field, the emphasis on international exchange of data was placed during 1959 on improving the availability of material and preparing specialized bibliographies.

Technical depository libraries. During 1959, the Commission provided 7 additional unclassified technical depository libraries to the Belgian Congo, Canada (2), Ecuador, El Salvador, France, and Ghana, thus making a total of 83 presented to 58 countries and 5 international organizations. These collections are kept up-to-date with the periodic addition of new reports.

Visits and technical exchanges. Highlights of exchanges of scientific and technical personnel and information during 1959, other than the previously mentioned United States-Soviet Union exchange, include:

United Kingdom. Following discussions initiated in 1958, specific areas of cooperation in basic research and development were singled out, and experts were designated by each government to facilitate a more rapid exchange of knowledge. Joint conferences were held in May and June on plutonium recycling, uranium oxide fuels, and beryllium technology. There also were meetings on other established programs relating to controlled thermonuclear reactions, nuclear cross-section programs and fast reactors.

Agreement was reached with the United Kingdom providing for an expansion of the gas-cooled reactor exchange program with the United States.

Documents and visits. During 1959, the United States received 31 classified documents from countries with which it has bilateral agreements, and transmitted 628 classified documents to these countries. Arrangements for unclassified visits to Commission facilities were established for about 1,303 foreigners, and approximately 582 Commission representatives visited atomic energy facilities abroad.

International conferences. In addition to bilateral exchanges and meetings sponsored by the International Atomic Energy Agency, the Commission participated in the Symposium on Health Physics at Riso, Denmark, in May, and in the Congress on Safety and Location of Nuclear Powerplants, held, in Rome, Italy, in June. The United

States also participated in the High-Flux Testing Reactor Conference at Mol, Belgium, in September, and in the October Conference on Aqueous Corrosion of Reactor Materials in Brussels, Belgium, the latter being sponsored by Euratom and the Commission. The United States sponsored the Chemical Reprocessing Conference at Richland, Wash., in October, at which representatives from foreign countries were present.

Second Inter-American Symposium. The Second Inter-American Symposium on the Peaceful Application of Nuclear Energy, organized and administered by the Pan American Union, with technical assistance from the U.S. Atomic Energy Commission and supported financially by a grant from Mutual Security Program funds of the United States, was held at Buenos Aires, June 1–5, with the Argentine Atomic Energy Commission as co-host. More than 200 representatives from 21 member states of the Organization of American States participated.

The University of Puerto Rico and the Pan American Union, with collaboration of the Commission, sponsored the Inter-American Symposium on Administrative and Legal Problems Connected With Peaceful Atomic Energy Programs held at San Juan, Puerto Rico, November 16–19. This symposium, the first international meeting on this subject, was supported financially by the United States through a grant of Mutual Security Program funds.

International scientific conferences. Thirteen conferences and symposia to examine specific areas of atomic energy were approved during 1959, under the Commission's program for financial support of international conferences. Eight were in the United States; others were in Argentina, Australia, Italy, England, and Poland.

Of the 13 conferences, 2 are described to illustrate the kinds eligible for Commission financial support.

The International Conference on the Application of Large Radiation Sources in Industry in Warsaw, Poland, September 8–12, was organized by the International Atomic Energy Agency. It was the first international scientific conference held on the particular subject and attracted approximately 200 scientists representing 26 countries. Among the 100 scientific papers presented during the conference, 16 were contributed by the United States.

The International Symposium on the Preservation of Foods by Ionizing Radiations at the Massachusetts Institute of Technology, Cambridge, Mass., July 27–30, had representatives of 15 countries, including the United States, as panel session members. In addition, representatives of 13 other countries attended as observers or delegates.

The primary objective of the symposium was to obtain information on problems of participating countries, and to explore the potentialities of radiation as a means of helping each to overcome problems of food preservation.

International nuclear energy exhibits. A nuclear energy exhibit depicting the latest scientific and technical advances in the peaceful uses of atomic energy was displayed by the Commission at the *Japan International Trade Fair*, Tokyo, Japan, May 5–22, 1959. The exhibit featured an operating training and research reactor developed by the American Radiator and Standard Sanitary Corp., and an operating SNAP–3 thermoelectric generator.

The Commission and the Departments of Agriculture and Commerce are participating in the *World Agriculture Fair*, New Delhi, India, December 11, 1959–February 14, 1960, which is expected to be one of the largest expositions of its kind ever held. President Eisenhower participated in the opening ceremonies of the fair during his recent 11-nation tour.

The Commission exhibit, part of the total United States exhibit, is entitled "The Atom on the Farm." An operating TRIGA reactor, manufactured and operated by the General Dynamics Corp., for the Commission, provides an active demonstration of a model laboratory reactor, including the production of isotopes for agricultural research.

A full-scale insect sterilization unit is being used. One unit is conducting research on sterilization of the Oriental fruit fly. An operating gamma facility, utilizing approximately 5,000 curies of cobalt 60, operated by the Brookhaven National Laboratory in collaboration with the Indian Government, is irradiating seeds and other materials for a demonstration agricultural research program.

Radioisotope Development

Demand for radioisotopes for industrial, medical and agricultural uses increased steadily during 1959. Quantity of radioisotopes shipped this year increased 20 percent over 1958. The number of licenses issued for radioisotope use also increased.

During the year, the Commission's new Isotopes Development Program undertook exploratory studies required for the achievement of its long-range goals—(*a*) to develop technology which can be extended throughout industry, applied medicine and agriculture, (*b*) to encourage private enterprise participation in isotope production, and (*c*) to provide basic training sources in radioisotope technology. A special report by the Commission, to be issued early in 1960, details

the scope and progress of activities in this field.[12] This Annual Report gives only examples and highlights of the current program.

Licensing, Production, Sales

Radioisotope Licensing

During the year ending November 30, 2,633 byproduct material licenses and 5,001 amendments and renewals of existing licenses were issued. Included in this number were 1,609 licenses issued to new licensees: 501 in the field of medicine, 333 to industrial users, 694 to Federal and State laboratories (this includes licenses issued for civil defense training), and 81 users in other fields.

As of November 30, 5,417 organizations and individuals in the United States possessed byproduct material licenses. This figure represents a net gain of 993 licensees during the past year (after eliminating all licenses expired and not renewed). The 5,417 licensed users as of November 30 consist of 2,255 medical, 1,600 industrial, 1,150 Federal and State laboratories, and 412 in other fields. Appendix 4 shows all byproduct material licensees and new licensees by State and type of user, domestic shipments of radioactive isotopes by the Oak Ridge National Laboratory, and the shipments of radioactive isotopes from the United States to foreign nations.

Production and Sales

Shipments. The total amount of radioisotopes shipped during the calendar year 1958 from Oak Ridge National Laboratory, the Commission's principal supplier was estimated at about 245,000 curies as compared with about 228,700 curies shipped during the preceding year. Due to price reductions, gross income from these sales declined from $2,438,000 in 1958 to $2,352,000 in 1959. Total quantities of radioactive isotopes shipped since radioisotope distribution began in 1946 amounted to nearly 860,000 curies.

Some 3,252 foreign shipments were made in 1959 compared with 10,261 shipments for the period 1946 through 1958. A total of 56 countries received shipments during 1959.

Many domestic shipments go to commercial firms that reprocess the isotopes to supply tracers, industrial radiography and gaging sources, as well as labeled pharmaceuticals for medical diagnosis and intense sources for radiotherapy applications. The Commission lab-

[12] "Radioisotopes in Science and Industry," February 1960, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

oratories have continued to become producer-wholesalers, rather than retailers in isotopes. This is shown by the increasing quantity of radioactivity per shipment, averaging 16.2 curies each in 1958 and 18.5 curies in 1959 as compared to 11.8 in 1957. There were 13,180 shipments during 1959 for a total of 131,835 shipments since August 1946.

Isotopes Development Program

Radioisotope Technology Development

The goal of the radioisotope technology program is to create a broad base for development of new and improved radioisotope technology capable of extension to many areas of the national economy. To demonstrate the value of radioisotopes in these areas, the Commission has entered into 50 cooperative research and development contracts with 5 major university centers, research laboratories, a limited number of industrial organizations, and other Government agencies (see appendix 4). This is in addition to work done at the Commission's laboratories.

Radiometric analysis and tracer technology is a large area of immediate interest. Efforts are being directed toward developing (*a*) isotope dilution techniques, (*b*) automatic analysis devices applying radiometric techniques, (*c*) new radiometric titration techniques, and (*d*) other new analytical methods.

Radioisotope Production Development

Objectives of the Commission's isotope production development program are (*a*) assurance of the availability of required quantities of radioisotopes at economical prices to meet present and future demand and (*b*) encouragement of private industry's entry into the production and distribution of radioisotopes. The Commission has continued its activities as virtually the only domestic supplier of wholesale radioisotopes.

An investigation of the feasibility of production of cobalt 60 and tritium in privately owned reactors has been completed. Two private companies now are offering radioisotopes for sale—the first United States sources of moderate or large scale supply developed independently of the Commission.

The Commission's Oak Ridge National Laboratory Fission Product Pilot Plant was placed in operation August 7, 1958. Basic processes have been developed for separation, concentration, and purification of kilocurie amounts of the principal fission products—cesium 137, cerium 144, promethium 147, strontium 90, technetium 99.

Development work. Ion exchange and solvent extraction systems using continuous countercurrent mixer-settler systems for purification of fission product rare earths were installed at the Fission Products Pilot Plant.

Work on enrichment of stable and radioactive isotopes by electromigration in fused salts progressed to a design and fabrication stage for small scale laboratory tests.

Production equipment for recovery of xenon 133 from off-gas of the iodine 131 plant was designed.

New radioisotopes made available by Oak Ridge National Laboratory were 1.3 year cadmium 109 (no cadmium isotope of a convenient long half-life has previously been available) and 12.5 hour iodine 130 (important for medical use since the short decay period minimizes radiation exposure and disposal problems). Work is progressing on calcium 47, important in medical research, and other short half-life radioisotopes with aid of the Oak Ridge Research Reactor.

Pricing. Pricing reductions have been accomplished through improvements in processing methods and large sales volume. The price of carbon 14 and iodine 131, for example, were reduced approximately 50 percent and 25 percent respectively. In a few cases, prices have been increased to reflect improved knowledge of the relative costs incurred in their production.

In February 1959, 100,000 curies per year of krypton 85 and in April 1959, 1 million curies of tritium were made available at low cost. The Commission's price for krypton 85 is $50 for each of the first two curies and $15 for each additional curie; the price for tritium is $2 per curie plus a packaging and handling charge. The availability of these isotopes in quantity is expected to stimulate new industrial uses.

High-Intensity Radiation Development

The Commission's program for high-intensity radiation development is designed (*a*) to produce a store of scientific and technical knowledge on radiation interaction with matter, and on radioisotope source design and ionizing radiation utilization including the possibility of making productive use of fission product waste from an expanding nuclear power economy, and (*b*) to encourage, through the availability of such information, private industry research and development efforts on high level ionizing radiation process applications.

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About 20 contracts for research and development on uses of high intensity radiation were agreed upon during the reporting period (see appendix 4).

During the year, a fluorocarbon plastic, with high chemical resistance and an adhesive, bondable surface, appearing for the first time in bright, permanent colors, became commercially available. This plastic, unobtainable by chemical means, is produced by irradiation with a cobalt 60 gamma source. Other radiation products commercially available include a plastic ion exchange membrane having high efficiency for desalination of brackish water, electron beam cross-linked polyethylene film and electron beam-sterilized surgical sutures.

A detailed survey of existing radiation technology and potentiality for industrial application has been completed.[13] The results of this survey and a technical analysis of its contents [14] suggest that high-intensity radiation has potential value as a new industrial processing agent, and stress the necessary fundamental research needed to bring this to practical reality. A few immediately competitive irradiation processes were identified.

Radioisotope Training and Education

Acceleration of radioisotope applications is contingent upon an increasing supply of trained personnel. In addition to supporting training programs in various fields related to isotope use, the Commission contracted for studies on course development and training aids, and is assisting colleges and universities through a program of equipment grants. During 1959, the Commission made three series of awards totaling $654,367 to 40 educational institutions in 28 States. Details of education and training programs are reported elsewhere in this report and in the special radioisotopes report noted earlier.

During 1959, conferences to inform industrial management on the potential value of radioisotope applications were presented at Manhattan, Kans.; Atlanta, Ga.; Buffalo, N.Y.; Morgantown, W. Va.; and Detroit, Mich. A joint conference sponsored by Armour Research Foundation and *Nucleonics* magazine with the cooperation of the Commission was held in Chicago, Ill., September 22–24.

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[13] Radiation—A tool for Industry. Arthur D. Little, Inc. Jan. 1959. 392 p. U.S. Government Printing Office, Washington 25, D.C., $5.50.

[14] A Management Evaluation of Massive Radiation for Industrial Utilization. Final Report. May 11, 1959. 30 p. AECU–4240. Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C., $1.00.

Licensing, Regulation, and Indemnification

Licensing in 1959

During 1959, five companies requested licenses to construct and operate developmental power reactors. Applications also were filed requesting authorization to construct and operate 13 research reactors and 2 critical experiment facilities, and to export 9 research reactors and 1 power reactor. During the year, construction permits were issued for 13 research reactors, and 1 critical experiment facility, and operating licenses were issued for 1 developmental power reactor, 2 testing reactors, 8 research reactors, and 3 critical experiment facilities. Licenses were issued authorizing the export of 11 research reactors and 1 power reactor.

The power reactor applications covered proposed construction of a 47,500 electrical kilowatt boiling water reactor in California; a controlled recirculation boiling reactor with designed capacity of 62,000 electrical kilowatts in South Dakota; a 17,000-kilowatt (electrical) vertical pressure tube reactor in South Carolina; a 5,000 electrical kilowatt pressurized water reactor in Pennsylvania; and a 50,000 kilowatt (electrical) pressure tube type reactor in Polk County, Fla.

The second power reactor license issued by the Commission authorized operation of the Commonwealth Edison Co. Dresden plant in Grundy County, Ill. Also, during the year the Commission issued the first two licenses to operate privately owned testing reactors: the first on January 7 to General Electric Co. for a 33,000-kilowatt (thermal) pressurized water test reactor at Vallecitos Atomic Laboratory, Alameda County, Calif.; the second on June 19 to Westinghouse Electric Corp. for a 20,000 kilowatt (thermal) pressurized water test reactor at Waltz Mill, Pa.

The presiding officer issued for the Dresden plant on September 26 an intermediate decision and order directing issuance of a limited license authorizing Commonwealth Edison to operate the reactor at power levels up to 1,000 kilowatts (thermal) for a period of time not to exceed 45 days from issuance of the order. This license allowed Commonwealth to initiate low power tests while the examiner was receiving and reviewing final testimony concerning the ultimate form of operating license. The limited license was subsequently amended to expire December 10, 1959. The presiding officer's supplemental intermediate decision, dated November 12, ordered that an amended license be issued authorizing operation of the reactor at power levels up to 315 megawatts (thermal) after December 10, 1959. The amended license was issued November 16, 1959.

By license amendment, General Electric was authorized to increase the power level of its Vallecitos Boiling Water Reactor to 50,000 kilowatts (thermal) and to install and operate a nuclear superheat test loop in the reactor to test fuel elements.

Applications were filed for licenses to construct and operate five nuclear power reactors as follows: The Northern States Power Co., Minneapolis, Minn., for a 62,000-kilowatt (electrical) controlled recirculation boiling water reactor to be located at the Pathfinder Atomic Powerplant, Sioux Falls, S. Dak.; the Pacific Gas and Electric Co., San Francisco, Calif., for a 47,500-kilowatt (electrical) boiling water reactor to be located at the Humboldt Bay Power Plant, Eureka, Calif.; the Carolinas Virginia Nuclear Power Associates, Inc., Charlotte, N.C., for a 17,000-kilowatt (electrical) vertical pressure tube power reactor to be located at Parr, S.C.; Saxton Nuclear Experimental Corp. for a 5,000-kilowatt (electrical) pressurized water reactor to be located at Saxton, Pa., and Florida West Coast Nuclear Group, Inc., for a 50,000-kilowatt (electrical) gas cooled, heavy water moderated power reactor of the pressure tube type, to be located at a site in Polk County, Fla., approximately 35 miles southeast of Tampa. An application was received, and license granted, to export a power reactor to the Federal Republic of Germany.

Permits were issued authorizing construction of 13 research reactors; relocation and modification of the Raleigh Reactor owned by North Carolina State College; and modification of the Naval Research Laboratory reactor. Eight research reactors were licensed to operate, including 7 reactors authorized for construction during this reporting period. In addition, 3 critical experiment facilities were licensed to operate.

Applications also were received for licenses to construct and operate 13 research reactors and 2 critical experiment facilities.

Twelve licenses were issued authorizing the export of 11 research reactors, 2 to Italy and 1 each to Brazil, Iran, Austria, Republic of Korea, Republic of the Philippines, Sicily, Turkey, Viet Nam, and Thailand, and a power reactor to the Federal Republic of Germany. The reactors involve a total value of $8,391,460.

An application was filed by Thor-Westcliffe Development, Inc., for license to construct and operate near Pittsburg, Kans., a multistage centrifuge production facility for separation of isotopes of uranium.

The year's licensing actions and hearings are summarized in Appendixes 10 and 11.

Operator Licenses

During 1959 there were 176 new operator licenses issued authorizing manipulation of reactor controls. As of December 31, there were a total of 465 licenses in effect.

Special Nuclear Material

Seventy-three new licenses were issued authorizing the possession and use of special nuclear material; as of December 31, there was a total of 294 licenses in effect.

As in 1958, four companies were engaged during 1959 in converting enriched uranium hexafluoride obtained from Commission plants to the forms needed for the manufacture of fuel elements, and for research and development. They were Davison Chemical Co., Erwin, Tenn., Mallinckrodt Chemical Works, Hematite, Mo., Nuclear Materials and Equipment Corp., Apollo, Pa., and Spencer Chemical Co., Kansas City, Mo.

At the end of the year 18 companies were fabricating fuel elements in their own facilities, for sale, for their own use, or for research purposes. Sixteen of these companies were licensed—one more than during 1958, the National Lead Co., Albany, N.Y., having entered this field during 1959. Two companies were not licensed since they manufactured exclusively for the Government.

The 16 licensed concerns were:

Aerojet General Corp., San Ramon, Calif.
The Babcock & Wilcox Co., Lynchburg, Va.
Battelle Memorial Institute, Columbus, Ohio
Carborundum Co., Niagara Falls, N.Y.
Clevite Corp., Cleveland, Ohio
Davison Chemical Co., Erwin, Tenn.
Engelhard Industries, Inc., D. E. Makepeace Div., Plainville, Mass.
General Electric Co., Atomic Power Equipment Dept., San Jose, Calif.
General Dynamics Corp., General Atomic Div., San Diego, Calif.
M & C Nuclear, Inc., Attleboro, Mass.
The Martin Co., Middle River, Md.
National Lead Co., Albany, N.Y.
Nuclear Materials & Equipment Corp., Appollo, Pa.
Nuclear Metals, Inc., Concord, Mass.
Sylvania-Corning Nuclear Corp., Hicksville, N.Y.
Westinghouse Electric Corp., Blairsville, Pa. and Forest Hills, Pa.

The two companies not requiring licenses were Combustion Engineering Corp., Windsor, Conn., and Olin Mathieson Chemical Co., New Haven, Conn.

The following companies were licensed to reclaim unirradiated enriched uranium from scrap generated in fuel fabrication and fuel material preparation:

Davison Chemical Co., Erwin, Tenn.
Engelhard Industries, Inc., Baker Platinum Div., Newark, N.J.
Mallinckrodt Nuclear Corp., Hematite, Mo.
Nuclear Materials & Equipment Corp., Apollo, Pa.
Spencer Chemical Co., Kansas City, Mo.

Source Material

Licenses issued during the year, including renewals, authorizing possession and use of source material totaled 1,889. This figure includes 721 licenses issued to exporters. As of December 31, there were 1,345 source material licenses in effect (exclusive of export licenses).

Byproduct Material (Radioisotopes)

These licenses are reported in the section dealing with Isotopes Development.

Waste Disposal Licensing

During the year, three licenses were issued to concerns authorizing the disposal of packaged low-level radioactive waste by burial at sea, bringing the total for this field to nine. Two companies previously licensed for disposal of low-level wastes, Atomic Energy Waste Disposal Service, Oakland, Calif., and American Electronics, Inc. (Reed-Curtis Nuclear Industrial, Inc.), Culver City, Calif., discontinued this phase of their business. One company, Radiological Services Co., Long Island, N.Y., is licensed to receive pre-packaged radioactive wastes for disposal by the Commission.

The companies licensed for disposal of low-level waste commercially, including four licensed for the first time, are:

Crossroads Marine Disposal, Boston, Mass.
Nuclear Engineering Co., Walnut Creek, Calif.
Isotopes Specialties Co., Burbank, Calif.
New England Tank Cleaning Co., Cambridge, Mass.
American Mail Line, Ltd., Seattle 1, Wash.
The Walker Trucking Co., New Britain, Conn.
Coastwise Marine Disposal Co., Los Angeles, Calif.
California Salvage Co., San Pedro, Calif.
Ocean Transport Co., San Francisco 11, Calif.

In addition, two Government agencies are licensed to dispose of low-level radioactive waste at sea: The National Institutes of Health, Bethesda, Md., and the U.S. Naval Radiological Defense Laboratory, San Francisco, Calif.

Indemnity and Regulation

Financial Protection and Indemnity

A proposed revision of the Commission's financial protection and indemnity regulation, 10 CFR Part 140, was published in the *Federal Register* for public comment on May 1, 1959. The proposed amendment would add a location factor to the formula for financial protection applicable to larger reactors, revise the amounts of financial protection required for smaller reactors, and require financial protection in the amount of $1 million for holders of construction permits authorized to receive and store special nuclear material at a reactor site for subsequent use as reactor fuel. The revision would exempt Federal agencies and nonprofit educational institutions from the financial protection requirement.

In the case of Federal agencies, Government indemnity would extend to all claims for public liability up to $500 million; with respect to nonprofit educational institutions licensed to operate a reactor in the conduct of educational activities, the regulation would authorize indemnity protection not to exceed $500 million to cover public liability in excess of $250 thousand. Two proposed rules,[15] previously published August 28, 1959, in the *Federal Register* for public comment, setting forth the proposed form of licensee indemnity agreement, and the latest form of nuclear energy liability insurance policy then available, are being revised.

In furtherance of its study of the question concerning whether or not to extend Price-Anderson Act indemnity to licensees using significant quantities of special nuclear material, but not operating reactors, the Commission has entered into a contract intended to furnish, in part, information concerning the criticality hazards potentially involved in use of the material.

Thus far, the Commission has entered into interim indemnity agreements covering nuclear reactors with 5 Federal agencies, 21 nonprofit educational institutions, and 16 licensed private organizations. Of the 16 licensees 14 are carrying nuclear liability insurance and two are relying on their own resources to satisfy any public liability claims that might arise.

[15] See p. 53, Twenty-fifth Semiannual Report to Congress (July–December 1958).

Under the Commission's policy of entering into agreements of indemnification with its contractors under the authority of section 170 d. of the Atomic Energy Act of 1954, as amended by Public Law 85–256,[16] the Commission has executed statutory indemnity agreements as to 33 contracts, 22 of them during the reporting year of 1959. These agreements cover most of the major installations operated by Commission contractors.

The Commission is negotiating with groups representing various segments of the insurance industry for use of their claims adjustment services, should these be required.

The status of public liability and indemnification in foreign countries is reported in the section on International Activities. Studies in connection with operation of the N.S. *Savannah* are covered in chapter II, Part One, of this report.

New Regulations

Major amendments. Amendments to existing regulations issued during 1959 included:

10 CFR Part 2—"Rules of Practice." An amendment, effective June 11, 1959, sets forth instructions with respect to the filing of exceptions to intermediate decisions, and of briefs in support of or in opposition to exceptions.

Another amendment, effective December 19, 1959, bans ex parte communications concerning substantive matters between an applicant or a licensee and the Commissioners after initiation of an adjudicatory proceeding; if such communications should be effected, however, the amendment to Part 2 and an accompanying amendment to 10 CFR Part 9, "Public Records," provide that they shall be made public.

10 CFR Part 9—"Public Records." Another amendment to Part 9 (see above), effective January 10, 1960, established procedures intended to assure that written communications to the Commission, including those from members of Congress, relating to licensing and rule making proceedings, be placed in the public record.

10 CFR Part 30—"Licensing of Byproduct Material." An amendment, effective February 10, 1959, provides for a general license to distribute gaging devices containing radioisotopes when manufactured and distributed under a specific license issued by the Commission to the manufacturer of such devices.

Text of new regulations is given in appendix 8.

[16] See p. 54, Twenty-fifth Semiannual Report to the Congress (July–December 1958).

Proposed regulations. Four proposed regulations of major import were published for public comment during 1959.

The first published in the *Federal Register* May 2, 1959, would amend 10 CFR Part 20, "Standards for Protection Against Radia tion," to incorporate recent recommendations of the National Committee on Radiation Protection and Measurements concerning, among other things, maximum accumulated radiation exposure.

The second published in the *Federal Register* May 23, 1959, is a general notice of proposed rule-making (10 CFR Chapter 1) stating factors to be considered by the Commission in evaluating proposed reactor sites.

The third would incorporate in 10 CFR Part 50, "Licensing of Production and Utilization Facilities," a definition of a "testing facility" and would incorporate provisions concerning the statutory requirement of review by the Advisory Committee on Reactor Safeguards and formal hearings in power and test reactor cases. A fourth would add to 10 CFR Part 70, "Special Nuclear Material," a semiannual reporting requirement concerning special nuclear material received, transferred or possessed by Commission licensees.

Cooperation With States

During the year, the Commission continued to inform State officials of the issuance by the Commission of licenses for byproduct, special nuclear, and source materials, nuclear reactors, and of all applications for facility licenses in their States. Notification also was provided on applications for, and proposed issuance of, licenses to dispose of radioactive wastes on a commercial basis.

The report of the American Municipal Association on the impact of peaceful applications of atomic energy on communities has been completed and will be made available for sale to the general public.[17] The report was based on a study conducted by the Association under contract with the Commission.

Reactor Safety

During the year, the Commission conducted 132 reviews on the safety of licensee and Government-owned reactors. In addition, advisory service was provided with respect to the safety of reactors planned in Belgium, Korea, Norway, Thailand, Viet-Nam, Venezuela, the Philippines, and New Zealand.

[17] "Community Impact of Peaceful Applications of Atomic Energy," Office of Technical Services, Department of Commerce, Washington 25, D.C., about March 1960.

The Advisory Committee on Reactor Safeguards held 10 meetings throughout the year to review and make recommendations on reactor projects referred to the Committee by the Commission. Proposed criteria for reactor site selection also were reviewed by the Advisory Committee.

Hearing Procedures on Commission-owned Reactors

In March 1959, the Commission announced that with respect to certain Commission-owned reactor projects, persons with a valid interest will be granted an opportunity to participate in consideration of the safety aspects of the projects in procedures which would parallel those observed in licensing actions. The reactor projects to which this policy applies are Commission-owned power demonstration reactor projects not located at Commission installations but to be operated as an integral part of operating utility systems.

Hazards Summary Reports filed with the Commission for construction or operation of these proposed reactors, reports of the Advisory Committee on Reactor Safeguards, and copies of the Commission hazards evaluations will be available for public inspection in the Commission's Public Document Room, 1717 H Street NW., Washington, D.C. In addition, the Commission will issue notice of hearings at least 30 days in advance. Appropriate amendments to the Commission's regulations are under preparation.

Under this new policy, hearings were held November 10 to consider the health and safety aspects of the 58.2 (thermal) megawatt reactor to be operated by the Rural Cooperative Power Association near Elk River, Minn., and November 20, concerning the 45.5 (thermal) megawatt reactor to be operated by the City of Piqua, Ohio. On December 18, 1959, the presiding officer issued his Intermediate Decision authorizing, subject to review by the Commission, the construction of the Elk River reactor. In his Intermediate Decision, the presiding officer also observed that questions raised by the Governor of the State of Minnesota concerning, among other things, compliance with laws and regulations of that State, may be more appropriately considered at the time of proceedings on the operating authorization.

Compliance Actions

Thirty-five orders were issued to licensees requiring specific actions to be taken by the licensees to achieve compliance with Commission regulations.

Eleven of these orders were issued to uranium processing mills. They were based on inspections which revealed that, in general, these mills had not made adequate surveys of radiation levels and concentrations of radioactive material in air and liquid effluents to demonstrate their compliance with 10 CFR Part 20, "Standards for Protection Against Radiation." The mills were ordered to submit detailed plans for bringing their operations into compliance, and all but one have submitted their plans. The exception, Mines Development Inc., requested a hearing. (See Appendix 11.)

As a result of information obtained by the Commission regarding the unlicensed importation of watches and clocks with luminous dials containing strontium 90, letter orders were issued to 13 watch companies directing them not to process, transfer or dispose of any such luminous hands or dials, and requiring them to make application forthwith for a license authorizing appropriate disposition of any strontium 90 in their possession. A similar order was issued to another company which had imported strontium 90 in a zinc sulphide solution for use as a luminous agent. Each company possessing strontium 90 has taken steps to comply with the regulations. Luminous-dial watches and clocks normally contain radium, a material which the Commission does not control. The Commission has not licensed the use of strontium 90 in watches or clocks.

Voluntary recall of watches. In mid-December, the Commission and the American Rolex Watch Corp. of New York initiated a nationwide search to recover several hundred Swiss-made "Rolex GMT-Master" navigational type wrist watches some of which were found to contain radioactive strontium 90.

The American Rolex Watch Corp. undertook the recovery operation after learning from the Commission that a watch of this type, purchased in Singapore, had been found to contain strontium 90. About 600 watches of this type had been imported by the company from the firm of Montres Rolex, S.A., Geneva, Switzerland, between October 1956 and November 1959.

The Commission issued a limited license to the firm authorizing receipt at its New York headquarters (580 Fifth Ave., New York 36, N.Y.) of the watches for inspection. The watches are required to be checked for radioactivity under the direct supervision of a Commission inspector. If any watch is found to contain strontium 90-painted markings and numerals, the parts involved are being replaced by the company.

At year's end, some 250 watches had been submitted to the firm for inspection. About three-fourths of them contained strontium 90.

Licensee Inspection

A decentralized system of Commission inspection of byproduct, source, and special nuclear materials licensees had been in effect for 3½ years at the end of December. About 5,500 inspections have been made during that time. Inspections are made on a priority system based on the kind and amount of material involved and the degree of potential hazard in the licensed operation.

Certain Commission inspection activities, as a part of its regulatory program, are designed to provide an independent and firsthand review of a licensee's operation. The basic objective is the safe use of radiation sources in private industry. The total licensee inspection program is divided into two major parts, corresponding to the two major categories of licensed activities: (*a*) use of licensed materials; and (*b*) construction and operation of production and utilization facilities (reactors).

Inspection of Users of Licensed Materials

Specific objectives of inspections are to gather factual data on compliance of a licensee with applicable rules and regulations, including special conditions incorporated in his license, and to investigate radiation incidents and complaints. The investigations include determination of the cause of any incident and a review of corrective action taken to minimize danger to the health and safety of the public and to prevent recurrence. Both inspections and investigations include the collection of information which may be of assistance to the Commission in determining the adequacy and effectiveness of its regulatory program.

Responsibility for inspection of byproduct, source and special nuclear materials licensees is decentralized to eight Commission Operations Offices, Albuquerque, Chicago, Hanford, Idaho, New York, Oak Ridge, San Francisco, and Savannah River, each responsible for a specified geographic area.

A preliminary General Inspection Guide defines criteria and standards for inspection. It includes a priority system for initial inspections, and for subsequent periodic followup and reinspections depending on the kind and amount of material involved and on the degree of potential hazard involved in a licensed operation.

Regulation 10 CFR Part 20, "Standards for Protection Against Radiation," defines four types of radiation incidents and requires that each licensee report occurrences of these kinds to the Commission. All radiation incidents are investigated which involve, or are likely

to involve: (*a*) an exposure to an individual of 3 rem or more, (*b*) the release of radioactive material in concentrations 500 times or more in excess of the limits specified, (*c*) the loss of one day or more in the operation of the facility affected, or (*d*) property damage in excess of $1,000. Purpose of these investigations is to gather information showing the number and identity of persons exposed, the extent of exposure, sequence of events leading up to and including the incident, the role of facilities and equipment in the incident, the role of personnel and the procedures in the incident, and the status of compliance of the licensee with Commission rules and regulations. Reports of exposures to persons in excess of the prescribed standard but less than 3 rem are not normally scheduled for investigation but are reviewed during a subsequent inspection, unless particular circumstances should indicate that an investigation is desirable.

Reports of investigations of accidents or incidents are reviewed to determine the compliance status of the licensee in connection with the incident and to assure that the corrective steps are adequate.

An analysis of inspections from July 1956 through June 30, 1959, showed that of the approximately 5,500 licensees inspected, less than 2 percent were in noncompliance with standards involving matters of possible personnel exposure, radiation levels, concentration of effluents in unrestricted areas, or measures to be taken after exposure. In about 43 percent of the inspections, licensees were in noncompliance with one or more administrative provisions of the regulations or a condition of the license. These violations involved such things as failure to maintain proper posting, labeling, record keeping, and filing of reports.

In all instances where a licensee is visited by a Commission inspection representative, the licensee is informed orally of the items of noncompliance observed during the inspection visit. Later, he is informed in writing of the status of his compliance with regulations and requirements.

Inspection of Licensed Facilities

Inspection of licensed nuclear facilities, or those authorized for construction, is performed by Commission Headquarters personnel with assistance from operations offices. Objectives are to obtain information related to compliance with Commission regulations and to observe and evaluate the safety of operations.

During the past year, one or more visits was made to each of the five power reactors and the three test reactors operating or authorized for construction at the beginning of the year. Approximately 23

research reactors, 7 critical experiments, and 14 special nuclear materials licensees, whose operations involved criticality considerations, also were visited one or more time. All facilities licensed or authorized for construction at the beginning of 1958 have been visited at least once during 1958 or 1959. A draft of a Reactor Inspection Guide was issued during the year.

Inspection

With transfer of its licensee inspection program to the Division of Compliance (see section on Personnel), the Division of Inspection's monitoring review of Commission inspections and investigations was extended to cover licensee as well as Commission and contractor operations. Inspections and appraisals of Commission and contractor operations were subjected to continuing test checks and reviews for consistency with Commission policies and standards. A number of refinements were made in the Commission's inspection practices including those covering the fields of health and safety and supply management.

Commission inspection standards were revised in mid-year to permit more flexibility in the inspection methods utilized while still requiring a critical appraisal of Commission and contractor operations. Under the Commission's contractor appraisal program, regular inspection and audit findings of its field staffs were used in preparation during 1959 of summary performance evaluations of some 40 major cost-reimbursable contractors.

Contract Appeals

Appeals under "disputes" articles contained in Commission contracts and subcontracts were governed until February 3, 1959, by Commission Rules and Regulations, Part 3, "Rules of Procedure of U.S. Atomic Energy Commission Advisory Board on Contract Appeals."

By revision of these regulations, effective February 3, 1959, the functions of the Advisory Board were transferred to the Commission's Hearing Examiner with respect to disputes appealed after that date. Under the revised procedure, appeals from decisions of the Contracting Officer are heard and initially decided by the Hearing Examiner. The decision of the Hearing Examiner becomes final within 60 days after its issuance unless a party during such period files a petition for review. The Commission may thereafter, in its discretion, grant the petition, review the case, and issue its own final decision.

During 1959, the Advisory Board completed all six appeals on its docket and, in all cases, the Board's recommendation was adopted by the General Manager. No appeals now remain under the jurisdiction of the Advisory Board, the existence of which has expired.

During 1959, 10 cases were either appealed, or transferred from the Advisory Board, to the Hearing Examiner. One such proceeding was settled before hearing. In four cases a decision or order disposing of the appeal was entered by the Hearing Examiner. Five cases were pending at the end of the year.

At the end of 1959 the Commission approved and published a complete revision of the rules of procedure governing contract appeals. This revision constitutes a practical formalization of procedural rules affecting such appeals and incorporates many of the provisions contained in the Commission's Rules of Practice, 10 CFR, Part 2. Among other things, the rules incorporate the complaint and answer procedure developed by the Armed Services Board of Contract Appeals and the provisions of Rule 34, Federal Rules of Civil Procedure, and Rule 26 of the Court of Claims with respect to the discovery and production of documents not privileged. The procedure for Commission review of decisions by the Hearing Examiner, as adopted February 3, 1959, is continued.

Classification and Declassification

Revision of classification guidance policies and a further declassification of information regarding military reactors made possible the release of additional technical information on an unclassified basis during 1959.

The "AEC Classification Policy Guide," formerly known as the "Declassification Guide for Responsible Reviewers," was revised in collaboration with its other users, the United Kingdom and Canada. New areas of information declassified include all production chemistry and chemical technology, excluding only quantities and specifications which are important for military reasons. Included in the declassification are green salt and uranium hexafluoride preparation, recovery of plutonium and uranium from nuclear fuels, and reduction of plutonium and uranium compounds to metal.

Since this guide states the Commission policy regarding classification applicable throughout the atomic energy program, any revision requires corresponding changes in the detailed local or project classification guides which must conform with it. A topic in such guides which is thus changed to unclassified not only permits newly generated information within that topic to be issued as unclassified, but also per-

mits publication of existing reports, previously classified because they contain information within that topic.

The policy of prompt release of technical information was continued during the past year. Ten new power and test reactor projects were reviewed in the light of current Commission classification policy and placed in the category of unclassified research; and a substantial amount of research and development work on sodium-potassium-eutectic coolant in stainless steel tubes and vessels has been declassified.

A study of the Commission's Access Permit Program which permits access to certain categories of classified information led to the conclusion that, consistent with the national security, it is not possible to declassify all information now available in the Access Permit Program. However, as a result of past declassification actions and declassification actions taken by the Commission during 1959, it will be possible to eliminate several categories of information from the Access Permit Program. These categories of information are no longer classified. The study of the Access Permit Program still is in progress and a revision is being prepared to Title 10, Code of Federal Regulations, Part 25.

A review of classification policy in the weapons field has been completed. Although no basic change has been made, the Commission has approved a new classification guide which incorporates many improvements suggested by experience.

The Commission is continuing its program of reviewing for declassification purposes reports and records held in the files of former Commission contractors in order that all documents not classified under current policies might be declassified. The principal value of this program is that the expense of maintaining classified files and the need for security surveys are eliminated. As of December 31, the files of 72 former contractors had been reviewed, and the files of 52 of these contractors have been declassified. About 6,000 items have been declassified as a result of this program.

The Commission is continuing to publish all fallout information which might be of concern to the public health and welfare, and is making the data available as soon as possible after its collection. Since some information of use to the public in this field sometimes appears in reports which are classified because of other information they may contain, a concerted effort was made throughout the Commission to find any such reports and a special declassification team was organized to review them in order that any fallout information they contained might be published. (See section on Fallout Studies.)

Information Services

Exhibits, Films, and Information Kits

Exhibits

Since establishment of the Commission's enlarged, traveling free exhibit program 4 years ago, the exhibits have been viewed by 23,049,345 persons in 49 States. Shown under nonprofit sponsorship, the exhibits attracted 8,439,327 during the last 12 months.

The Commission's three large exhibit units, in constant use since mid-1956, have been replaced by two new units titled "You and the Atom." The units embody new design to help viewers understand the general principles of nuclear power, radioisotope applications, and radiation safety. Featuring lecture-demonstrations on fission power, radioisotopes, and remote handling equipment, these units, like their predecessors, are primarily for display in large centers. One was displayed throughout the summer at the Oregon Centennial Exposition at Portland, where it was viewed by 1,174,750 persons.

Five mobile vans containing scaled-down, exhibits for walk-through viewing have been completely reworked. Titled "Atoms at Work," these exhibits are being displayed in smaller communities under the continuing cosponsorship of the National University Extension Association and the United States Junior Chamber of Commerce. They are used in a coordinated "Town and Atom" educational program including speaking engagements at schools and before civic groups.

This year the mobile units were utilized also in cooperation with the National Science Foundation to assist in teachers' summer training courses. The National University Extension Association sponsored showings on a number of college campuses.

In addition to the larger exhibits, the program includes six "This Atomic World" units which feature a trained demonstrator and equipment for presentations to secondary school assemblies and science classes. There also are 14 package units, shipped without an attendant, to meet the needs of special events in small cities, educational and science fair activities of schools, and at museums, libraries, and county fairs.

Since establishment of the Commission's traveling exhibit program 4 years ago, and through December 31, the large units have shown in 38 States to 11,263,463 persons; the mobile walk-through units in 2,854 communities in 48 States to 2,230,290; the high school demonstration units at 3,063 schools in 48 States before 2,563,564 students, and the package-type units in 639 communities in 49 States to 6,992,028 view-

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ers. For the 12-month period ending December 31 the totals were: for the large units, 19 States, 4,193,545 persons; mobile units, 624 communities in 23 States, 743,277 persons; "This Atomic World" demonstration units, 1,067 schools in 19 States, 922,223 students; and package-type units, 257 communities in 42 States, 2,580,282 viewers.

Educational Information

Some 65,973 kits of atomic energy informational material were distributed during the reporting period to college, high school, and elementary school students, teachers, and guidance counselors; to adult study groups, teachers' institutes, and other interested organizations; and to the general public in the United States and elsewhere.

Films

During the reporting period, the Commission's 10 domestic motion-picture libraries, stocked with more than 150 popular-level and professional-level films, loaned them for more than 60,768 showings viewed by 1,984,691 persons. The film libraries and the geographical areas they supply are listed in Appendix 7.

Arrangements were completed for commercial sale of French, Spanish, Russian, and English-language versions of the 45 technical films premiered at the United Nations Second International Conference on the Peaceful Uses of Atomic Energy held at Geneva, Switzerland, September 1–13, 1958. On loan from the Commission's libraries, the Geneva films also have been made available in foreign countries through the Commission's liaison offices in London, Tokyo, Brussels, and Buenos Aires, and the United States Information Agency's libraries throughout the world.

The Commission added 6 technical professional-level, and 5 popular-level films to its motion picture libraries during the reporting period. The libraries currently stock 76 professional level films and 78 popular level films. Films added were:

Professional Level

RESTORATION OF THE NRX REACTOR, 23 minutes, black and white, produced by the Department of Agriculture for the Commission and Atomic Energy of Canada, Ltd. The film covers the 14-month repair and restoration of the NRX Reactor at Chalk River, Ontario, after a power level excursion, the first case of a nuclear reactor runaway in history. It describes the new safety system.

FUEL ELEMENT BURNING EXPERIMENT, 24 minutes, color, produced by the Department of Agriculture for the Commission, describing an experiment at the National Reactor Testing Station in which aircraft reactor fuel elements, together with other materials, were melted in a simulated aircraft crash.

FUEL FABRICATION FACILITY, 9 minutes, color, produced by Argonne National Laboratory, describing the fabrication process developments laboratory for manufacture of unique fuel elements and test pieces containing plutonium.

OMRE FUEL ELEMENT REMOVAL AND SECOND CORE LOADING, 15 minutes, color, produced by Atomics International, summarizing operating experience and test program from September 1957 to July 1959 of the Organic Moderated Reactor Experiment. Removal of the first reactor core and loading of the second core is detailed.

Professional and Popular Level

PRODUCTION OF URANIUM FEED MATERIALS, 28 minutes, color, describing the step-by-step production of uranium in the Commission's feed material plants at Fernald, Ohio, and Weldon Springs, Mo. This is the first film ever made on the subject.

ISOTOPES, 20 minutes, color, produced by Oak Ridge National Laboratory, describing what isotopes are, how they are used, and primarily, how they are produced, chemically separated, stored and shipped.

Popular Level

HIGH ENERGY RADIATIONS FOR MANKIND, 16 minutes, color, produced for the High Voltage Engineering Corp. and made available for loan through the Commission, describes the principles, assembly, and uses of a Van de Graaff particle accelerator.

ATOMS FOR PEACE: GENEVA—1958, 15 minutes, black and white, produced for the Commission by the Department of Agriculture, summarizes United States participation in the Geneva Conference in 1958.

POWER AND PROMISE, 29 minutes, color, describes the Shippingport Atomic Power Station: production and control of heat and radioactivity through nuclear fission; manufacture of the fuel; description and installation of some of the major components—pumps, heat exchangers, the pressure vessel; construction of the station proper; erection and installation of the core.

Films in production and planned for release during 1960, include: industrial uses of radioisotopes, being produced for the Commission

by the Army Pictorial Center; the Gas-Cooled Reactor Experiment being produced for the Commission's Idaho Operations Office and the U.S. Army by the USAF's Lookout Mountain Laboratory; construction and launching of the NS *Savannah*, being produced for the Maritime Administration and the Commission; and the Fast Source Reactor being produced by Argonne National Laboratory.

Technical Information

Nuclear Science Abstracts

The rapid growth of atomic energy literature has resulted in a corresponding increase in the number of subjects covered in "Nuclear Science Abstracts"—from 6,700 abstracts in 1953, to 18,000 in 1958, and to approximately 24,000 in 1959. The increased volume is due largely to expanded atomic energy activities in foreign countries, and to the expanded program of exchanges with foreign scientific sources, and the United States scientific translation program.

Beginning with volume 13 (1959) each semimonthly issue of "Nuclear Science Abstracts" contains complete subject, author, and report number indexes. These indexes are cumulated without delay on a quarterly, semiannual, and annual basis. New automatic machine indexing procedures were developed by the Commission to permit this immediate and detailed identification of the information sources. Similar machine indexing techniques are being adopted by other abstracting services.

Foreign exchanges. "Nuclear Science Abstracts" and unclassified research and development reports published by the Commission are supplied to 420 organizations in 44 countries including laboratories, research institutes, and universities in return for monographs, research and development reports, and scientific journals from these foreign sources. Publications received in exchange, besides being abstracted in "Nuclear Science Abstracts," are made available to the scientific community of this country through the Commission's depository libraries or by interlibrary loan from the library of the Oak Ridge Institute of Nuclear Studies. The Commission received 200 publications in this manner during 1959.

Technical Books

In its program for preparing and publishing handbooks, technical texts, and other reference works on atomic energy subjects required

by scientists, engineers, and management personnel in nuclear fields, the Commission during 1959 issued two volumes—"Cryogenic Engineering" and "Uranium Production Technology" [18]—and completed arrangements for publication of the "Reactor Handbook," a work in four volumes on physics, engineering, materials, and fuel reprocessing. Contracts were awarded for preparation of books with the following titles: "Fast Reactor Theory and Core Design," "Fast Reactor Plant Design," "Nuclear Propulsion of Merchant Ships," "Metallic Hydrides," "Nuclear Graphite," "Atomic Energy Deskbook," and "Reactor Control Systems."

Publications of the Atomic Energy Commission are listed in Appendix 6.

Technical Progress Reviews

The Commission began publication of a fourth quarterly Technical Progress Review designed to meet the needs of scientists and engineers, "Nuclear Safety," [19] the first issue being distributed in September. The contractor who prepares it is W. B. Cottrell, R. A. Charpie and Associates, Oak Ridge National Laboratory. This quarterly, like the others, summarizes and evaluates important developments in key areas of nuclear science and technology, and will include reactor kinetics and control; nonnuclear reactions that could result in release of fission products, containment, and environmental factors; nuclear safety in fuel fabrication, fuel reprocessing, fissionable materials storage and shipment; and other plant and laboratory activities in which a criticality incident might occur.

Technical Symposia

During 1959, the Commission published 19 collections of papers presented at scientific and technical symposia, meetings, and conferences. Among the subjects covered were: "Reactor Fuel Measurement Techniques," "Welding," "Gas-Cooled Power Reactors," and "Safety and Fire Protection." These collections are listed in Appendix 6 with other special publications sponsored by the Commission.

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[18] Copies of a catalog "Technical Books Sponsored by the U.S. Atomic Energy Commission" available on request to Technical Information Service Extension, AEC, P.O. Box 62, Oak Ridge, Tenn.

[19] Available by subscription (domestic, $2.00 a year; foreign, $2.50 a year), or by individual issue, ($0.55), Superintendent of Documents, Government Printing Office, Washington 25, D.C.

Translations

The Commission had translated from Russian into English and published some 20 monographs on subjects such as "Applied Magneto Hydro-Dynamics," "Heat Transfer in Condensation and Boiling," "Many-Particle Theory," and "Using Radioactive C^{14} in the Study of Photosynthesis."

Most of these have been produced under contractual arrangements with commercial translators and with the U.S. Joint Publications Research Service. The Commission also participated in the tranlation program being conducted in accordance with Public Law 480, section (k), which authorizes the use of foreign currencies accruing from the sale of surplus agricultural commodities. Under this program, coordinated by the National Science Foundation, translations of the Russian *Zhurnal Neorganicheskoi Khimii* (Journal of Inorganic Chemistry), volume 2, 1957, and the Russian *Uspekhi Fizicheskikh Nauk* (Advances in Physical Sciences) volumes 61, 62 and 63 (1957) are being made in Israel. In Poland, translations are being made of original Polish articles appearing in *Nukleonika* (Nucleonics) volume 2, 1957 and volume 3, 1958.

Although the emphasis was on publications from the Soviet Union, translation coverage is being expanded to other languages. The emergence of Communist China and other Soviet Bloc countries in the nuclear field, and the growing body of technical literature published in Japan, require inclusion of significant publications from these countries. Translation of one Japanese monograph, "Semi-Homogeneous Breeder Reactor" was completed during the year and another is in process.

Abstracts of the translations appear in "Nuclear Science Abstracts," and full texts are for sale by the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.

Distribution of Reports

During this reporting period 166,051 copies of classified and unclassified reports were sold. A total of 4,836 new unclassified reports was placed on public sale.[20]

Engineering Materials

During this reporting period, more than 8,000 new engineering

[20] Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.

drawings [21] were made available for sale. The engineering drawings include specifications, parts lists, bills of materials, design data, etc., pertaining to equipment, processes, and facilities developed in the national atomic energy program.

Since this service was established in 1956, more than 85,000 copies of drawings have been sold on subjects ranging from portable radiation detectors and small laboratory equipment to complete research and power reactors and uranium processing plants.

Reproduction copies of engineering materials in a wide variety of format and sizes, are offered for sale by Cooper-Trent Blueprint and Microfilm Corp., Arlington, Va., and Rapid Blueprint Co., Los Angeles, Calif.

Depository Libraries

During 1959, 10 new depository collections of unclassified Commission reports were established. Three of these were domestic—Syracuse University, Montana University, and Hawaii University—making a total of 85 such libraries. The other 7 were overseas making a total of 81 depositories now outside the United States (see Appendix 6).

Technical Information Exhibits

The Commission placed its technical information exhibit "Nuclear Information for Science and Industry" at the Nuclear Congress and Atom Fair, Cleveland, Ohio, May 5–10, and conducted a demonstration of the SNAP III radioisotope thermoelectric generator, featuring an amateur radio station powered by electricity from the generator. Operating under the special call sign W8NPC—"Nuclear Powered Communication"—this first radioisotope-powered radio station reached out to Idaho, New Mexico, Texas, Puerto Rico, and the Canal Zone.

A technical information display also was placed at the annual meeting of the American Nuclear Society, Gatlinburg, Tenn., June 15–20, the Western Electronics Show and Convention, August 18–21, the United States atomic energy exhibit at the Tokyo International Trade Fair, Tokyo, Japan, May 5–22, and the New Delhi World Agricultural Fair, New Delhi, India, in December.

[21] A catalog, "Engineering Materials List" (TID-4100, Rev.), and periodic loose-leaf supplements, available on request, Technical Information Service Extension, AEC, P.O. Box 62, Oak Ridge, Tenn.

Education and Training

The Commission continued during 1959 to support training at university and high school teaching levels in scientific fields of interest to atomic energy programs, and to industry. Courses were given for faculty members, grants made to colleges and universities for equipment, laboratory manuals and training material were prepared, and fellowships were granted in a variety of sciences. The general objective of the programs is to assure an adequate supply of trained manpower for the growth and development of the Nation's atomic energy science and industry.

Physical and Engineering Sciences

Commission Assistance to Schools

Faculty training. During the summer of 1959, the fourth consecutive year, five institutes on reactor technology for faculty members of engineering schools were jointly sponsored by the Commission and the American Society for Engineering Education. The 1959 institutes were attended by 104 faculty members from 64 universities. Twelve schools and four States not represented before were included. In all, 372 individual faculty members from 118 educational institutions in 46 States, Puerto Rico and the District of Columbia have attended institutes. Of 48 universities now participating in the Commission's Special Fellowship in Nuclear Science and Engineering, 90 percent have sent faculty members to institutes. Two basic institutes for university faculty were held in 1959; one at Cornell University in cooperation with the Brookhaven National Laboratory, and the other at North Carolina State College in cooperation with the Oak Ridge National Laboratory.

Advanced institutes for engineering faculties were held in Chemical Processing at the Hanford Laboratory; in Special Topics in Reactor Operation and Design at the University of Michigan; and in Specialized Nuclear Studies at the Argonne National Laboratory. The advanced institutes are for faculty members who have attended basic institutes or have the equivalent background.

In developing a core of technicians trained for employment in the nuclear reactor field, a summer institute attended by 22 faculty members from 12 technical schools was held at Pennsylvania State University in 1959, the second institute of this kind. Total attendance for the two was 51 from 25 schools.

A new program of training for isotopes technology, in which the National Science Foundation is cooperating with the Commission, will support courses for college faculty in the 1960 National Science Foundation Summer Institute Program.

Equipment grants. Grants during 1959 to 56 universities and colleges for equipment needed in physical science and engineering curricula primarily directed toward reactor technology totaled nearly $1.8 million. Since the program was initiated in September 1956, a total of $12.7 million has been awarded to 125 educational institutions including funds for 30 teaching reactors and 56 subcritical assemblies.

Grants for teaching aids, demonstration apparatus and student laboratory equipment in the isotopes development program are described in that section of the report.

Providing teaching tools. During 1959, the Commission approved the loan, without charge, to 47 schools of neutron sources, natural uranium reject slugs, enriched uranium and other nuclear materials for use in subcritical assemblies and for other nuclear instructional purposes. Under the program, 30 subcritical assemblies have been built or are planned by colleges and universities using their own funds. This is in addition to 56 subcritical assemblies obtained or being acquired with Commission grants.

The Commission assisted four nonprofit educational and medical institutions in building or refueling research reactors during 1959 by lending enriched uranium, and paying fuel fabrication costs. Eight institutions have been aided under this program, and four other requests are pending.

The Commission also has prepared short courses in specialized subjects, textbooks, teaching aids, films and curricula plans.

Effects of assistance programs. Although many of these programs have been in effect only 2 or 3 years, Commission contractors report employing some 700 graduates who have taken nuclear courses from schools receiving Commission assistance. Contractors estimate that graduates of these courses are effective in their new work assignments as much as 6 months before those without specialized training.

The Commission's Oak Ridge School of Reactor Technology was closed in 1959 because universities and colleges now are providing courses at levels equal to those previously offered.

Technical institutes and vocational schools in California introduced nuclear courses in 1959 and others have indicated that they will give courses in 1960. Labor unions began nuclear training in apprentice

program in 1959 and some private companies also have adapted Commission material for use in their plants.

Fellowships

In addition to the direct assistance to educational institutions, the Commission in 1959 awarded 183 fellowships in nuclear science and engineering for the 1959–60 academic year. A total of 212 students has done graduate work under this program, 190 of these fellows reported their activities as follows:

	1957–58	*1958–59*	*Total*
Continuing University Study:			
Under Commission Fellowships	22	45	67
Other	14	31	45
Working for Atomic Energy Commission	3	1	4
Holding Faculty Appointments	5	0	5
Working for National Laboratories	2	2	4
Working for Atomic Energy Industry	35	20	55
In Military Service	8	2	10
Data Not Received	3	19	22
Total	92	120	212

Assistance to Industry

Shippingport reactor supervisors training course. Early in 1959 the Commission launched a training program for reactor supervisory personnel at the Shippingport Atomic Power Station, with the training to be conducted by the Duquesne Light Co. for the Commission. The first session had 24 trainees enrolled from United States utilities and from foreign countries (see International Activities).

The second Shippingport course, begun July 13, with 12 students, 5 from foreign countries. The next course is scheduled to begin in April 1960.

In September the Commission announced an expanded reactor supervisors training program to include work assignments at Commission sites in addition to the Shippingport course.

Industrial training in radioisotopes. This course, conducted by the Oak Ridge Institute of Nuclear Studies, was introduced in 1959 to provide sufficient experience for technical personnel to enable them to use radioactive isotopes safely and efficiently in industrial organizations. In all, 93 industry representatives and 9 university instructors attended three courses offered in 1959.

Assistance to Schools

Faculty training. The program of summer institutes for teacher training in radiation biology was expanded in 1959 to include 2 institutes attended by 40 teachers of biology from liberal arts colleges. Institutes were held at 17 universities for 240 high school teachers, bringing the total during the 4 years of this program to 780; 740 high school and 40 college teachers.

Equipment grants. During 1959, 138 nonprofit educational institutions asked Commission financial assistance for the purchase of nuclear equipment and materials for use in life science courses. In all, 108 schools received $1,113,416 under this program during the year. The totals are 230 grants to 146 schools receiving $2,627,406 in awards (84 receiving more than 1) since the inception of the program.

Effect of programs. Reports from schools receiving equipment grants indicate that approximately 50 courses have been expanded to include nuclear aspects of medicine, public health, agriculture, pharmacy, biology, and veterinary medicine. Fifteen of 108 institutions, at their own expense, enlarged laboratory space or provided new facilities for use of equipment purchased with their grants. Approximately 25 new faculty have been added. Enrollment of students in courses involving radiation has been increased by about 300 per academic year.

Fellowships

In addition to assistance to aid educational institutions in developing courses in radiological aspects of the life sciences, the following fellowships are offered:

Industrial medicine. Six physicians began graduate training under the auspices of the Commission's industrial medicine fellowships program in the academic year 1959–60. Four of last year's seven fellows are continuing graduate study. Some 56 physicians have accepted fellowships under this plan since 1950.

Industrial hygiene. Six industrial hygiene fellowships were awarded to qualified candidates for the school year 1959–60. Of the 48 fellows

to date, 45 are active in industrial hygiene, as follows: AEC and contractors, 13; public health departments, 7; private industry, 16; and students or teaching, 9.

Health physics. Fifty-one new appointments were made for the coming academic year 1959–60. Sixteen of last year's 73 fellows are continuing graduate study. Approximately half the 450 trainees to date have gone into work directly associated with radiation protection, while others are through teaching or in research. The University of Puerto Rico, University of California, University of Michigan and Harvard University were added to the four universities already participating in the program in 1959—Vanderbilt University, and the Universities of Kansas, Rochester, and Washington.

Advanced training in health physics. Beginning with the academic year 1959–60, the Commission established a program of training of health physicists to the doctoral level. Five fellows were appointed.

Program for State Employees

Special assistance in radiation control. Six State employees attended the Schools of Public Health at the University of Michigan and at Harvard University under this program, during the 1959–60 year. Four took the first courses offered in the previous year. Because States have had problems in granting a year's leave of absence to some employees, efforts are being made to provide an intensive 3-month course at the Oak Ridge National Laboratory.

Physical Research

Basic and applied research in the atomic sciences, covering physics and mathematics, chemistry, metallurgy and materials, and controlled thermonuclear reactions, continued during 1959 to make useful and important contributions to man's knowledge in nuclear science and technology. In addition to sponsoring research in the large national laboratories and at universities, colleges and other institutions of research, the Commission contributed to the design and construction of complex research machines and other special facilities for research. Contracts for research in the physical sciences at other than the major Commission research centers is given in Appendix 12.

Highlights of activities during 1959 include:

Publication by the White House of the so-called "Piore Report," a proposed Federal program in support of high energy particle accelerator physics prepared by a special panel of scientists chaired by Dr. Emanuel Piore of the President's Science Advisory Committee.

Announcement by the President of the decision to seek Congressional authorization and appropriations for the design and construction by the Commission of a 2-mile long linear electron accelerator at Stanford University. Completion of this project was a recommendation of the Piore Report. The Joint Committee on Atomic Energy held hearings during July and August to obtain testimony from Commission officials and others on the Commission-sponsored legislation that would authorize appropriations for the project.

Completion and operation of a liquid hydrogen bubble chamber of unprecedented size for use in high energy physics research with particle accelerators at the University of California Lawrence Radiation Laboratory.

Announcement of the discovery at the Lawrence Radiation Laboratory of the xi-zero hyperon, a neutral particle of greater mass than the neutron. This completes identification of the currently predicted set of particles of ordinary matter.

Photographing at the Lawrence Radiation Laboratory the first complete reaction containing the neutral anti-lambda hyperon, including the particle initiating the event. The first anti-lambda was observed on photoemulsion plates exposed in a pi meson beam in 1958.

Ground-breaking and initiation of construction of a 12.5 Bev (billion electron volts) proton accelerator, the Zero Gradient Synchrotron (ZGS), at the Argonne National Laboratory.

Completion of repairs and return to operation of the 3 Bev Cosmotron at the Brookhaven National Laboratory.

Completion by the Midwestern Universities Research Association (MURA) of a 35–50 Mev (million electron volts) electron model of the clashing beam type of accelerator.

Initiation of a Commission-wide transplutonium isotope production program, with the long-range objective of producing milligram quantities of very heavy elements.

In controlled thermonuclear research, the photographing for the first time of X-radiation emitted by very hot plasmas, and a showing that advantages may be obtained in research looking toward fusion power by using magnetic confinement coils of sodium at cryogenic temperatures.

High Energy Physics

Progress in High Energy Accelerators

The basic objective of the Commission's program in high energy physics is to further man's knowledge and understanding of the processes that take place in the submicroscopic nuclear world. In their efforts to extend the frontiers of knowledge about the fundamental particles of which the physical world is made, physicists have required methods of producing particles of higher and higher energy. To provide these particles, ever more complex accelerators have been developed and constructed. For a more complete description of high energy accelerator physics, see Appendix 13.

Also, as the frontiers of science have been pushed back, it has been necessary continuously to develop new apparatus and to refine the techniques for further experimentation. Consequently, the Commission's effort in high energy physics will emphasize development and construction of additional and novel type accelerators, toward modifications and improvement of existing machines in order to realize their research potential more fully, toward establishment of higher beam intensities as well as higher energies, and toward development of new experimental devices and techniques and the construction of better ancillary facilities. This pattern of development is expected to continue for the foreseeable future.

The first accelerators in the billion electron volt range were constructed during the early 1950's, and by 1956 the United States had four synchrotrons in operation capable of accelerating electrons or protons to 1 Bev (billion electron volts) or higher, the most powerful being the Bevatron—a 6.2 Bev proton synchrotron at University of California Lawrence Radiation Laboratory at Berkeley. During the latter part of the 1950's, design and construction of additional high energy accelerators progressed, and by 1962, one linear accelerator and four additional synchrotrons are scheduled to be in operation in the Bev range (see table V).

Linear accelerator. Work is under way to extend the 220-foot long Mark III linear electron accelerator at Stanford University to 310 feet to allow operation at about 1.2 Bev. Built and operated for the Office of Naval Research (ONR) under the ONR-AEC joint program of research in nuclear physics, this machine first went into operation at 350 Mev (million electron volts) in December 1952 and at present produces electrons with energies up to 730 Mev.

TABLE V.—ACCELERATORS IN BILLION-VOLT RANGE

	Institution	Maximum Energy (Bev)	Year
	Electron Synchrotrons		
OPERATING:			
	California Institute of Technology	1.4	1956
	Cornell University	1.5	1956
BEING BUILT:			
	Cambridge Electron Accelerator (CEA), Harvard University and Massachusetts Institute of Technology	6.0	1961
	Proton Synchrotrons		
OPERATING:			
	Cosmotron, Brookhaven National Laboratory	3.0	1952
	Bevatron, University of California, Lawrence Radiation Laboratory	6.2	1953
BEING BUILT:			
	Princeton-Pennsylvania Proton Accelerator (PPA)	3.0	1960
	Alternating Gradient Synchrotron (AGS), Brookhaven National Laboratory	25–30	1960
	Zero Gradient Synchrotron (ZGS), Argonne National Laboratory	12.5	1962

72-inch hydrogen bubble chamber. Construction and testing of Lawrence Radiation Laboratory's 72-inch liquid hydrogen bubble chamber was carried to a point of initial success; the first pictures of high-energy particle tracks in the 72-inch chamber were obtained on March 24.

Design and construction of the chamber has taken 5 years and required 65 man years of scientific effort. A variety of entirely new problems had to be solved; for instance, the window through which the chamber is viewed is the largest piece of glass of optical quality ever cast. It had to be gasketed to the metal chamber with a vacuum-tight joint at liquid hydrogen temperature, and the whole had to withstand the mechanical shock of the expansion of the chamber. With the observation of particle tracks in the chamber, it now is clear that this and many other problems of large bubble chamber operation have been solved.[22]

Progress in the Cosmotron repair. The 3.0 Bev Cosmotron at Brookhaven National Laboratory was brought back into test operation after having been under repair for more than a year. Pulsing tests started in February, and the experimental program has been resumed, with a full series of experiments in early 1960. The newly designed shielding has been completed.

Total shutdown time was minimized by the fact that the repair work was carried out concurrently with previously authorized ex-

[22] See pp. 235–237, Twenty-third Semiannual Report to Congress (July–December 1957).

tensive construction activities designed to expand and improve the auxiliary equipment and other experimental facilities and areas centered around the accelerator.[23]

The improvements are designed to permit a major portion of future experiments with high intensity external proton beams (as many as 10^{12} protons per pulse), since past experience has shown that external beams have many advantages over internal beams, and make possible some additional types of experiments.

Brookhaven's Alternating Gradient Synchrotron. Progress on construction of the 25 to 30 Bev Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory continued approximately on schedule with plans for systems testing by early 1960. The AGS is estimated to cost about $31 million.

All 240 magnet sections have been positioned radially around the ring, having undergone the necessary magnetic testing. The main magnet power supply, which required six railroad flatcars to deliver, now is installed and is undergoing tests. Initial pulsing of the synchrotron magnets at one-quarter voltage (1,500 volts) has been conducted, and no undersirable performance characteristics, such as high transient voltages, have been observed.

Progress continued on the linear accelerator (linac) particle injector. All 124 drift tubes have been machined to the final contour, and now are being installed in the linac tank and undergoing precision alignment. The Cockcroft-Walton pre-injector for the linac has been completed, and in its first acceleration a one milliampere, 750 Kev (thousand electron volt), ion beam was obtained. Subsequent system modifications resulted in a beam output of up to four milliamperes.

The 13 (12 operating and 1 spare) radiofrequency power amplifiers for the AGS have been delivered. The ferrite-loaded accelerating cavities have been assembled and positioned around the ring. All vacuum pumps have been received, tested and accepted.[24]

Princeton-Pennsylvania Proton Accelerator (PPA). The Commission is supporting construction of a 3 Bev proton synchrotron at Princeton, N.J., as a joint venture of Princeton University and the University of Pennsylvania.[25] The Princeton-Pennsylvania Proton Accelerator, scheduled for completion by the end of 1960, will be similar to the Cosmotron at Brookhaven National Laboratory, but

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[23] See pp. 132–133, Twenty-fourth Semiannual Report to Congress (January–June 1958) and p. 199, Twenty-fifth Semiannual Report to Congress (July–December 1958).

[24] See pp. 125–130, Twenty-fourth Semiannual Report to Congress (January–June 1958).

[25] See p. 81, Twentieth Semiannual Report to Congress (January–June 1956).

is designed to provide a much higher number of protons per second in its beam, largely because of its higher pulse rate. It is hoped to achieve a total increase in current by a factor of at least 100 as compared with the Cosmotron. The higher intensity beam will make possible experiments on nuclear events that occur too rarely for successful study in the lower intensity machine.

The completely shielded building for the accelerator is finished. Prototypes of the radiofrequency cavities, magnets, and magnet power supply have been operated successfully. The design of all components has proceeded satisfactorily and is virtually complete. All major components are on order and many have been delivered.

Cambridge Electron Accelerator (CEA). A 6 Bev electron synchrotron the Cambridge Electron Accelerator, scheduled for completion in the spring of 1961, is being built with Commission support at Cambridge, Mass., as a joint effort between Massachusetts Institute of Technology and Harvard University.[26]

This accelerator will provide one of the highest energy electron beams in the world. Since energy loss by electrons in circular orbits increases rapidly with energy, CEA is believed to be close to the ultimate that can be economically achieved with circular electron acceleration. The interactions of electrons with nuclear matter and strange particles are weaker than those of protons, but high energy electrons have the advantage that, by using them as probes, pure electromagnetic interactions can be studied at short distances.

The energy available for reactions with 6 Bev electrons is the same as for 9.5 Bev protons. The average beam current in CEA will be considerably higher than that in the Bevatron at Lawrence Radiation Laboratory; hence it is expected that comparatively large numbers of strange particles will be produced despite the weaker interaction of electrons as compared to protons.

Because of the rapid energy loss of energetic electrons, the radiofrequency system must provide very high accelerating voltages. Various cavity designs have been tested and the problems are being solved. The CEA linac injector is under construction.

Argonne's Zero Gradient Synchrotron. Design work on the 12.5 Bev Zero Gradient Synchrotron (ZGS) at Argonne National Laboratory, scheduled for initial operation in 1962, proceeded satisfactorily.[27]

Groundbreaking ceremonies on June 27, 1959, signaled the start of construction. The foundations for the synchrotron ring magnet

[26] See p. 81, Twentieth Semiannual Report to Congress (January–June 1956).
[27] See pp. 130–131, Twenty-fourth Semiannual Report to Congress (January–June 1958).

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and the 50 Mev linear accelerator (linac), that will inject protons into the synchrotron, are scheduled for completion in the spring of 1960. The shop and assembly building and the laboratory and office building are scheduled for completion in the summer of 1960. Contracts for the major components of the injector system have been let; bids for the ring magnet power supply have been received and are being evaluated. Final prototypes of the ring magnet coil and vacuum chamber were nearing completion at the end of the year, and fabrication is expected to start early in 1960. The water-cooling systems for main components are in the design stage, with construction to start in 1960.

New Stanford linear accelerator. Congress has before it for consideration a request for authorization to proceed with design and construction of a new high energy electron accelerator at Stanford University. The machine would be of linear design, approximately 2 miles in length, and in the initial stages would achieve an energy of 10–15 Bev. Design and construction would require about 6 years.

The President, in an address in New York City on May 14, 1959, at the Symposium on Basic Research, sponsored by the National Academy of Sciences, the American Association for the Advancement of Science, and the Alfred P. Sloan Foundation, said, in part:

> ". . . Physicists consider the project, which has been sponsored by Stanford University, to be of vital importance. Moreover, they believe it promises to make valuable contributions to our understanding in a field in which the United States already is strong, and in which we must maintain our progress. Because of the cost, such a project must become a Federal responsibility. This proposed national facility, which will be by far the largest of its kind ever built—a machine 2 miles long—has the endorsement of the interested Government agencies—including the Treasury. . . ."

Detailed study of the accelerator was started by Stanford early in 1956, and initial proposals were submitted to the Government in 1957. Construction of the machine was recommended by a Special Panel on High Energy Accelerators appointed by the President's Science Advisory Committee, and the Commission's General Advisory Committee.

The average current delivered to the target would be approximately 30 microamperes. The accelerator will be powered by 240 klystron tubes operating at a frequency of 2,856 megacycles per second. The accelerating tube is to be housed in a horizontal 10-foot wide tunnel which will be deep enough underground to provide the necessary shielding. A parallel tunnel, 24 feet in width, would contain the radiofrequency equipment and wiring. The two tunnels

would be separated by 35 feet of earth so that personnel can service the equipment during accelerator operation.

The proposed accelerator would not require development of new basic components. The present Mark III linear machine at Stanford has been successfully operated for several years with energies as high as 730 Mev. To achieve a higher energy, a longer machine of the type already in operation is required. Previous performance indicates that 24-hour operation should be possible. It is planned to divide the 2-mile accelerator into 40 250-foot sections, which can be aligned and tuned individually during startup operations. Several sections can be inoperative (by klystron failure, for example) without affecting operations of the accelerator as a whole.

Initial operation of the klystrons is planned at a level of 6 megawatts, which would give a beam of 10 Bev electrons. With present day techniques, klystron power can be increased to give a beam of 15 Bev. The tunnels, waveguides, accelerator tube, and power facilities are being planned so that at a later date the beam energy can be increased further to 45 Bev, if developments in high energy physics then make a higher energy electron beam desirable.

The proposed linear electron accelerator would provide at 10 Bev the highest energy electron beam in the world. Its average current of 30 microamperes is approximately 50 times greater in intensity than can be attained with a circular electron machine.

Midwestern Universities Research Association (MURA). In an attempt to arrive at new types of accelerators, hopefully encompassing higher energies and intensities, the Midwestern Universities Research Association (MURA), a cooperative organization for research in high energy physics with headquarters in Madison, Wis. and with a membership of 15 midwestern universities,[28] has been working for several years on design and development of various devices for high energy acceleration of charged particles.

MURA's solution to the problem of obtaining high intensity ion currents is based on the so-called Fixed Field Alternating Gradient Principle (FFAG). An accelerator embodying this principle differs from the conventional high energy accelerator in that a magnetic field constant in time is used to guide the accelerated particles in their circular paths. The magnet pole pieces would be so shaped that the field strength would increase rapidly from the inner to the outer edge of the doughnut-shaped chamber. Because the field is steady,

[28] The Universities of Chicago, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Wisconsin; Iowa State College: Michigan State, Northwestern, Notre Dame, Ohio State, Purdue and Washington (St. Louis, Mo.) Universities.

particles can be injected continuously, or in rapid successive pulses, instead of at intervals as is necessary with the pulsed magnetic field used in a conventional synchrotron field. Alternating gradient focusing, the application of a succession of alternate focusing and defocusing magnetic fields to a charged particle rotating in an orbit, would stabilize the particle orbits, and prevent them from flying out of the machine either vertically or radially.

This focusing is being studied both theoretically and through the use of small electron models in two different geometries: Radial Sector, in which the magnet sectors are pie-shaped, and Spiral Ridge, in which the magnetic sectors spiral out from the inside.

The Spiral Ridge geometry is essentially a MURA development and several low energy accelerators are currently being built at various sites in the country, using this approach to obtain high intensity beams.

In their efforts to extend the parameters of high energy accelerators, nuclear physicists for several years have been studying the possibilities of having two high energy beams intersect and collide. In this way, the energy available for reactions can be very substantially increased. For example, the energy available for the creation of matter in a head-on collision between two 15 Bev protons would be equivalent to that of a 540 Bev proton striking a stationary proton as in a conventional accelerator.

The difficulty of realizing this effect lies in the fact that high energy accelerators, such as synchrotrons, operate in pulses, and the particle currents are very small. Therefore, collisions among the particles in two such intersecting beams would be rare. With two high intensity particle beams circulating in opposite directions, from two FFAG accelerators, however, the number of very high energy collisions could be large enough to lead to significant results.

It has been determined that it is not necessary to have two separate accelerators; under certain conditions two beams moving in opposite directions can be maintained in a single machine. A new model two-way Radial Sector accelerator was completed at MURA late in 1959 which will be able to accelerate currents of electrons of the order of 50 amperes to an energy of 50 Mev, and in which it will be possible to accelerate simultaneously beams of electrons traveling in opposite directions. This model will provide design information for a full-scale proton accelerator. It has been estimated that a 15 Bev "clashing beam" proton machine together with associated laboratory and service facilities would cost over $200 million.

Bevatron Contributions

The *72-inch liquid hydrogen bubble chamber* has been used to study the interactions of high energy antiprotons (momentum=1.65 Bev/c) with the hydrogen nuclei (protons) in the bubble chamber. One of the problems that had to be solved before this experiment could be performed was how to separate the relatively scarce number of antiprotons from the very copious number of lighter particles in the beam passing into the bubble chamber. (There are about 20,000 light particles for every antiproton in such a beam.) A system of magnets and electrostatic separators has been used to reduce the number of light particles per antiproton from 20,000 to 3 without seriously affecting the transmission of antiprotons. With this system it is possible to shoot about 1 antiproton for every second Bevatron pulse into the bubble chamber. Approximately one-half of these antiprotons interact with the hydrogen nuclei of the bubble chamber. To date more than 20,000 such interactions have been observed. Among these interactions more than 10 cases have been observed of the creation of a new type of antiparticle, the antilambda hyperon which had previously been observed only once.

The separation scheme described above to remove light particles from a beam of antiprotons actually was first developed and used to remove light particles (pi mesons) from a beam of negative K mesons in an experiment in which the K mesons were shot into a 15-inch liquid hydrogen bubble chamber. The beam separation techniques developed during the past year constitute a great advance in this field and have made possible several experiments heretofore considered "impossible" or at least very difficult. The object of this particular experiment was to look for the neutral so-called *xi-zero hyperon*—an elementary particle which had been predicted on theoretical grounds but never observed experimentally. Seventy thousand pictures were taken and analyzed. One unmistakable example of a xi-zero hyperon was observed. This one event was sufficient to confirm the theoretical predictions of the existence of this particle.

The *15-inch liquid hydrogen bubble chamber* also was used for further studies of the associated production of the so-called "strange" particles (K mesons and hyperons) as well as the interaction of these particles with hydrogen and deuterium. Much information about these processes has been obtained during the past year but undoubtedly much more will be needed before these strange particles become less "strange" and more susceptible to theoretical interpretation. The 15-inch bubble chamber can also be filled with liquid deuterium.

The *30-inch liquid propane bubble chamber* also was exposed to

both the separated negative K and the antiproton beams. The experiment involving negative K interactions in propane was designed to measure precisely the mass of the negative xi hyperon (the negatively charged counterpart of the neutral xi-zero hyperon), to study the interaction of the more common lambda-zero hyperons with free protons, and to observe the decay characteristics of lambda-zero hyperons. The antiproton exposure was designed to study further the antiproton-nucleon annihilation process in order to answer questions about the number and kind of particles produced in the annihilation process, and to determine if certain types of particles have directional correlations when emitted together in an annihiliation process.

Another bubble chamber, the *21-liter liquid xenon chamber*, constructed at the University of Michigan also is being used for experiments at the Bevatron. The distinguishing characteristic of this bubble chamber is that it is a very efficient detector for certain neutral radiations such as gamma rays as well as being a good detector for the usual charged particles. It thus is possible to study the neutral decay modes of the strange particles directly, whereas such experiments are extremely difficult, tedious, and sometimes impossible in bubble chambers filled with hydrogen or propane.

Several *counter experiments* have been performed to study the interaction and annihilation of antiprotons with protons and deuterons. These experiments generally complement, rather than overlap, the corresponding bubble chamber experiments. Results show that antiproton-nucleon interactions at all energies measured so far (0 to 2 Bev) have a considerably larger cross section than the corresponding nucleon-nucleon processes.

184-Inch Synchrocyclotron Contributions

Because of the heavy demand for experimental time on the 184-inch Cyclotron at the Lawrence Radiation Laboratory, this accelerator was placed on 3-shift, 24-hour-day operation early in 1959. The experimental physics program at the Cyclotron was concerned mainly with the study of the interactions and decays of pi and mu mesons. An intense beam of positive pions or pi mesons, has been formed at the 184-inch Cyclotron in order to perform experiments relating to the scattering of pi mesons from protons. The analysis of these experiments promises to provide detailed information on this fundamental process.

An experiment also has been performed to study the production of an additional pi meson by the collision of a pi meson with a proton.

The results of this experiment indicate that a much greater number of pi mesons are created than had been expected on the basis of prior theoretical predictions. New theoretical ideas which include effects of interactions between the pi mesons are in reasonable agreement with experimental results.

Atmospheric Neutron Spectrum

An experiment to study the atmospheric neutron spectrum and its relation to the Van Allen radiation belts of the upper atmosphere recently has been completed at the Lawrence Radiation Laboratory through the cooperation of the U.S. Air Force. Techniques originally developed for surveying the neutron fields produced by the Bevatron were utilized to determine the flux and spectrum of neutrons leaking outward from the earth's atmosphere and decaying in space. It seems highly probable that a large fraction of the charged particles in the inner Van Allen radiation belt arise from the capture of the electrons and protons emitted when these neutrons decay.

California Institute of Technology Pi-Meson Results

Experiments performed with the 1.4 Bev electron Synchrotron at the California Institute of Technology have added to knowledge of the pion-nucleon system of particles. It has been found that there are two further peaks in the photoproduction curve at 700 Mev and 1 Bev in addition to the known resonance at 300 Mev. This discovery has occasioned much theoretical interest.

Other Physics Research

Neutron Cross Sections

In predicting the interaction of neutrons with nuclei such as the probability of neutron capture, for example, the starting point is a phenomenological model of the nucleus based upon, and fitted to, the information available from the measurements of neutron cross sections at quite low energies (energies in the range of, and somewhat above, that corresponding to thermal agitation of atoms). The properties of the resonance levels observed in the cross sections at these low energies, treated statistically, allow prediction for the capture cross section as a function of neutron energy, and to extend this prediction into the region of energy approximately 1 million times higher than that cor-

responding to thermal motion. Comparing these extrapolated predictions with measurements of the capture cross section in this higher energy range leads to correcting the nuclear model to represent the observed facts. Such a method of procedure allows, with reasonable confidence, estimates of the behavior of nuclei which are beyond the realm of experimental investigation; e.g., relatively short-lived fission product nuclei which occur in high flux reactors.

In order to investigate the structure of heavy nuclei in greater detail and with greater accuracy in low energy (thermal) range, a neutron spectrometer, capable of making neutron cross section measurements from thermal energy to 100,000 times thermal energy, has been installed at the high flux Oak Ridge Research Reactor. The resonances observed in total neutron cross section measurements on several radioactive fission product nuclides, such as the 2.7-year promethium 147 and the 100-year samarium 151, and the transuranic nuclides neptunium 237 and americium 241, have been studied in detail. Recently, samples of enriched odd-odd isotopes (those having an odd number of protons, and an odd number of neutrons in the nucleus), such as lutetium 176, have been produced at the Oak Ridge National Laboratory. Until now, no neutron cross section resonance data were available on odd-odd heavy nuclides. Also, the lutetium 176 nuclide has the highest spin and the largest distortion from spherical symmetry of any known nuclide. The properties of many resonances in this nuclide have been measured and the spacings and the strengths of the resonances are useful in furthering knowledge of the structure of heavy nuclei.

Experimental observations of the neutron capture process have been relatively meager in the past because of the great difficulty of measuring small cross sections in the presence of much larger competing processes. During the past year at the Oak Ridge National Laboratory, however, three different approaches to this problem have proved fruitful. The first approach consists of a quantitative measurement of the radioactivity induced by the calibrated number of neutrons. While restricted to nuclides which become radioactive with a convenient half-life, this technique has the advantage of high sensitivity as well as an automatic separation of isotopic cross sections as a result of the different half lives. The accuracy is limited by uncertainties in the radioactivity measurements as well as the absolute neutron intensity calibration. For reasons of stability and homogeneity, photoneutron sources are used in this type of measurement.

The second approach involves the use of samples made in the form of spherical shells. The transmission of neutrons through the shell is related to the absorption cross section. This technique enables meas-

uring the capture cross sections to an accuracy of a few percent, since no absolute measurements are required. Again, however, the use of a photoneutron source for stability reasons is essential, so cross sections are measured only at a specific neutron energy.

The third technique utilized direct detection of the gamma rays emitted as the neutron is captured and the cross sections, as a function of neutron energy, are measured. This technique is necessarily much more elaborate than the other two described. Oak Ridge's pulsed electrostatic accelerator produces neutron bursts of extremely short duration (about 5 thousandths of a microsecond). The neutrons pass through a central hole in a large liquid scintillator tank, striking the sample under study at the middle of the tank. Prompt gamma rays from neutron capture are detected in the scintillator tank and the energies of the neutrons are measured by their time-of-flight from their origin at the accelerator target to the sample position. Capture cross sections as a function of neutron energy now have been measured by this technique for a number of nuclides in the energy range of 20 to 170 Kev, i.e., 800,000 to 6,800,000 times thermal energy.

Comparison of the results of these three independent measurements of capture cross sections, with the predictions based on the accumulated data from time-of-flight experiments at thermal energies and above, is making it possible to improve the nuclear models employed to explain the data. This increases confidence in foretelling the behavior of nuclei which are included in the structure, or produced by the fission process in high flux nuclear reactors.

Asymmetry in the Beta-decay of Polarized Neutrons

The recent discovery [29] that parity is not conserved in weak radioactive interactions has stimulated interest in the beta-decay interaction. Beta decay is fundamentally a process in which a neutron in the nucleus of an atom is transmuted into a proton by emission of an electron (beta-particle) and a neutrino.

In an experiment performed at the Argonne National Laboratory, free neutrons from a reactor were polarized, that is, with the spins oriented in a given direction, by reflection from a magnetized cobalt mirror. Some of these decayed in flight as they traversed a vacuum chamber. Although no attempt was made to detect the neutrinos, their directions of emission could be inferred from the measured momenta of the resulting electron and proton. The electrons seemed to have a very slight tendency to be emitted opposite to the direction

[29] See p. 231, Twenty-third Semiannual Report to Congress (July–December 1957).

of spin; the neutrinos showed a marked preference for emission in the direction of spin.

These measurements on the asymmetry of neutron decay provide an important test of a general theory of weak interactions. An experiment on the decay of helium 6, performed at Argonne by a group from the University of Illinois and Argonne, gives results in agreement with this theory.

An additional experiment on the asymmetries of neutron decay has shown that, in contrast to the inapplicability of the parity concept to the process of beta decay, the concept of invariance under time reversal is valid within the accuracy of the experiments.

A precision helium 6 recoil experiment in progress at Oak Ridge National Laboratory also shows that the beta decay interaction is predominantly axial-vector, in agreement with the parity experiments. A second experiment involves the determination of the longitudinal polarization of the betas. Lee and Yang's two-component neutrino theory predicts this to be equal to the velocity of the beta ray divided by the velocity of light, at least for allowed transitions. Experiments, accurate to better than 2 percent, verify this hypothesis.

Nuclear Reaction Studies

Nuclear reactions have been produced by bombarding target elements in a cyclotron since the early thirties but the mechanisms of the reactions still are not clear.

A common reaction, for example, is one in which a proton strikes the target nucleus and a deuteron is produced. It is possible to imagine several ways in which the proton could combine with a neutron to produce the deuteron. The incoming proton could, for example, attach itself to a neutron in the nucleus and pull it out of the nucleus. Another possibility is that the proton enters the target nucleus, agitates all the nucleons, and that out of the chaos a neutron and proton, bound together, emerge. Other possible models between these extremes can be conceived. Ordinarily, it is difficult to determine which, if any, of these models gives a valid description of the nuclear reaction.

Studies with 22 Mev protons from the Oak Ridge National Laboratory 86-inch Cyclotron show that only certain energy groups of deuterons appear when various targets are bombarded by protons. The energies of these groups indicate that pickup of a neutron in the nucleus by the incoming proton is a good description of the re-

action and that little, if any, agitation of the target nucleus takes place. Similar work in which tritons have been observed as reaction products shows that the proton can also pick up two neutrons without disturbing the rest of the nucleus.

Scattering of Slow Neutrons

The scattering of very slow, or "cold," neutrons is a useful technique for the study of the motions of atoms in solids and liquids. In this method, as developed at Brookhaven National Laboratory, a beam of approximately 0.005 electron volt neutrons, produced by beryllium filtration, is directed against a thin sample. Measurement of the changes in energy at scattering gives directly the desired information concerning the atomic motions in the sample. As the energy changes are usually large compared with the incident energy, they can be measured accurately. In the case of an incoherent scatterer, such as hydrogen, a further advantage of the cold neutron technique is obtained: essentially all motions of the atoms can be measured because all momentum gains are possible. The cold neutron method has been applied to water in some present experiments because of the intrinsic interest of the atomic motions and because the inelastic scattering of neutrons in water has an important bearing on its function as a reactor moderator.

In order to clarify further the present results, additional measurements have been made at higher temperatures and for vapor and ice as well as for heavy water. As far as the application to moderation of neutrons in reactors is concerned, the small energy changes observed are of little significance relative to the extremely prominent interchange of energy with the hindered rotation. The results also show that the motions in water are not represented well by a gas consisting of points of mass 18, an approximation often used in reactor calculations.

A second method for studying the neutron interaction with atomic energy states and the properties of moderators has been developed at National Reactor Testing Station. This method utilizes a phased double rotor neutron velocity selector and allows studies to be made for many different incident neutron energies. Direct measurements of reactor moderator properties can be made. Scattering measurements from steam, methane, beryllium, and liquid sodium-potassium eutectic, are underway. These give information directly applicable to reactor calculatons and demonstrate the versatility of the velocity selector.

Determination of Nuclear Constants

In experiments at the Argonne National Laboratory the relative values of the capture cross section of uranium 238 for monoenergetic neutrons in the range 0.36 to 1.50 Mev have been determined. It has been shown that there is a small resonance peak in the region around 1 Mev. These determinations are of interest to designers of fast reactors because an appreciable fraction of the neutron captures, and thus the conversion of uranium 238 into Plutonium 239, occurs at these energies.

Age Determination of Meteorites

With the use of a mass spectroscope, samples of meteorites have been examined to determine their origin and the length of time they were exposed to cosmic rays after being fragmented from the parent asteroidal body.

An iron meteorite, discovered in a Colorado wheat field in 1927, was suspected of being spurious. A sample was supplied to the Brookhaven National Laboratory by the Smithsonian Astrophysical Laboratory of Harvard University. Mass spectroscopic analysis showed the meteoritic nature of the sample.

In experiments on seven other iron meteorites, cosmic ray exposure times were determined from measurements of the cosmic ray-induced chlorine 36 activity, and the accumulated argon 36 decay product.

A study using the Cosmotron as a source of high energy particles should provide information on such questions as cosmic radiation in space, the sizes of meteorites before entering the earth's atmosphere, and the length of time the meteorites have been in space.

Neutron activation analysis techniques have been used, which indicates that stony meteorites have a maximum age of 5 billion years, and iron meteorites range from 5.3 billion to 13 billion years.

Theoretical Physics

In the elementary particle field, a notable development has been the rapid increase in the range of applicability of what is called "dispersion theory." This development makes use only of general theoretical concepts of quantum mechanics together with relativity theory, and provides relations among various experimentally measured quantities. The approach opens a new attack on problems which for years have been inaccessible to calculation. Of particular

interest are the interactions of pi mesons with each other, and a number of other phenomena related to them (e.g. scattering of mesons by protons and neutrons, and the production of mesons by electromagnetic radiation). At present no disagreements between theory and experiment have been found.

In nuclear structure, important theoretical work has been done in exploring the "excited states" of nuclear matter, which result when nuclei are bombarded by other particles. A variety of modes of nuclear motion have been found, some of which correlate with experimentally known behavior while other patterns have yet to be observed. Especially interesting are some new studies of the details of fission, as, for example, of nuclei that have been struck a glancing blow by a particle from a heavy ion linear accelerator, so as to acquire a very high spin. It is found that these spinning nuclei are much more likely to undergo fission than those subjected to head-on collisions.

Low energy electromagnetic interactions of atoms and ions continued to attract the attention of theorists. In particular, details of atomic scattering and ionization have been worked out in connection with the problems of producing and studying highly ionized gases or plasmas required to produce controlled thermonuclear power. A variety of possible instabilities arising when two such plasmas stream through each other have been studied, because of their bearing on the behavior of future very high current particle accelerators. Several theoretical studies on accelerators that will be needed for future research are in progress.

Stable Isotope Separation

Separation of stable isotopes continued at Oak Ridge National Laboratory. A total of approximately 15 grams of all enriched isotopes was collected. During the period a special run was made to separate calcium 46 for ultimate use as a target in the production of the radioisotope, calcium 47. In addition, in the special separations program, approximately 12 grams of 99.999 percent uranium 233 and 100 grams of 99.9998 percent uranium 238 was collected.

Work on an inhomogeneous field electromagnetic separator was continued to a point where experimental runs were made. With such an instrument, large yields and high resolution are expected to be possible.

Work is under way to renovate equipment and to make modifications so as to place and additional 16 calutrons in service. These calutrons

will speed up collection of highly enriched isotopes for use in cross section measurements for physical research.

Physical Properties of Rare Earth Metals

The magnetic properties of a number of rare earth metals were determined at the Ames Laboratory and some interesting results obtained. It was found that normally ferromagnetic gadolinium becomes antiferromagnetic when about 15 percent by atoms of lanthanum or 40 percent by atoms of yttrium is added to pure gadolinium.

Single crystals of yttrium, dysprosium and erbium were grown, suitable for electrical resistivity measurements.

The cohesive energies of europium, gadolinium, holmiun and erbium were determined, giving useful information for an understanding of the solid state of the rare earth metals.

Chemistry

Heavy Element Production Program

The Commission initiated a long-range heavy element production program during this reporting period. Twelve kilograms of plutonium 239 will be irradiated annually in a reactor and processed further through various Commission facilities over a period of several years. The objective is to produce research quantities of californium 252 and other transplutonium isotopes for chemistry and physics research.

Hanford has fabricated the fuel elements, and initial irradiation of the plutonium is being done at the Savannah River plant.

Advances in Heavy Element Chemistry

A new and simple method for separation of americium and curium has been developed at Los Alamos Scientific Laboratory. It involves ozone oxidation of americium to a soluble bicarbonate species, leaving the curium in an insoluble form.

Pentavalent americium is unstable in a strong acid solution and undergoes rapid self-oxidation and reduction to form hexavalent americium and trivalent americium as end-products.

The reverse of this reaction, never previously observed, has been established using a few milligrams of the scarce, long-lived americium 243 isotope. New details of the forward reaction also have been uncovered using this isotope. These were previously obscured, when

americium 241 was used in solution, by the effects of its intense alpha particle radiation on the water.

Fundamental research on ion-exchange properties of americium, using thiocyanate and anion resin, led to the development of a process now in use for the routine large-scale separation of americium 241.

Chemical separations studies for recovery of neptunium and americium have been carried out through pilot-plant-scale operation at Oak Ridge National Laboratory. Gram quantities of both elements were successfully separated. The neptunium was recovered from the fluorination ash of uranium from reactors recycled to the gaseous diffusion plant for enrichment. The americium was recovered from plutonium metallurgical waste.

A program was initiated several years ago by the Commission's laboratories to subject plutonium to massive neutron irradiation in the Materials Testing Reactor in Idaho, with the aim of producing very heavy elements. As a result it was possible to separate, at the University of California Lawrence Radiation Laboratory, the first weighable amounts of berkelium and californium, and macroscopic properties of these elements were measured for the first time in 1958. The salts of the elements were found to be colorless and strongly paramagnetic. Experimental measurements on 0.06 micrograms of californium and 0.23 micrograms of berkelium gave values of 8.7 and 9.2 Bohr magnetons, respectively, for the magnetic moments of the tripositive ions. These values agree well with those predicted by theory for the eighth and ninth members of the actinide series of elements.

Of general interest is the recent discovery at Lawrence Radiation Laboratory of ternary fission in the spontaneously occurring fission of californium 252. This was found by examination of fission tracks in nuclear emulsions impregnated with the isotope. Two distinct types of ternary fission were observed. Thus far, more than 50 ternary-fission events have been found in which the third fragment is a long-range alpha particle of about 20 Mev energy. Of greater interest is the recent confirmation of seven events of ternary fission in which the three fission fragments are of roughly equal masses. Work now is in progress to determine the energy and angular correlations of the emitted fragments.

Using rather novel recoil techniques, studies were completed on the decay properties of element 102. Decay products from curium bombarded with carbon 12 ions from the heavy ion linear accelerator at Berkeley were caught on a moving aluminum-coated mylar belt. Varying the belt speed past a fixed-grid ionization chamber permits short half-life periods to be detected. Using this method, verification

of an alpha-emitting isotope with a half life of 3 seconds and an alpha energy of 8.3 Mev was obtained. The exitation function for its formation indicates a mass number of 254.

By bombarding the same curium target with carbon 13 ions, an alpha-emitting isotope was formed with a half life of 10 to 20 seconds and an alpha energy of 8.8 Mev; this radioisotope is believed to be 102^{253}.

Fundamental Chemistry of Plutonium

Work on the fundamental chemistry of plutonium at Los Alamos Scientific Laboratory has included for several years a study of the kinetics of the aqueous oxidation-reduction reactions of that element. This work provides further information on the chemical behavior of plutonium and contributes to a general understanding of the factors which influence the rates of chemical reactions.

The rate laws, and the temperature coefficients of the rate constants, have been determined for eight reactions, the most recently studied being the reduction of plutonium of valences VI and IV by Ti(III) and by U(IV). This has allowed the calculation of nine net activation processes and their heats and entropies of activation. When these results were compared with those from nine other reactions involving uranium and neptunium it was found possible to make valuable generalizations in this type of reaction.

Vaporization of Refractory Materials

A knowledge of the chemical stabilities of compounds at high temperatures is of importance in many technological applications. A continuing program at Argonne National Laboratory has been concerned with the kinds and abundances of molecular species evaporating at 1,400 to 2,300° K (0° Kelvin is equivalent to absolute zero, about −273.1° centigrade), as well as with a determination of the associated thermodynamic constants. In an experiment, the sample is heated in a closed crucible by electron bombardment, so that vapor is in equilibrium with the solid or liquid sample. The stream of vapor effusing from a small hole in the crucible has a density proportional to the vapor pressure inside. After being ionized by electron impact, this vapor is analyzed by a mass spectrometer that measures the abundance of each molecular species.

Among the substances studied recently are the carbides of aluminum, gallium, lanthanum, and beryllium; the oxides of lithium, uranium

and beryllium; and the halides of the alkali metals lithium, sodium potassium, rubidium and cesium. The vapor pressures measured at different temperatures were used to compute such constants as the heats of vaporization, heats of dissociation, and some equilibrium constants for dissociation of these vapors. Contrary to indications from infrared spectrometry that the vapors of the alkali halides consisted almost entirely of the monomer MX (where M is the metal and X the halide, in this case the halogens chlorine or bromine), the mass spectrometric technique clearly showed the presence of polymers up to the trimer $(MX)_3$ and, in some cases, the tetramer $(MX)_4$. In a number of cases, the dimer was the most abundant molecule in the vapor; the absence of its infrared spectrum apparently resulted from a non-equilibrium condition in the source. The vapor of beryllium oxide in a tungsten crucible showed an even more suprising array of polymers. In addition to polymers up to the hexamer (the trimer and tetramer being the most abundant polymeric species), there were complex molecules of the form WO_x $(BeO)_y$, when x equals 2 or 3 and y equals 1, 2, or 3.

This difference from the molecular structure of oxides of all other alkaline earths probably arises from the directional character of the covalent bonds between beryllium and oxygen atoms.

In addition to their value to physical chemists, these data are of interests to astrophysicists who find vapors of these types in the outer atmospheres of stars, and to engineers who use these refractory materials in such high-temperature applications as rocket engines.

Fission Gas Disposal

A radioactive tracer technique, employing pulses of krypton 85, has been utilized at Oak Ridge National Laboratory for studying the adsorption and holdup of fission gases on various types of activated charcoal and other adsorption agents under conditions of varying gas flow, temperature, bed diameter, and other experimental parameters. A mathematical relationship was developed between the adsorption isotherm characteristics of a gas and its behavior in a dynamic adsorption system. The results have been found to have wide applicability to a number of situations in which fission gases may be released deliberately or accidentally.

In-Line Gamma Monitor

An instrument for continuously monitoring the gamma activity of flowing streams was developed and successfully demonstrated at Oak

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Ridge. With it, instantaneous process control is possible, and fewer high-cost radiochemical analyses are required than with former measuring methods. An important part of the instrument is the highly polished fluorothene sample cell, which does not accumulate significant amounts of radioactive materials on its surface.

Steam Pulser

A nonmechanical, leaktight device was developed at Oak Ridge for pulsing solvent extraction columns or for pumping radioactive solutions. A close-coupled water boiler and condenser are connected to the bottom of the column, and pulsing results from the movement of the steam-water interface between the boiler and the condenser. The pulse characteristics may be controlled by adjusting the pressure drop between the boiler and condenser.

Solar Energy Converters

During the past year, scientists at the Lawrence Radiation Laboratory constructed the first "solar battery" made entirely of organic chemicals. While this battery is of very low efficiency, it appears to resemble the extremely efficient energy-conversion apparatus of green photosynthetic plants much more than it resembles inorganic batteries. The study of this battery as a model system is expected not only to provide a much better understanding of the conversion of light energy to chemical energy in plants, but also to aid in the design of more efficient solar-energy converters. An efficient and economical battery for converting solar energy to electrical energy would have enormous implications, not merely in the specialized applications in communications where it is used today, but as an economical source of power in areas with high annual sunshine.

Thorium Oxide Studies

Methods of preparing thorium oxide of controlled particle size (± 30 percent in the range of 0.5 to 3 microns) through oxalate precipitation and thermal decomposition were developed at Oak Ridge National Laboratory for routine use in large scale production. Methods of preparing thorium-uranium oxides of controlled particle size by adaptations of the oxalate technique also were developed. Extensive thoria surface chemistry studies included gas phase adsorption of carbon dioxide and organic acids, liquid phase adsorption of sulfate, silicate and phosphate ions, infrared investigation of surface hydroxyl

groups and conductivity measurements in carbon dioxide atmospheres.

The slurries of these oxides have acceptable characteristics for use in homogeneous reactor blankets and possibly as a fuel. This work may have important applications in the preparation of uranium oxide fuel elements.

Thorium-Amex Process

The Thorium-Amex process was developed at Oak Ridge for solvent extraction recovery of thorium, uranium, and rare earths from monazite (30 parts of thorium to 1 part of uranium and 180 parts of rare earths) and Blind River ores (1 part of thorium to 3 parts of uranium). The uranium is extracted with a tertiary amine, triiso-octylamine, and the thorium and rare earths by a primary amine. Recoveries are high, separation of the elements is good, and operating costs are lower than those of other methods now in use.

Fluorox Process

Engineering studies at Oak Ridge on the Fluorox process were terminated. In this process uranium tetrafluoride (UF_4) is converted at 810° C. to uranium hexafluoride (UF_6)—the process gas used for separation of uranium isotopes by gaseous diffusion—by reaction with oxygen or air instead of with elemental fluorine. With metal grade UF_4 and either air or oxygen, the yield of UF_6 was 90 percent of theoretical values. The UO_2F_2 produced simultaneously may be reconverted to UF_4 by reaction with hydrogen and hydrogen fluoride. The nickel alloy used proved to be a satisfactory material for construction of the fluidized bed reactor when metal-grade UF_4 was used as feed. However, with crude UF_4 from an ore concentrate, the alloy was corroded at an excessively high rate.

Thermal Conductivity of Hydrogen Gas at High Temperatures

The thermal conductivity of hydrogen gas in the temperature range 1,200° K to 2,100° K has been measured at Los Alamos Scientific Laboratory, thereby extending data to a temperature region three times higher than any previous measurement. The experimental values are reasonably consistent with each other, having a standard deviation of 2.5 percent.

The curve depicting these results can be extrapolated smoothly to low temperature data.

Volatile Fluorides

A number of interesting results have been obtained in a program of fundamental research at the Argonne National Laboratory with inorganic hexafluorides and the fluorides of bromine and chlorine. Of related interest are studies of the use of the halogen compounds, bromine trifluoride (BrF_3) and chlorine trifluoride (ClF_3), for the volatilization of uranium as the hexafluoride in processes for the decontamination and recovery of uranium from irradiated reactor fuel elements.

Conditions have been discovered under which plutonium hexafluoride (PuF_6) vapor can be handled without decomposition despite its thermodynamic instability and the high specific alpha-radiation activity of plutonium. Since PuF_6 is the only known volatile compound of plutonium, knowledge of conditions under which it can be handled without appreciable decomposition is of importance to its possible use as a process gas for separation of plutonium isotopes.

A novel method developed for preparation of highly unstable hexafluorides has resulted in discovery of platinum hexafluoride, the only known hexavalent compound of platinum. Osmium octafluoride, OsF_8, for more than 40 years the only compound thought to have eight atoms attached to a single central atom, now has been shown to be, in fact, osmium hexafluoride OsF_6, and it appears that an octafluoride never has been prepared.

Spectrum measurements with the vapor of uranium hexafluoride have removed a final uncertainty concerning its structure. When these measurements are combined with other data, a more accurate determination of its gas density can be derived that should permit an accurate evaluation of the holdup of UF_6 in various processes. Electron diffraction measurements made in collaboration with scientists at the California Institute of Technology have shown that the sizes of the molecules decrease in the order UF_6, NpF_6 (neptunium hexaflouride), and PuF_6, while the platinum group of hexafluorides show a slight increase in size in advancing through the series.

Methods of preparation of gram quantities of NpF_6 have been developed, and many physical, magnetic and optical properties of this compound have been determined. The electronic spectra of the vapors of platinum group hexafluorides, and of corresponding actinide group, have been studied and an explanation obtained. Studies of the spectra of BrF_3 and ClF_3 have confirmed the fact that these molecules have the unusual structure of a slightly distorted planar "T". Infrared spectroscopy has also been used for analyzing mixtures of the bromine fluorides.

Decontamination of Plutonium-rich Fuels

Research and development work on processes for decontamination of plutonium-rich fuels is in progress at Los Alamos Scientific Laboratory. Processes being studied include oxidative and halide slagging, liquidation and filtration, metal extraction and recrystallization, fused salt conversion and electro-refining.

Although no demonstrated processes exist for recycling plutonium-rich fuels at the present time, significant advances in basic investigations indicate potential methods. Aqueous anion exchange research methods under study at Hanford appear especially attractive. An aqueous extraction process using a secondary amine has been developed for decontaminating plutonium from fission product elements used in this work. Hot cell facilities are being constructed to investigate these processes on irradiated plutonium.

Alpha Particles as a Source of Ionization in Mass Spectrometry

The distribution of ions observed in a mass spectrometer upon introduction of a particular molecule—for example, a hydrocarbon has long been used to identify the molecule, and at times, for quantitative analysis. This "cracking pattern" also has been used to predict something about the ions to be expected in the radiation chemistry of the molecule. Since the ions in a conventional mass spectrometer are produced by electron bombardment, there has always been considerable question as to the validity of carrying over the pattern thus obtained (usually with 75 electron volt electrons) to the situation in radiation chemistry, where the ionizing particles may be electrons of much higher energy, or, as an extreme difference, alpha particles.

A significant advance has recently been made at Oak Ridge National Laboratory by using a polonium alpha-particle source instead of the electron gun for ionization in a mass spectrometer. The cracking pattern obtained with several hydrocarbons, including ethane, ethylene, and butane, are much different from those from electron bombardment. Specifically, the patterns are simpler, a much larger fraction of the ions being the "parent ion," the ion formed by simple ionization of the parent molecule without further reaction. Part of this is probably intrinsic to the mode of ionization, but part of it may arise from the absence of high-temperature surfaces in contact with the gases. It has been determined that even if the electron-emitting filament is isolated (by slits or small holes) from the ionization region, the power dissipated in the filament heats the walls of the ionization region to a few hundred degrees centigrade.

This development is important not only to radiation chemistry, presenting a more correct picture of the ions actually present in a radiation-chemical reaction, but also potentially to analytical mass spectrometry because of the simpler patterns observed.

Studies on the Behavior of Nuclei

In a continuing program of research accumulating data on the behavior of nuclei and aiding in testing current theories of nuclear structure, the decay characteristics of a number of radioactive nuclides have been investigated at Brookhaven National Laboratory. Beta and gamma transitions have been determined, new or more accurate measurements of half-lives obtained, and decay schemes developed where possible. The following are the nuclides included in these studies: beryllium 11, calcium 39, barium 129, europium 152, and terbium 156.

Tritium Labeling of Organic Compounds

The labeling of organic compounds and biologically interesting materials by exposure to tritium gas [30] has proved useful, but is limited to laboratories with *facilities for handling* tritium in multicurie amounts.

Increased opportunities for labeling compounds with tritium are promised by a new technique developed at Argonne National Laboratory which utilizes the ionization and excitation produced by an electric discharge in tritium gas. Labeling which approaches that achieved by the other method is accomplished in a matter of minutes and with much smaller amounts of tritium. Products must be rigorously purified since labeling is accompanied by formation of tritiated byproducts. This electric-discharge technique must be investigated more fully, but it appears to be of general use.

Determination of Trace Oxygen in Metal

A routine analytical method based on activation by thermal neutrons and radiochemical separation has been developed at Oak Ridge National Laboratory to determine the amount of trace oxygen in lithium metal. A sample is irradiated in a reactor with the production of a radionuclide (in this case fluorine 18) from the stable oxygen atoms contained in the sample.

[30] See p. 108, Twenty-second Semiannual Report to Congress (January–June 1957).

The process is this: lithium 6 bombarded by a neutron yields an alpha particle and tritium, and the recoil tritium reacts with the oxygen; oxygen 16 bombarded by tritium yields a neutron plus fluorine 18. The radioactive fluorine 18 is separated from other induced radionuclides by radiochemical separation, then a known amount of inactive fluorine is added as an isotopic carrier to a solution of the irradiated sample. The inactive fluorine and the fluorine 18 are distilled from the mixture and precipitated as lead chlorofluoride. The gamma activity of the fluorine 18 is measured with a scintillation counter.

The concentration of oxygen in the unknown sample then is measured by comparing the fluorine 18 found in it with the fluorine 18 found in a comparison sample irradiated and radiochemically processed in the same manner. Concentrations as small as 20 micrograms of oxygen per gram of lithium have been determined by this method.

Metallurgy and Materials

Rare Earths

Continued research at Ames Laboratory on rare earth separation processes has resulted in use of more effective complexing agents for ion exchange separation of rare earths from mixtures. In such ion exchange, a mixture of rare earth salts is passed across special resins, which pick up the rare earth ions. A complexing agent, which is allowed to trickle across the resin, will selectively separate a rare earth and carry it along. Processes have been developed in which the complexing agent can be recovered and recycled with a substantial reduction in the chemical cost of ion separation. Two new complexing agents have been found to be very effective in isolating pure yttrium.

An improvement was made in the ion exchange process by which lutetium can be retained in the exchange column by the addition of hydrogen ions, making possible the recovery of 95 percent of the lutetium present.

The laboratory has continued to prepare pure rare earths. Distribution of pure rare earth specimens has facilitated basic research on these elements throughout the world.

The Ames Laboratory scaled up the process for producing high purity yttrium oxide and yttrium metal, and was the first to produce yttrium metal in ton quantities. The processes developed by the Ames Laboratory have been made available to the public and private

industry may now provide these metals and compounds for commercial operation.

Physical properties of rare earths were determined at Ames. The melting point of lutetium was found to be approximately 1,700° C., of gadolinium, 1,312° C., and scandium, 1,538° C. These metals are of interest in developing materials that will withstand high temperatures. A new series of rare earth carbides was found.

Advances in the chemistry of rare earths were made at Los Alamos Scientific Laboratory with formation of compounds of hitherto unknown valence states for thulium, neodymium and dysprosium. Divalent thulium was established with the preparation of thulium diiodide. Complex alkali fluorides of tetravalent praseodymium and terbium, were characterized, and qualitative evidence was obtained for the formation of analogous compounds of tetravalent neodymium and dysprosium.

Studies on Irradiated Graphite

Graphite recently has been used more extensively as a moderator in gas-cooled reactors, increasing the importance of understanding the effects of radiation on the chemical properties of graphite. It has been known for some time that graphite irradiated with neutrons reacts more rapidly with air or oxygen than unirradiated graphite. The rate of reaction with carbon dioxide is, on the other hand, not altered very appreciably by prior irradiation. Correlation of the chemical effects with the lattice defects produced by neutron bombardment has indicated that of the various types of defects produced, the lattice vacancies are most probably responsible for the observed effects on the reaction with oxygen. This conclusion is based primarily on studies of single-crystal surfaces by means of microscopy and particularly of electron microscopy. These studies show that irradiation produces a multitude of nuclei for attack by oxygen in the surface layers of graphite, whereas there are relatively few such nuclei in unirradiated graphite.

Irradiation produces other lattice defects in addition to vacancies, such as displaced atoms and dislocations. In order to isolate the effects of vacancies to the exclusion of these other defects, vacancies were introduced into unirradiated graphite by heating to very high temperatures and quenching. Experiments on such quenched single crystals of graphite had earlier failed to reveal changes in electrical properties which could be attributed to vacancies. The studies of surfaces after reaction with oxygen, and even with carbon dioxide, reveal definite differences betwen quenched and untreated crystals

which are attributed to vacancies. This confirms the assignment of lattice vacancies as the responsible defect causing pronounced radiation effects on surface reactivity.

Several other graphite reactions have been examined at Argonne National Laboratory by combining kinetic and electron microscope studies. The reaction of air with a graphite moderator below 400° C. is considerably enhanced during reactor operation. This enhancement is very probably due to ozone produced by the ionizing radiation. The reaction of ozone and graphite was therefore studied in some detail. Ozone was found to attack graphite crystals preferentially at the cleavage planes and at twin lines. Edge atoms of graphite burn more slowly because they are protected against ozone attack by adsorbed oxide layers. The effect of prior irradiation on the reaction of graphite and ozone appears to be minor.

Another class of reactions studied in some detail are catalyzed oxidation reactions. Electron microscope studies have shown that prior neutron irradiation exerts a very pronounced effect on the catalysis by metallic impurities of the interaction of graphite and oxygen. Although these reactions have less practical importance to reactor operations than the other reactions discussed, they add considerably to an understanding of the radiation damage and of the mechanism of catalysis as well. In unirradiated crystals relatively free of vacancies, the catalyst particle increases the reactivity of carbon atoms only in selected crystallographic directions parallel to the layer planes causing "channel" formation. "Quenched-in" vacancies permit the catalyst in the presence of oxygen to penetrate perpendicular to the carbon layer planes leading to the formation of well-defined pits.

Radiation Effects in Solids

Fundamental investigations of radiation effects in solids are continuing at Oak Ridge National Laboratory. Comparison of the low-temperature magnetic susceptibility of samples of silicon before and after irradiation is yielding quantitative information about the density of magnetically active centers which are produced or removed by irradiation. The degree of correlation between the number of those centers and irradiation-induced electrical traps, as well as changes of introduction rate, then can be interpreted in terms of a proposed model for the centers created by irradiation.

Using optical microscopy, it is not possible to observe the effects of individual neutron collisions with atoms in a solid. All evidence of these events has been indirect, for example, changes in electrical, magnetic, and mechanical properties. Regions of lattice disorder

caused by neutron collisions theoretically should be observable using electron microscope techniques.

Recent observations by this means at Oak Ridge and Hanford reveal what appears to be tracks left by fission fragments produced in thin films of uranium oxide. Groups at both Oak Ridge and Franklin Institute have observed effects that are tentatively assigned to the neutron-lattice interactions.

Mechanical Properties of Metals

Basic research to determine the factors controlling fracture of metals has revealed some facts in connection with the effect of dynamic loads and multiaxial stresses. Conventionally, the strength of materials is determined by application of static, uniaxial loads to a test specimen. The engineer must use these data to solve design problems in which dynamic loads and multiaxial stresses exist.

Recent results from multiaxial-creep tests and stress-reversal experiments at Oak Ridge National Laboratory indicate it is possible to propose analytical models to predict a metal's behavior under complex states from the simple uniaxial case. Creep rate can be described by equations related to the maximum shear stress and the deviatoric stresses. On the other hand, rupture life appears to be controlled by the maximum principal stress. Under certain limiting conditions, it now is possible to predict the life expectancy of specimens subjected to a combination of static and dynamic stresses.

Metal Surface Reactions

The high-temperature usefulness of many structurally important metals and alloys is limited by the extent to which the formation of thin, protective oxide films on these materials can prevent the occurrence of destructive oxidation. A research program was instigated at Oak Ridge National Laboratory in an effort to understand the factors that determine the degree of "protectiveness" of such oxide films.

Niobium and tantalum were selected for study because, in appropriate temperature ranges, they form oxide films that are initially protective, but which become nonprotective as oxidation proceeds. By means of an electron microscopic examination of the oxidized specimens, it was established that the transition from protective to nonprotective oxidation could be correlated with the formation of microscopic, blister-like cracks in the oxide film. An explanation for this phenomenon was developed in terms of an analysis of the stress

state of the films during oxidation. It was concluded that for the oxidation of any metal where oxidation proceeds through an anion diffusion process, stresses are continually generated in the oxide, and there will be a tendency for the oxide film to crack and become nonprotective.

Cryogenic Research

Research at cryogenic (very low) temperatures is of increasing importance to basic studies on materials, and contributes to understanding the properties and fundamental behavior of materials.

The annealing behavior of radiation-induced changes which occur in some materials below 16° K. is being examined in detail at Oak Ridge National Laboratory by means of special equipment installed in the graphite reactor that allows specimens to be irradiated at liquid helium temperatures. Also, a study now is possible of the effects of neutron irradiation upon the properties of superconductors—materials which show almost complete loss of electrical resistance at cryogenic temperature.

Recent experiments at Oak Ridge National Laboratory have shown that some of the defects produced in metals by neutron bombardment are unstable at temperatures as low as 12° K. These experiments, as well as others at University of Illinois and by Atomics International, have revealed much about the nature and behavior of lattice defects. In particular, they have shown that the damage remaining at room temperature in a bombarded sample of pure metal is a residuum after considerable healing (annealing) of the primary damaging process has taken place. Thus, in order to obtain a fundamental understanding of the interaction of radiation and matter, experiments must be carried out at temperatures approaching absolute zero in order to "freeze in" the results of the initial interactions.

In addition to the complication of temperature in studying primary radiation effects, it has often been considered that the damaging radiations also may assist in the healing process and thereby further complicate the study. This recently has been verified at Purdue University in the electron bombardment of negative type germanium. Bombardment at 10° K. with electrons whose energy is insufficient to cause lattice displacements has caused partial annealing similar to effects produced by high energy electrons. The results of the radiation annealing appear to be similar in many respects to those of thermal annealing.

Helium energy states at cryogenic temperatures. An experiment to determine by neutron scattering the energy-momentum relation of

thermal excitations in liquid helium was performed at Los Alamos Scientific Laboratory. The liquid helium target was cooled to near 1° K., and the neutron energy and scattering angle were measured with high accuracy. Detailed calculations on an electronic digital computer of the thermodynamic properties of liquid helium, starting with the curve depicting measured excitation, were in excellent agreement with experimental measurements of these properties.

Helium 3 research. Scientists at Los Alamos Scientific Laboratory have completed studies which show that liquid helium 3 can exhibit a thermal expansion that is positive, negative, or zero depending on temperature and pressure conditions. In the region of negative thermal expansion, the volume decreases with rising temperature. Pressures and temperatures at which the thermal expansion is zero were determined from the vaporization curve and the melting curve.

From measurements of the volume change on melting helium isotopes, the existence of two solid modifications of helium 3 were discovered. The transition curve representing the separation of the two solid forms was found to intersect the melting curve at 3.15° K. Subsequently the two structures were determined by X-ray diffraction. The difference in density between the two forms is less than 1 percent.

Studies of surface-barrier counters. A low temperature study of broad-area germanium surface-barrier counters has been carried out at Oak Ridge on both theoretical and experimental bases. A simple theory gives satisfactory agreement with measurements at 77° K. of the sizes and rise times of pulses from alpha particles. At this temperature, rise times were found to be less than 2×10^{-8} seconds. At liquid-helium temperatures, the rise time was found to be longer, indicating that the electrostatic potential gradient was not confined to a thin barrier region, probably due to the very large electrical resistivity of germanium at such temperatures.

A very significant advance was made recently in developing surface-barrier counters with good resolution at room temperature. Silicon counters exhibit good energy resolution and pulse height-energy linearity if the alpha range does not exceed the barrier depletion region. The energy resolution of a 5 x 5 mm. counter operating at room temperature was 45–50 Kev (0.9 percent) full width at half-height for polonium 210 (5.4 Mev) alpha particles. A 4 x 4 mm. germanium surface-barrier counter operating at dry-ice temperature (198° K.) gave a resolution of 1.2 percent for uranium 233 (4.28 Mev) alpha particles.

High Pressure Metallic States of Nonmetals

Using high static pressures, experiments at Lawrence Radiation Laboratory have effected conversion to the metallic state of an insulator, phosphorus, and a semi-conductor, silver oxide. The metallic state is lost when the pressure is released. At pressures of 2.3 million p.s.i. (pounds a square inch) the electrical conductivity of the two substances is about $\frac{1}{50}$ that of ordinary copper. In the case of phosphorus, the electrical conductivity has been increased a billion fold.

Experimentation on iodine to pressures of 3 million p.s.i. indicate that this element also will become a metal at very high pressures.

Crystal Structures of Intermetallic Compounds

The structures of the intermetallic compounds, plutonium nickel ($PuNi_3$) and cerium nickels ($CeNi_3$ and Ce_2Ni_7), have been determined at the Los Alamos Scientific Laboratory to be new types for binary compounds. They are representative of a possible structural series intermediate between the calcium-zinc structure type, ($CaZn_5$) at one extreme and, at the other extreme, the MX_2 structure type, where one atom of the metal M combines with two atoms of another element X.

The crystal structures of a sufficient number of plutonium intermetallic compounds have been established to permit division of such compounds into two general groups. In one group the volume of the plutonium atom is approximately equal to that of delta-plutonium, and in the other the volume is approximately that of epsilon-plutonium, (delta- and epsilon-plutonium are two of six allotropic forms of solid plutonium). These groupings can be correlated with the relative solubilities of the combining elements in delta- and epsilon-plutonium, i.e., those elements which influence the plutonium atoms to assume the larger delta-phase volume in compounds are more soluble in delta than in epsilon plutonium, and those which cause the plutonium atom to assume the smaller volume are more soluble in epsilon-plutonium.

Controlled Thermonuclear Research

Work in this field has been conducted on a completely unclassified basis since August 30, 1958, when the United States and the United Kingdom jointly announced the declassification of their controlled thermonuclear programs. Free interchange of information through papers and discussions on controlled thermonuclear research at the

United Nations Second International Conference on the Peaceful Uses of Atomic Energy (Sept. 1–13, 1958; Geneva, Switzerland),[31] revealed a high degree of similarity of results among nations working in this field.

The background of thermonuclear research, the basic technical problems, and the principal methods being used in the United States research program to solve them have been reported previously.[32]

Cooling Magnetic Coils for Thermonuclear Machines

One device used for thermonuclear research is the magnetic mirror machine which makes use of the tendency of charged particles moving in a nonuniform magnetic field to be repelled from regions where the magnetic field is strongest. The regions of strongest magnetic field thus act as "mirrors" to repel and confine the plasma.

The advantage in the case of magnetic mirror machines operating on a direct current basis is that a favorable balance of power production by the confined plasma can perhaps be obtained with a much lower plasma density and total quantity of plasma than formerly was thought possible. It is generally believed that, at low plasma densities, instabilities are less likely to occur than at high plasma densities.

Scientists at the Lawrence Radiation Laboratory, and the Bureau of Standards Laboratory at Boulder, Colo., are investigating the use of magnetic coils cooled to cryogenic temperatures (10° to 30° K) for confining plasmas in magnetic mirror machines. The Naval Research Laboratory measures magnetic properties of metals needed for this purpose.

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[31] See pp. 154–161, 285–291, Twenty-fifth Semiannual Report to Congress (July–December 1958). The key research problems are: (*a*) the relative energies which the ionized gas particles need in order for fusion reactions to occur at an appreciable rate are exceedingly high; i.e., the gas must be at an extremely high temperature; (*b*) the ionized gas must be suitably confined, with adequate density, while it is heated to these extreme temperatures.

In every instance reported, the ionized gas, termed a plasma, is confined by magnetic fields. Instabilities in the body of the plasma make confinement difficult; the consequences of these instabilities are, the rapid loss of particles to the walls and cooling of the plasma by various processes.

[32] See pp. 217–275, Twenty-fourth Semiannual Report to Congress (January–June 1958). In brief, harnessing the nuclear fusion reactions for the production of power requires that three goals must be reached successively: *First,* a fusionable material such as heavy hydrogen must be heated to the ignition temperature—the threshold temperature for a self-sustaining reaction. At this point, fusion energy is being released within the fusion fuel at a rate sufficient to offset the loss of energy from the fuel by emission of X-rays. For fusion fuels consisting of heavy hydrogens, this ignition temperature is of the order of 100 million degrees, representing energies of some 10 Kev (kilo electron volts; 1 Kev equals 1,000 ev). *Second,* after ignition temperatures have been achieved, a machine—a fusion reactor—must be designed that will produce an excess of power, more power than is consumed in operating the machine. *Third,* production of power from a fusion reactor must be made economically competitive with electricity produced by other means.

Cooling magnetic coils to these very low temperatures greatly lowers the electrical resistance of the metal conductor in the coil as compared with its value at room temperature. Therefore, the electrical power dissipated in the coils is greatly reduced. However, the coil must operate in the strong magnetic field which it produces and the increase in resistance resulting from this magnetic field presents an important problem. Early studies in the controlled thermonuclear program at Princeton dealt with the possible use of copper coils. However, copper does not provide great power savings at cryogenic temperatures. In 1956, investigators at Los Alamos Scientific Laboratory suggested that sodium or aluminum coils would have advantages due to their relatively small magneto-resistance. Thus such coils might permit construction and operation of thermonuclear power-producing devices of relatively modest size, if and when the necessary stable plasmas can be created.

It is necessary, of course, for the refrigeration to remove the heat generated by the passage of current through the coils. However, the total power required to operate the refrigeration plant and the coil can be made much lower than the power needed to create a magnetic field of comparable strength and volume with coils at ordinary temperatures.

Shock Mirror Program

The Los Alamos Scientific Laboratory and the Naval Research Laboratory have continued their studies of well randomized plasmas produced in shock mirror devices. These devices use magnetically-driven shock waves to raise the plasma temperatures and a "magnetic mirror" geometry for plasma confinement; the shock waves are pressure waves similar to, but much more intense than, ordinary sound waves.

A Los Alamos apparatus of this type, called Scylla I, which was demonstrated at Geneva in 1958, has been subjected to intensive study. It was established in 1958 that the neutrons produced did not show the energy or asymmetry characteristics of neutrons resulting from instability of the plasma. Experiments with Scylla I indicate that an ion temperature of 15 million degrees and an ion density of 6×10^{16} per cubic centimeter have been attained. The electron energy is low, about 200 electron volts, and the duration of the neutron burst is 0.7 microseconds. For comparison, the ideal ignition temperature for a deuterium-tritium mixture is about 4,600 electron volts, equivalent to about 50 million degrees. In the present experiments, only deuterium is employed. In the recently completed Scylla II device the already-

heated plasma is subjected to a second compression by a magnetic field designed ultimately to reach 200,000 gauss. This second compression has extended the neutron pulse to a duration of 6 microseconds.

Similar devices at the Naval Research Laboratory also have yielded high plasma temperatures and densities, using a central magnetic field strength of 200,000 gauss. Based on optical spectra, and photographs of X-rays, the indicated electron temperature in one experiment was about 0.55 Kev and the electron density was approximately 5×10^{16} particles per cubic centimeter. These observations imply that the ratio of plasma pressure to magnetic field pressure was about one-tenth. No instabilities were observed during the period of heating and confinement. More recently, the energy and confinement time have been increased. It appears that a well randomized plasma at 20 million degrees, lasting for about 10 milliseconds, has been obtained.

Though there still is some doubt as to the nature of the mechanism whereby the plasma is heated in the shock mirror experiments, the indication is that much of the heating is produced by the intermixing of magnetic fields which initially have different directions in the plasma.

The results obtained at Los Alamos and the Naval Research Laboratory complement each other through differences in the measurements emphasized by the two groups of scientists. The controlled thermonuclear research program at the Navy laboratory is jointly funded by the Department of the Navy and the Commission.

New Plasma-Trapping Method

An improved method, called entropy trapping, for injecting and trapping plasma in a magnetic confining system recently has been proposed at Los Alamos. The method depends on production of intense directed beams of plasma which can exert enough pressure to drill into a magnetic confining system; when inside, the beam loses its piercing power by becoming randomized. The general idea of injecting plasma into a confining device, with provision for trapping it by a variety of means is well-known. However, the present embodiment has novel and interesting features.

A much improved plasma-projecting gun has been developed at Los Alamos which is suited for implementing this concept. The gun has produced bursts of plasma containing up to 10^{19} ions with an energy of 200 ev. The gun has a high electrical efficiency, about 30 percent. Plasma already has been trapped into static "picket-fence" and mirror geometries at densities of the order 3×10^{15} particle per cubic centimeter. ("Picket-fence" is a phrase used to describe a device using mirror coils connected in opposition; the predicted ad-

vantage of the resulting magnetic field is increased stability of the plasma, provided it is sufficiently dense; a disadvantage is increased loss of plasma-particles by diffusion.)

Magnetic Mirror Program

In work with a magnetic mirror machine, called Table Top, at Lawrence Radiation Laboratory, evidence was obtained in 1958 that plasma had been stably confined for periods of several thousandths of a second. The electron temperature was approximately 20 Kev (equivalent to about 200 million degrees) and the ion density was estimated to be about 10^{14} per cubic centimeter. The ion temperature was lower—perhaps 10 million degrees—because the device was not designed to contain ions of higher energy. The absence of instabilities in the plasma at such temperature and density is very encouraging for magnetic mirror confinement.

Work is in progress for measuring the energy distribution of the positive ions in the magnetically compressed plasma, and for experimenting further with multiple magnetic compression and transfer of a plasma. Improved guns have been developed for injecting plasma into the machine, resulting in higher temperature and greater purity of plasma before compression.

Experimental development of an intense beam of energetic (10 to 20 Kev) neutral deuterium atoms has been started. The neutral particles will pass through the residual gas within a mirror machine and become ionized, resulting in an accumulation of energetic ions forming a hot plasma confined by the mirror field.

Pinch Effects

The "pinch effect" method of magnetic confinement was first taken up in this country at Los Alamos, and has also been studied at Livermore and Berkeley facilities of Lawrence Radiation Laboratory.

At Los Alamos, the Perhapsatron S–5, a stabilized toroidal (doughnut-shaped) pinch device, came into operation and has revealed information concerning the process causing energy loss from the pinch which was extensively discussed at the 1958 Geneva Conference. Scientists at Los Alamos are reducing their research on the pinch effect in favor of work on the novel plasma-trapping method described above.

More information has been gained at the Lawrence Radiation Laboratory on conditions necessary for pinch stability. In a pinch device, confinement of the plasma column is accomplished through

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magnetic fields which result from an electric current passed along and around the column. The current flow and magnetic compression result in heating the plasma.

An electron beam probe, which produces a fine pencil of 200 Kev electrons, has been developed at Lawrence Radiation Laboratory for exploring the plasma boundary layer in a linear stabilized pinch. The gun, mounted at one end of the pinch tube, fires a short burst of electrons along a chosen line of force axially through the pinch tube at any chosen instant during the pinch cycle. The beam-spot on a screen at the opposite end of the tube shows whether the electron beam has been scattered by electrical oscillations while passing lengthwise through the plasma.

Experiments on a "hard core" pinch, that is a tubular plasma column with a central current-carrying copper rod, indicate that, contrary to previous belief, there is a marked improvement of fine-scale stability when the magnetic field distribution in the plasma region is not sharply defined. Lack of sharp definition does not cause the loss of gross stability in hard core pinches, as it would in pinches of the conventional type. If further experiments confirm this conclusion, the design of pinch devices will be significantly altered.

Stellarator Program

The Stellarator Program at Princeton has yielded further knowledge on the conditions under which instabilities impair the confinement of the heated plasma. In a stellarator, the plasma is confined in an endless tube by means of a very strong, externally applied magnetic field. Understanding of plasma instabilities is required to control the loss of plasma and energy to the wall.

Studies of pump-out (loss of plasma during ohmic heating) continued with the B–3 stellarator. Addition of a transverse stabilizing field which in theory should stabilize the plasma against instabilities of the confining magnetic field, does not affect the pump-out rate, indicating that pump-out is not caused by instabilities in the confining field used. Instead it appears that this particular effect is due to an instability of electrostatic type caused by the flow of electric current during ohmic heating. Direct measurements of the fluctuating electric fields associated with this type of instability have been made in the Etude device, a small stellarator which has a direct-current confining magnetic field and obtains many discharges in each second. Other methods of heating, which might not be subject to this form of instability, are under study.

If energy can be supplied to a plasma at a frequency equal to that at which the ions rotate around the lines of force of the confining magnetic field, the efficiency of transfer of that energy into the plasma should be especially high. This is a resonance effect, and the method is known as ion-cyclotron-resonance heating. There is, however, a secondary effect which limits this transfer. At Princeton, a way around this difficulty was discovered and power now has been supplied to a stellarator at a rate of 200 kilowatts and an efficiency exceeding 75 percent. In this work the plasma was heated from a completely cold condition. It is believed that the method will be very useful, and it is possible that this heating method will be used on the Model C stellarator. An improved device called B–66 has been constructed to develop the method further.

Detailed measures of the impurities present in the plasma have been made in several stellarators. The flow of heavy atoms from the wall into the deuterium plasma will be a serious problem in any sustained thermonuclear device or plasma source. A fairly recent innovation has been the installation of a mass spectrometer inside the tube of the Etude stellarator. This spectrometer has been very useful in identifying wall impurities and in showing how the impurity level declines with repeated pulsing.

Construction of the buildings for the Model C stellarator research facility has been completed. To permit experimentation on large-scale plasmas confined by magnetic fields, large versatile power supplies are needed for magnetic coils and for plasma heating; the C facility as a whole is comparable in cost and complexity with some of the large high-energy particle accelerators. The C stellarator itself, the first major device to make use of these powerful new facilities, is scheduled for preliminary operation during the fall of 1960. This device, with a racetrack tube 8 inches in diameter and 40 feet in circumference, is about four times the diameter of presently operating devices, and should yield much more complete information on the behavior of a hot plasma.

High Energy Injection Program

In the DCX machine at the Oak Ridge National Laboratory, molecular deuterium or hydrogen ions are injected at high energy—in effect preheated. The molecular ions are dissociated by passage through an arc. The resultant atomic ions are trapped within the magnetic field, describing orbits of smaller radii than did the molecules.

Experiments with the carbon arc have shown that dissociation of molecular ions occurs almost as efficiently when the ions pass within ⅛ inch of the visible arc as when they pass directly into this region. This is due to the presence in the arc of appreciable quantities of triply- and quadruply-charged carbon ions.

DCX has been operated with beams of up to five milliamperes of injected 600 Kev molecular hydrogen ions and with an operating pressure lower than 10^{-6} millimeters of mercury. The spread of the orbits of the trapped atomic hydrogen ions is being intensively studied.

As the ambient pressure is decreased below 10^{-5} millimeters of mercury, the region occupied by the trapped particles spreads until the plasma occupies a region 14 inches long with an 8-inch radius. It now is believed that the spread is largely due to oscillations in the arc, producing electric fields which deflect the trapped ions during their repeated passages through the arc.

As the vacuum conditions in DCX improved, another factor limiting the confinement time came into view, namely, neutralization of the trapped atomic ions during their multiple passages through the arc. Various changes of the DCX structure have been made to study and to minimize this effect. However, it has been clear for some time that the device is nearing the end of its useful life. Design of a highly flexible successor, DCX–2, has been in progress since late 1958. The new device will be an instrument for research and development, not an attempt at a pilot machine for a power-producer.

Efflux of molecules from the walls is a limitation on the attainment of satisfactory plasma in steady-state mirror machines. Now the Oak Ridge National Laboratory has demonstrated the production of a hollow cylindrical arc that can ionize a large fraction of the molecules escaping from the walls—thereby excluding neutrals from the space inside the arc. The dissociation of hydrogen molecular ions by this hollow arc also has been accomplished.

Great improvements in ion sources and accelerator tubes have been made during the year. A rectifier set providing 1 ampere at 600 kilovolts was constructed at Oak Ridge, so that these ion sources and tubes can be utilized.

The Astron Approach

Work continued at the Lawrence Radiation Laboratory on the Astron approach, a method utilizing relativistic electrons (electrons whose velocity is very nearly the velocity of light) to heat and confine the plasma. In this approach, relativistic electrons are to be in-

jected into a tube in the presence of an external magnetic field, so that they execute spiral orbits and build up into a cylindrical layer. It is expected that the spiralling electrons will then (*a*) create a confining magnetic field by reversing the field inside the layer and establishing a closed pattern of magnetic lines of force, (*b*) ionize injected neutral atoms and (*c*) raise the temperature of the plasma.

An electron gun capable of producing a beam current of 60 amperes at 700 Kev for pulse times of about one-half millionth of a second has been developed and tested at Berkeley.

A noteworthy feature of the beam is the very small random angle, amounting to less than one-third of a degree.

Preliminary inflection experiments have been carried out using a 20-foot long vacuum tank. The electrons have been reflected from a mirror at the end of the tank, and trapped for several hundred microseconds by the fast application of a second mirror near the input end.

Preliminary design for an accelerator to boost the energy of the beam from the existing 700 Kev electron gun to 3 Mev or more was completed. At an energy of perhaps 5 Mev it should be possible to demonstrate whether an electron layer can be built up to the density required for reversing the magnetic field within the layer, and whether such a system can produce and confine a hot plasma.

Biology and Medicine

The Commission's biomedical program continued during 1959 to be directed toward protecting the health and safety of atomic energy workers and the general public against potential radiation hazards emanating either from Commission operations or from other atomic sources in its area of responsibility. To hasten the resolution of existing problems, to develop an inventory of needed knowledge in these areas, and to permit scientific programs on radiation effects to stay ahead of or keep pace with technological progress in atomic energy, attention was concentrated on specific programs.

The Program

Medical research. This program has emphasized the following areas:

Concentrated studies of long-term effects of fission products, with special emphasis on cesium 137, the most important single source of whole body, genetically significant radiation from weapons tests.

Studies on the nature of radiation-induced life shortening and other possible delayed effects, such as leukemia.

Studies of human genetics to obtain data needed to evaluate the hazard of radiation to man and his environment; the prime point of attack is to determine the normal rate of mutation in man and what may alter it.

Development of protective agents to eliminate or alleviate harmful effects of radiation.

Toxicological studies to meet the potential problems and hazards introduced by use of new metals, alloys, and compounds of modern reactor technology.

Studies on the assessment of the radiobiological hazards associated with space travel with specific reference to the biological hazard of high speed heavy particles. Newly developed high-energy accelerators are used for this type of research.

Development of whole-body radiation counters to provide additional detector systems capable of measuring in the bodies of man and large animals accumulation of naturally occurring radionuclides, such as potassium and radium, and fission product nuclides.

Biological research. This program has emphasized the following areas:

Studies on the genetic effects of radiation at the cellular level including chemical and physical changes and factors that modify such changes.

Studies of metabolism of radionuclides in man and other mammalian species.

Studies on the possible hazards to plants, animals, and agricultural food chains from reactor operations.

Environmental sciences research. This program has emphasized the following areas:

Long-range studies on total environment, including radiation, at Commission installations.

Programs utilizing fallout as an ecological tool through which geologic, soil, and vegetational processes can be better understood.

Observation of trends, periodicities, and fluctuations in the biota and environment in special areas of landscapes, grassland, forest, desert, and woodland.

Studies of biological processes in fresh water and marine communities and the biological and geographical distribution of fission products in the ocean.

Stratospheric sampling program with increased number of samples collected and accompanying radiochemical analyses.

Meteorologic studies of atmospheric electricity, turbulence, and diffusion by micro-meteorological methods, and of natural and artificial radioactive tracers.

Dosimetry and instrumentation research. This program takes into account the need for instrumentation that accompanies increasing use of atomic energy. Features of new instrumentation include economy, performance, and versatility for engineering, health physics, and research applications. Improvements are expected to be attained through the following specific areas where emphasis has been placed:

Intensive effort on the development of image amplifiers.

New types of basic radiation detectors.

Very low level radiation counting equipment.

Medical and biological instrumentation.

Instrumentation for space biology, adapting accelerators, cyclotrons and other high energy units for biological studies, and developing ion chambers and crystal spectrometer techniques for study of radiation problems beyond the atmosphere.

Civil effects test program. The goals of this program include the study of neutron and gamma radiation from nuclear weapons in order to correlate physical data on radiation doses to medical data being collected by the Atomic Bomb Casualty Commission in studies of the Japanese survivors of Hiroshima and Nagasaki.

Training, education, and information. Activities during the past year in this field affecting the life sciences are reported in another section of this report.

Some Highlights of 1959

To illustrate progress made during this past year toward accomplishment of some of the stated goals, the Commission reports here on activities in the biomedical field. During 1959, the Commission as part of its biomedical research program:

Began receiving patients in its new Medical Research Center at the Brookhaven National Laboratory, Upton, N.Y.;

Cared for and studied further, five men who made a good spontaneous recovery from the radiation effects that resulted from an Oak Ridge criticality accident in June 1958;

Conducted its sixth medical survey of the Marshallese people of the Rongelap Atoll, accidently exposed to radioactive fallout in March 1954, and found no apparent subacute affects which could be related to the exposure;

Announced study findings relative to radiation shielding afforded by typical residences as determined by tests conducted in Nevada during 1958.

In addition, Commission-sponsored research, in meeting its stated objectives, continued to make important contributions to man's knowledge of protection against radiation damage, effects of external and internal radiation, radiation effects on populations, toxicology of radioactive and non-radioactive materials, cancer production and treatment, blast and burn effects, and radiation instrumentation.

A special section of this report deals with fallout studies and covers monitoring and surveillance activities but includes only limited reporting on supporting research activities. Much of the research in the progress section which follows lends support to the research efforts on the effects of fallout; additional projects are included in the list of research contracts in the life sciences in Appendix 12.

Brookhaven Medical Research Center

Patients were moved in early January into the 48-bed research hospital of the new $6.8 million Medical Research Center, dedicated December 16, 1958. The last research division moved into quarters in the Center in late February.

Assembly and testing of the components for the Medical Research Reactor (MRR) was completed and criticality was achieved March 15. Approximately a month for instrumentation testing and nuclear measurements followed before the reactor was used for medical research. Initial operation was at 1 megawatt. Later the Commission gave authorization to operate routinely at power levels up to 3 megawatts and to develop procedures for treating patients.

Radiation Accident in Oak Ridge

One of the few radiation accidents that have occurred in Commission installations happened at the Y-12 plant in Oak Ridge on

June 16, 1958.[33] Five men who were exposed to significant amounts of whole body neutron and gamma radiation were treated at the Medical Division of the Oak Ridge Institute of Nuclear Studies. Evidence of profound depression of bone-marrow activity was found particularly during the fourth to sixth week after the accident. The men made good spontaneous recoveries from the initial radiation effects, and have all returned to work in good physical condition. Extensive studies and observations were made throughout the year following the exposure. Most laboratory evidences of radiation injury now also have disappeared.

From this unfortunate experience much valuable information has been obtained. Because of the circumstances of the accident it was possible to estimate reasonably well the amount of radiation dosage to each man. The absence of blast, burns, or uneven dosage of radiation made it possible to observe uncomplicated whole body radiation effects in man. Two publications present the initial clinical and laboratory findings regarding the men exposed, and the physical characteristics of the accident.[34]

Medical Re-Examination of the Rongelapese

The sixth medical survey of the inhabitants of Rongelap Atoll in the Marshall Islands 5 years after they were accidentally exposed to radioactive fallout in March 1954,[35] was conducted by a team headed by physicians from the staff of Brookhaven National Laboratory. Complete physical examinations of about 200 people were carried out, including examinations of children for growth and development. Whole-body gamma-ray measurements were made with a whole-body counter, a 21-ton steel room designed and constructed at Brookhaven and transported to the Atoll. Examinations of the people for internal levels of radioisotopes revealed low levels (a small fraction of the maximum permissible levels) of cesium 137 and zinc 65. These were not increased appreciably over the levels found in the previous year, indicating that the body burdens of these isotopes in the people have reached approximate equilibrium with their slightly contaminated en-

[33] See p. 213–14, Twenty-fourth Semiannual Report to Congress (January–June 1958).

[34] "The Acute Radiation Syndrome, A Medical Report on the Y–12 Accident June 16, 1958" ORINS–25 was published April 1959 and is available from Office of Technical Services, Department of Commerce, price $2.75; and "Accidental Radiation Excursion at the Y–12 Plant", Y–1234, published July 1958 and available from Office of Technical Services, U.S. Department of Commerce, Price $2.75. (This document supplements the ORINS report, and provides information on the physical characteristics of the accident.)

[35] The Rongelapese were returned to their home island on June 29, 1957, after the Commission had determined that the degree of contamination from fallout after a weapons test had declined on Rongelap Atoll to an acceptable level. See pp. 132–135, Twenty-second Semiannual Report (January–June 1957).

vironment. Radiochemical urinalyses for strontium 90 have not yet been completed.

The survey found no apparent effects related to penetrating radiation from the fallout with the possible exception of a persistent lag in complete recovery in surface circulation of levels of blood platelets (a type of small blood cell). The lymphocytes (a type of white blood cell) have recovered to a level about the same as in the unexposed population from other islands in the Marshall group. A possible slight lag in growth and development of 17 irradiated children [36] at 2 and 3 years after exposure—based on height, weight, and bone age studies—is being reevaluated since ages of some children are not firmly established.

Residual effects of beta irradiation of the skin were confined to 12 cases which showed varying degrees of pigment aberration, scarring, and atrophy at the site of deeper burns. In no case is there evidence of chronic radiation dermatitis or premalignant or malignant changes in the skin. History and physical examinations to date reveal no clinical evidence among the Rongelapese of any illnesses which could be related to whole-body exposure.

Protection Against Radiation Damage

Two avenues in the treatment of damage resulting from exposure to radiation have been followed for some years. One of these is the use of transplanted bone-marrow to support the individual whose own bone-marrow has ceased to perform its critical function of supplying the daily requirement of new blood cells. Another approach has been the development of a class of chemical compounds which have been effective in reducing the apparent lethal radiation dose by a factor of between two and three, when administered before irradiation takes place. The compounds are completely ineffective when given after radiation.

While a considerable number of studies on experimental animals still are in progress, the emphasis on studies of bone-marrow therapy has shifted from the laboratory to the clinic. Experimental animals proved the basic feasibility of marrow transplants but it has become increasingly clear during the past two years that the immunologic characteristics of a given strain or species can be extrapolated only in a general way to another species.

At the Oak Ridge National Laboratory it has been shown in animals that radiation and certain chemicals which suppress the bone-marrow

[36] 13 of the children being studied were 5 years of age or younger at the time of the incident; 4 others were *in utero*.

also will suppress the normal immunologic antagonism between species, strains, and individuals to the point that tissues from another individual (and in some cases, species) are not immediately destroyed by the irradiated recipient. These transplanted cells survive and multiply so as to become the progenitor line for new cells in the recipient. When this happens, tissues such as skin which formerly would not take on the recipient will then do so. Thus it is possible to make a successful graft of rat skin on a mouse whenever the mouse's blood stream is repopulated by transplanted rat bone-marrow.

These foreign cells in a recipient may be recognized as an antigen by the recipient's recovering immunogenic tissues, in which case the resulting antibodies, if produced in sufficient amount, would destroy all of the transplanted lineage of cells; when this happens the host can recover uneventfully. However, in the other direction, the growing transplanted cells may recognize the normal components of the recipient's tissues as an antigen and thereupon produce antibodies which will suppress the cells of the recipient. This has happened so frequently that the effect has come to be known as the "delayed reaction."

Establishment of the mechanism of the variations of this reaction has been one of the chief lines of development in this field. Studies described in this section are aimed at specifying the cell or cells responsible for the generation of the blood cells lineages when a "take" is secured.

AET (S,2-aminoethylisothiuronium·Br·HBr) remains the prototype of the really effective prophylactic agent. Work at Oak Ridge National Laboratory has centered around efforts to find a derivative or congener of AET which would exhibit a more favorable effective dose-to-toxicity ratio than does AET. The compounds given most consideration thus far are the propyl (APT) congener and the methyl derivatives of AET and APT—β-mercaptoethylamine (MEA). The effect of oxygen and its mechanism in affording protection also is being studied. Some Commission-sponsored research on this class of protective compounds and oxygen effect is described in this section.

Studies of removal of radioisotopes once deposited in the body through use of certain compounds such as diethylenetriaminepentaacetic acid (DTPA) and ethylenediaminetetraacetic acid (EDTA) are described in the section on "Studies on Effects of Internal Radiation."

Bone-Marrow Work

The use of bone-marrow and other living cellular materials is one of the most effective methods so far found for combating or compen-

sating for the damaging effect of radiation, after radiation has occurred. The development of techniques for transplantation or grafting of bone-marrow may be important in at least three ways:

a) They may prove an important clinical technique for the treatment of persons accidentally exposed to large doses of radiation.

b) They make possible new advances of transplantation of tissues other than bone-marrow, since it has been demonstrated in experimental animals that an individual that has tolerated marrow from a homologous donor (from the same species) later will tolerate transplants of other tissues from the same donor. In the absence of preliminary marrow transplants, other tissue would be rejected because of immunologic incompatibility.

c) Marrow grafting may conceivably lead to the development of a form of treatment for diseases of the bone-marrow such as leukemia and aplastic anemia, and may make possible the safe therapeutic use of doses of radiation or cell-damaging drugs that otherwise would be lethal.

Clinical applications. At the Oak Ridge Institute of Nuclear Studies a group of 11 patients with acute leukemia have been treated with large doses of whole-body gamma-irradiation from a cobalt 60 beam. Most of them have received homologous bone-marrow infusions following the radiation. In a few instances distinct remissions in the leukemia have occurred but as yet evidence of true marrow grafts is not clear. It appears that whole-body irradiation alone at certain dose levels can produce improvement in some cases of acute leukemia as demonstrated by the use of radiation without bone-marrow. Extensive studies are underway to clarify various aspects of this therapeutic approach.

Radiation dose relationships as a function of body size have been studied using chemical as well as conventional measurement techniques. As a part of this program, a new facility for delivering more even whole-body radiation is under construction at the Medical Division of the Oak Ridge Institute of Nuclear Studies. This facility will consist of a specially shielded room containing eight sources of cesium 137 located in the corners of the room. These sources will deliver a uniform radiation dose to the whole body of a patient. Equipment is available to control the dose rate so that this can be varied over a wide range. The radiation facility was ready for operation late in 1959.

Laboratory experiments. To support and assist clinical applications, Argonne Cancer Research Hospital carries out experiments with la-

boratory animals. Long-term survival studies on mice of a specific strain given normally lethal doses of irradiation and protected with a variety of hematopoietic (blood cell-forming) tissues have been completed. The lethally-irradiated mice of that strain survived longer when injected with liver or spleen suspensions from newborn mice than when treated with equal numbers of mature bone-marrow cells. Adult bone-marrow from other strains of mice did not protect the test animals very far beyond the initial 30-day lethal period apparently because the transplant gave rise to the antigen-antibody reaction. Embryonic cells of other strains of mice, however, kept test animals alive for over 500 days following normally lethal irradiation. Presumably embryonic cells are less prone to form antibodies, and hence do not become involved in the lethal secondary antigen-antibody conflicts that arise when mature bone-marrow cells are injected and they colonize.

Encouraging progress has been made at Oak Ridge National Laboratory toward preventing the immunological reactions associated with transplantation of bone-marrow and spleen. "Immunological paralysis" of the spleen or marrow cells to be grafted is accomplished by incubating them *in vitro* with antigens taken from the recipient animal prior to cell implantation. This has prevented fatal reactions in more than 80 percent of the transfused experimental animals observed thus far.

The immunological maturity of mice has been found to be a function of the antigen-host genetic relationship; thus, in young mice, the response to an antigen from a more distantly related animal is greater than that to an antigen from a more closely related animal. These results are identical to those obtained previously from X-ray irradiated, adult mice. It can be concluded, therefore, that the radiosensitive nature and maturation of the immune mechanisms are a reflection of the antibody-producing cells failure to recognize the existence of a given antigen.

Antigens capable of inducing immunity for heterologous bone-marrow transplantation have been found in nucleated cells of hematopoietic and non-hematopoietic tissues. The highest concentration appears to reside in the microsomal (granular) fraction of a given cell, and such antigens show properties of being a polysaccharide.

Studies at Argonne Cancer Research Hospital to find the earliest link in the chain of events leading to immunologic rejection of grafts of foreign tissue have resulted in the detection of a bioelectric field of considerable strength about the graft and the formulation of a field theory which includes many interesting predictions, such as the protection of a graft by using external forces to reverse the bioelectric

field. By means of techniques which theoretically would displace the position of the maximum field gradient, a rejection has been produced in skin grafts in which one part of the graft has been sloughed off rapidly and the remaining part gradually replaced in a manner similar to that which occurs in bone or artery homografts. A method has been designed which should make possible some accurate measurements of the field gradient at the junction of the graft and host tissue and also of boundaries between cancer and host tissues.

Free Radicals in Radiation Protection

One primary effect of ionizing radiation on biological material is the formation of free radicals. Present views differ as to whether this result is a direct action of the radiation on the biochemical itself, or indirect, from irradiated water molecules forming free radicals which later react with the biological matter. Certain chemicals that inhibit radiation damage might act by combining with the suspectible biological group to reduce its radiation sensitivity, or by joining into some structural unit which, due to its high radiation sensitivity, behaves as a trap for the products of the radiation. Indirectly, the protective chemical might act as a scavenger for the free radicals formed in the water and thus prevent their degrading action upon the biological material.

Some differentiation between these processes has been attained through measurement at Argonne National Laboratory of the free radicals produced by irradiation of yeast. The system studied was a suspension of deuterated yeast (*Saccharomyces cerevisiae*) in heavy water (D_2O) to which was added the protective agent β-mercaptoethylamine (MEA). Under gamma irradiation the components of this system produce distinct free radicals which can be detected and identified by electron paramagnetic resonance techniques.

The yeast suspension and MEA in varying concentration were mixed, quickly frozen by cooling to 77° K, and irradiated with gamma rays. The relative concentrations of free radicals in MEA, yeast, and heavy water were measured. The number of free radicals formed in the heavy water ice was independent of the MEA concentration. When the temperature of the system was raised to 125° K these rather mobile and unstable radicals disappeared without affecting the number of free radicals in the yeast and MEA. This indicates that these experimental conditions the free radicals formed in the heavy water do not interact with the other molecules and play no part in the protective mechanism.

If the protective action can be represented as a competitive process

between the radiation-sensitive molecules of the yeast and the MEA, the free radicals formed in the yeast should decrease with increasing MEA concentration. The experimental observations supported this concept; as the MEA concentration was increased, the number of MEA free radicals increased at the expense of the number of free radicals in the yeast.

Although this simplified physical picture ignores many biological details, the results indicate that the action of radiation on radiation-sensitive material may well be direct as is also the action of the protective agent.

Chemical Protection

The mode of action of a class of radiation protective compounds, typified by AET (S,2–aminoethylisothiuronium·Br·HBr) initially developed by the Oak Ridge National Laboratory, has been investigated using isotopically labeled compounds and examining various radio-sensitive tissues. It has been found that these compounds are selectively distributed within the animal to such radiation sensitive systems as the spleen, bone-marrow, and intestine. The degree of initial damage, as well as the rate of recovery of bone-marrow and intestine could be directly correlated with the dose of protective compound. AET compounds were present in higher concentration in normal tissue than in mouse ascites tumor in which case the tumor was not protected against radiation damage. Since these compounds also inhibit the action of nitrogen mustards used in treatment of some tumors, clinical evaluation has been undertaken at Tulane University in collaboration with Oak Ridge National Laboratory, using AET to protect bone-marrow against either nitrogen mustard or radiation damage. Encouraging results are being obtained.

Studies of Effects of External Radiation

Studies continued on the biological effects of the various qualities of ionizing radiations including acute and delayed effects, and varying beam intensities. Objects for study range from effects on simple biological systems to the most complex organisms, including wherever possible, effects on man himself. A major effort is directed to the genetic and carcinogenic effects of ionizing radiations from external sources. A later section discusses studies of internal sources of radiation from radioisotopes deposited within the body.

All these studies are designed to give answers to the problems arising in the use of nuclear energy for power and other peaceful uses—

answers which will assist in setting standards of permissible levels of radiation for workers in the plants and other places where nuclear energy is used, as well as for the general populations around such installations.

Genetic Effects of Radiation in Mice

The results of studies conducted at Oak Ridge National Laboratory show that the mutation rate of specific genetic loci in cell chromosomes in female mice is significantly higher after acute irradiation as compared with equivalent chronic irradiation. Conditions in the adult mouse ovary make complications from secondary factors unlikely. Hence, it appears that in oocytes (immature ova) there is a dose-rate effect on the mutation process itself. The influence of dose rate on the frequency of mutations following irradiation of spermatogonia (immature sperm) in males, which could have been due to secondary factors, now is considered also to be due to a dose-rate effect on the mutation process.

The most significant features of the results, from the point of human hazards are: (*a*) that there is, at present, no evidence that females are less sensitive than males; and (*b*) that the findings of a dependence of mutation frequency on radiation dose rates, now extended from males to females, applies to those stages of germ cell development that are important in human hazards.

New data have confirmed earlier findings that specific locus mutation rates obtained by chronic gamma radiation of spermatogonia are lower than those obtained from acute doses of X-rays. Since this result is in contrast to classical findings for the spermatozoa (mature sperm) of *Drosophila* (fruit flies), and apparently contradicted a basic tenet of radiation genetics, it was important to determine what factors were responsible for it.

Experiments undertaken for this purpose at Oak Ridge National Laboratory reveal that (*a*) the lower mutation frequency is due mainly to difference in dose rate of radiation, rather than to its quality; (*b*) a dose-rate effect is not obtained in experiments with mouse spermatozoa, confirming classical findings for spermatozoa and indicating that the explanation for the dependence of spermatogonial effects on radiation intensity resides in some characteristic of the stage of cell development; and (*c*) a dose-rate effect is found not only in spermatogonia, but also in oocytes, where cell selection is improbable, indicating that the radiation intensity effect acts on the mutation process itself.

These findings have not indicated the existence of a threshold response for all mutations in spermatogonia and oocytes. The results

indicate that the genetic hazards, at least under some radiation conditions, may not be as great as those estimated on the basis of mutation rates obtained with single acute doses of radiation. However, the lower mutation rates obtained with the prolonged low levels are still appreciable.

X-ray and Gamma-ray Toxicity

A long-range program at Argonne National Laboratory has the primary objective of finding a valid basis for estimating the injurious and lethal effects of radiations in man. The first effort is to establish the relation between the lethal effects in animals and certain physiological factors, such as intestinal damage and increased susceptibility to infection. Afterward, a link must be established between effects in animals and man by comparison of the essential physiological factors.

Lethality studies. Previously it had been suggested that the relation of survival time to daily radiation exposure level is governed by a number of independent variables. This suggestion has now been substantiated at Argonne National Laboratory in experiments with mice, and a detailed picture of the sequence of events in radiation mortality has been obtained. Five thousand hybrid mice (LAF strain) were irradiated at 24 daily exposure levels ranging from 1,650 *r* (roentgens) a day to 6 *r* a day (survival time ranging from about 4 days to 500 days), beginning at 100 days of age and continuing until death.

The curve on a chart representing a relation of mean survival time to daily dose characteristically rises in a series of shallow steps, with the first rise in deaths at 5 days, a second steep rise at 15 days, and a third broader rise at about 35 days. Relationships between the dosage-death curve and various physiological injury processes are beginning to appear: depression of the leucocyte (white blood cell) count with accumulated exposure at a constant daily dose of radiation follows the same series of phases as the lethality curve. The study also revealed a hitherto unsuspected sex difference manifested by a sharp rise in the relative sensitivity of female mice in the period from 20 to 40 days after the beginning of exposure.

Genetics. Lethality among different genetic strains of mice was expected to differ significantly in ways that would contribute to understanding some important variables that affect injuries from radiation exposure. Five inbred mouse strains and some of their hybrids (about 5,000 mice in all) were irradiated throughout life at 10 levels of

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standard daily dosages. The survival curves of the different strains differed to a considerable degree.[37]

Genetic influences on the radiosensitivity of mouse strains also have been studied in mice given single or divided doses of gamma rays or X-rays ranging from 150 to 1,000 *r*. Both acute and chronic effects were studied. The results indicate that resistance to acute radiation injury (measured by LD_{50}) is related to the average "natural" length of life as indicated by control groups of animals. It appears that ability to resist acute radiation stress in general parallels the animal's ability to withstand other natural environmental stresses, especially those resulting from infectious diseases. The strains that deviate most from this pattern are those that experience heavier mortality from cancer.

The chronic, life-shortening effects of single doses (expressed as reduced life-span per roentgen of radiation delivered) vary little from strain to strain, than do the acute lethal effects, and the differences appear to be associated with susceptibility to leukemia. When mortality from all other causes is compensated for, there are almost no differences between strains in life-shortening as a result of radiation.

This result is potentially of great importance in relation to the problem of evaluating possible life-shortening in human populations. The results also extend an earlier finding that female mice are more susceptible to the life-shortening effects of radiation; this was found to be true of all the strains investigated at Argonne. This finding is important in view of the common practice of conducting long-term toxicity experiments on mice of one sex, usually females.

The radiation responses by the first-generation hybrids of these mouse strains indicate that the offspring generation almost always is as resistant as, or more resistant than, the more resistant of the two parent strains. The dosage-survival curves of second-generation hybrids show much greater variation. One kind of radiosensitivity appears to be linked to a gene locus in the chromosomes identified with albino characteristics.

Effect on fertility of small chronic X-ray doses. In an experiment at the University of Rochester designed to measure the margin of safety in maximum permissible dose levels for external radiation to the whole body, male beagle dogs have been exposed to X-radiation for the last 8 years and will be irradiated for the remainder of their life spans. In the early and intermediate phases of the experiment,

[37] See pp. 167–68, Twenty-fourth Semiannual Report (January–June 1958).

attention was directed to the effect of X-rays on fertility as assessed by sperm counting and by test-mating with unirradiated females.

The findings of this study are that the dog groups irradiated at 0.3 *r* a week (the maximum permissible whole-body dose in 1950 when the experiment was designed) and at 0.6 roentgens a week, have shown no effect of X-ray on their ability to produce sperm. On the contrary, as the dog colony has grown older these two groups have tended to show a lower incidence of sterility than the non-irradiated control group. In the group irradiated at a rate of 3.0 *r* a week, 8 of the 10 dogs became infertile in one year (150 roentgens total dose) and have remained so. The remaining two dogs, despite an accumulated dose of about 950 roentgens, still produce sperm and irregularly have sired litters.

The work now is in its later phases and the primary concern is a search for effects of radiation on physiological aging, and on production of morphological changes. The deaths among these dogs were as follows (experimental group, age at death, and cause of death):

Controls: 8.2 years, nephritis; 7.1 years, and 9.1 years, hepatitis.

0.3 *r* a week, 9.2 years, spleen tumor.

3.0 *r* a week, 8.2 years, cerebral hemorrhage.

Blood and tissue studies. To provide information on blood and tissue responses to radiation to be correlated with lethality data, groups of mice of the LAF_1 strain were irradiated at Argonne National Laboratory at 9 exposure levels (220 *r* a day to 12 *r* a day). Mice from these groups were sacrificed at 12 intervals distributed throughout most of the survival period. All the blood elements, bone-marrow, and lymphoid tissues were serially studied; complete histological studies of all tissues will continue.

Tissue and cellular changes under low-level daily irradiation are difficult to characterize. During early phase damage, cells are either repaired or replaced, which results in a microscopic picture qualitatively similar to that of non-irradiated animals. Later, the recovery potential fails to keep pace with accumulating damage, and changes become obvious. At daily doses as low as 6 to 12 *r*, the germinal cells of the ovary were completely destroyed during the first 30 days, while the testes were reduced to interstitial tissue and Sertoli cells by 60 days, indicating complete loss of reproductive capacity.

The sequence of changes in the *small intestine* in mice studied at Argonne National Laboratory under daily exposure follows a well-defined pattern. Under daily exposures up to 220 *r*, a small number of degenerated nuclei can be detected in the crypts (the areas where

new lining cells are produced). However, the production of new cells is sufficient to maintain the mucosal covering of the villi (minute finger-like projections in the intestinal lining). Hence intestinal damage *per se* does not play a dominant role in the death of these animals at this dose level. At lower doses very few dead cells can be found in the crypts even after extended periods of irradiation. There is, however, a continued reduction in the number of dividing cells paralleled by a gradual reduction in the length of the villi. This reduction in villar length makes it possible to maintain the mucosal covering in the face of a reduced rate of proliferation. The consequences in terms of functional capacity of the intestine are as yet unknown.

Changes in so-called radioresistant tissues such as the *liver* and *kidney* are apparent even at doses as low as 6 to 12 *r* a day. Striking cytological and histochemical changes have been detected in the liver of mice. The incidence of such degenerative changes is especially high in mice surviving extended periods of irradiation, and is, in fact, a primary cause of death in this period. Degenerative changes in the kidney also are common after extended exposure, and kidney diseases reach a high level.

Tumor incidence is markedly increased at daily dosage levels that permit survival for 9 months or more. Lymphocytic leukemia, pulmonary tumors, ovarian tumors, mammary tumors, hepatomas, and adrenal tumors are among those increased by radiation exposure. The incidence of leukemias was highest in mice receiving 24 *r* a day and was significantly higher in the females at all exposure levels.

Observations on dogs which have survived LD/50–90 dosages (fatal to 50–90 percent of the group) of X-ray or cobalt 60 gamma-irradiation continued at the University of Rochester. A residual depression of the total *blood* count continues to the extent that after 2 or more years total counts in 31 of 38 dogs have not risen to pre-exposure levels. In 7 animals in which cells regenerated to preexposure levels, 4 were corrected in 12 months, 2 at 18 months, and 1 at 24 months.

The observations of platelet level depression in accidental human exposures parallels continuous measurement in 12 dogs surviving 16 months after irradiation. Studies of these animals showed a return in platelet levels to normal values between 2 and 3 months after exposure. Beginning at 12 months post-exposure counts in 5 of the 12 animals have declined progressively to the 16th month in which mean platelet level is 66 percent of control values.

Two years after exposure to LD 80/30 (lethal dose for 80 percent in

30 days) one dog developed progressive anemia after apparent initial partial recovery. Autopsy revealed contracted *kidneys* resembling a condition of chronic nephrosclerosis.

The ability to withstand "stress" is impaired in that animals surviving the acute radiation syndrome do not tolerate barbiturate anesthesia or gamma irradiation as well as normal animals do. The greater sensitivity to gamma-irradiation has indicated a vascular defect.

Amino acids after irradiation. At the Medical Division of the Oak Ridge Institute of Nuclear Studies detailed biochemical analyses were carried out on the excreta of the group of normal men exposed to neutron and gamma irradiation in the accidental criticality at Oak Ridge.[38] Of particular interest was the demonstration in the urine of creatine, normally present in muscle, and creatinine which is present in blood and urine. Total-body irradiation at levels up to about 300 *r* did not alter creatine or creatinine excretion in these men. Amino acid nitrogen showed no consistent changes. The chromatographic analysis to give detailed information about excretion of individual amino acids, will be performed. Preliminary data indicate that taurine (which occurs in bile) excretion was increased and that beta aminoisobutyric acid was excreted in increased amounts in irradiated subjects. The increased excretion of taurine is not so clear-cut as that of beta aminoisobutyric acid. There is some suggestion that the levels of excretion of this latter amino acid are correlated sufficiently well with dosage of radiation to give useful measurements of exposure. The data also suggests that a change in serine excretion follows total-body irradiation.

Neutron Toxicity

Argonne National Laboratory is studying the effects of neutrons on living systems, particularly in comparison with the effects of other radiations. Damage from fast neutrons is presumed to result largely from recoil protons which produce dense, but widely scattered, columns of ionization. Gamma rays produce damage by means of recoil electrons, the ionization tracks being much less dense but more uniform in distribution. The radiation energy absorbed by tissue per unit length (linear energy transfer) thus is quite different for these two radiations, and well may be reflected in dissimilar biological damage.

[38] See pp. 213–214, Twenty-fourth Semiannual Report (January–June 1958).

Comparative toxicity of neutrons and gamma rays. Differences in the actions of fission (fast) neutrons and gamma rays were indicated by earlier work in which lethality of the two radiations were shown not to be additive. Within the acute lethal range, fast neutrons killed mice much more rapidly than did physically comparable amounts of gamma rays. The earlier peak of neutron deaths (at 4 to 10 days after irradiation) was correlated with intestinal injury; the peak of deaths following X-rays or gamma rays (at 12 to 16 days) was correlated with injury to the blood-forming system.

These observed differences in acute effects have been clarified by a detailed histological study of intestinal damage after comparable physical doses of the two radiations. In deaths occurring between 3½ and 6 days, the major factor was intestinal injury, characterized by destruction of the crypts, the regions in which new lining cells arise. The sequence of changes was the same regardless of exposure pattern (single, continuous, or fractionated) or quality of radiation (X-rays, gamma rays or fast neutrons). However, two important differences between effects produced by neutrons and gamma or X-rays have been observed: (*a*) inhibition of cell division lasts longer after neutron irradiation (at least 22 hours after exposure to 350 rads [39]); and (*b*) chromosome damage is much greater.

In mice irradiated with gamma rays from cobalt 60 in the 30-day LD_{50} range, death is rarely the result of intestinal injury. After 1,000 rads, a rapid recovery (within about 3 or 4 days) is apparent; this seems to be associated with the shorter period during which cell division is inhibited (about 10 hours). Neutrons were at least 6 times as effective as gamma rays in producing intestinal injury. The evidence suggests that bacteremia (bacteria in the blood) represents a major factor in neutron radiation death in mice.

Isologous bone-marrow transplants were not effective against deaths occurring during the first week, although the 30-day mortality was decreased. A combination of streptomycin and bone-marrow was much more effective, probably reflecting improved recovery from neutron damage of two different physiological systems—the blood-forming, and the intestinal. Protective action could be increased further by injection of cysteine before irradiation. While no one of the three agents was very effective alone, the three-way treatment, in mice exposed to from 350 to 400 rads of fission neutrons, decreased 30-day mortality from 100 percent to 5 percent.

Pre-irradiation administration of AET also was tested in neutron-irradiated mice. Oral administration of AET reduced mortality from 85–90 percent to 53 percent, almost identical to the rate pro-

[39] *One hundred ergs of absorbed energy per gram of absorbing material.*

duced by cysteine. A comparison of these two agents used in conjunction with postirradiation treatment with isologous bone-marrow cells and streptomycin indicates that, in the concentrations used, cysteine was somewhat more effective.

Effects of dose fractionation. The effects of divided dosages of radiation on the relative biological effectiveness (RBE) of fast neutrons relative to gamma rays from cobalt 60 were studied in mice using 13 daily exposures with total doses ranging from the 30-day LD_{50} dose to very low levels. The mice receiving the highest daily dose of each radiation (70 rads neutrons, 210 rads gamma rays) exhibited the mortality pattern associated with acute exposures. Under the conditions of these experiments, neutrons appear to be approximately 3 times as effective as gamma rays in shortening life.

It appears that these brief, daily divided doses, given over a 2-week period at relatively high intensities, affect the animal exactly like single acute doses, so far as survival is concerned.

Comparative recovery studies. Rates of recovery have been studied in mice exposed to equal, paired doses of fast neutrons or gamma rays, with varying intervals between the two. Since 30-day mortality is decreased as the interval is increased, reduction in mortality provides an index of recovery during the interval. Results indicate that the portion of the first dose from which the animal has not recovered is related exponentially to the time between two doses, at least when this period is between 1 and 10 days. Recovery after neutron irradiation is much slower than recovery after comparable doses and dose rates of gamma rays. The "half-recovery time" after gamma rays is of the order of 5 to 6 days, and after neutrons 9 or 10 days. Complete recovery from the first sublethal neutron dose takes place within about 60 days.

Fast neutrons and female mice fertility. The reproductive capacities of female mice appear to be easily suppressed by fast neutrons. Survivors of single doses in the lethal range (250 to 350 rads) produced no living young when tested at 2½ to 5 months after irradiation. After sublethal doses (as low as 32 rads) some fertility was retained for 2 or 3 weeks, but the average litter size was reduced 60 percent; after 1 month, only 2 of 20 mice tested produced any young. In 1 group exposed to 11 rads, 3 tests at weekly intervals after irradiation showed reduced litter size; 5 months later these mice were completely sterile. Thus, single exposures to neutrons are at least 5 to 10 times

more effective than similar exposures to X-rays or gamma rays in producing sterility in the female mouse.

Another series of experiments tested the effects of repeated irradiations on female mouse fertility. The mice were irradiated with fast neutrons (3 to 30 rads each day) for 9 or 13 successive exposures with daily exposure times ranging from one-half to 60 minutes. In all groups tested, average litter size was reduced and the percentage of females becoming pregnant decreased with time after exposure. Six months after exposure, when fertility was still high in control females, almost all the irradiated mice were sterile. Even in the groups receiving the lowest dose (3 rads daily for 9 days), only 2 of about 25 females gave birth.

Cosmic Ray Primaries

The linear accelerator at the Donner Laboratory of the University of California at Berkeley, and the cyclotron at Brookhaven National Laboratory afford unique opportunities to simulate cosmic ray primaries that man would encounter in outer space and facilitate study of their effects in a variety of biological materials. Although such studies are in an early stage, some interesting findings already have been reported.

Tolerance of mouse brain tissue. A striking relationship between the size of the impact area of a deuteron beam and the threshold dose for a radiogenic lesion has been noted in investigations at Brookhaven National Laboratory. The experiments reported are part of a program designed to investigate the biological effects of cosmic ray primaries upon brain tissue by a simulated technique This technique is based on the expectation that most of the biological effect of a cosmic ray primary would result from a dense cluster of secondary protons surrounding the path of the primary cosmic ray particle. This creates a core of ionization about 25 microns in diameter. Thus a beam of protons or deuterons about 25 microns in diameter might be expected to simulate a cosmic ray primary in its biological effects. The present phase of the study is concerned with the independent variable of beam size.

For production of a gross histologic lesion in mouse brain tissue 24 days after exposure to deuteron beams of 1.0 mm., 0.075 mm. and 0.025 mm., radiation doses of approximately 25,000 rad, 75,000 rad, and 1,000,000 rad respectively were found to be necessary. These results indicate that there is an inverse relationship between radiosensitivity and tissue volume exposed for small volumes, and if the beam

size were further decreased the sensitivity might be very low indeed.

The basis of this increased tolerance is not well understood; it has been surmised that it results from a protection of the irradiated tissue by its unirradiated surroundings. Another explanation, more appropriate to the present experiments, would be that the microbeams cause predominantly a direct radiation injury, whereas the large beams produce additional indirect effects. Other studies suggest that in large radiation areas, vascular disturbances in the form of plasma exudation, hemorrhages and edema play an important role in the pathological development of radiogenic lesions of the nervous system.

Such factors hardly apply to the lesions produced by microbeams, because vessels are only occasionally located within the beam path. Assuming a length of 1,400 mm. of capillaries per 1 cubic millimeter of brain tissue the capillaries would be spaced about 78 microns apart from outside wall to outside wall. This would theoretically permit even a 75 micron beam to pass through the tissue without hitting a vessel. Further support for a direct action by the microbeams is derived from the observation that the lesions are sharply delimited and do not follow any vascular distribution pattern.

It would appear from these results that the biological effects of primary cosmic rays may not be as damaging as has hitherto been supposed. These data also have important implications for basic radiobiology.

Studies of other biological materials. At the University of California, Berkeley, equipment has been completed for study of the heavy particles, carbon, oxygen, and neon accelerated to very high energies. Exposure of several enzymes to radiation from these particles has resulted in inactivation of the enzymes. These same particles have a greater damaging effect on mouse skin and hair than X-rays of the same dose.

Experiments with yeast cells showed that the water content of the cell influences the radiation effect of heavy particles almost as much as it does with X-rays. The heavy particles are more effective than light ones in inhibiting yeast cell division.

Experiments will be expanded in this complex and important field. Additional studies will be carried out with more energetic particles yet to be accelerated.

Studies in Fundamental Biomedical Research

Preceding sections of this report have dealt with studies of mammalian species conducted at Commission laboratories. Much basic

research in cytology, genetics, biochemistry, and other fundamental studies using appropriate plant material, single-celled organisms (bacteria, protozoa) and certain insect cells are conducted at these same laboratories and account for an appreciable percentage of the biomedical research program. Some examples of such research currently under way are reported here.

Seed Dormancy From Gamma Rays

Plant physiology studies at Oak Ridge National Laboratory have been concerned with a hitherto unknown effect of ionizing radiation on lettuce seeds. Seeds given 300,000 to 1 million *r* of gamma radiation fail to sprout when subsequently put in water. Certain chemicals (gibberellin) or physical agents (light) could, however, enable such irradiated lettuce seeds to sprout. Studies of oxygen consumption, mitotic activity, chromosomal abnormalities, and growth rates showed that the gibberellin and other chemicals had "radioprotective" activity specific for the germination phase of development. The effect of gamma radiation on sprouting was not caused by killing, mitotic inhibition, or general inhibition of growth. Rather, the results showed that the effect of the radiation was to maintain a state of physiological dormancy similar to dormancy sometimes found in unirradiated (yet viable) seeds.

Cytology and Genetics

It has been known for several years that some mutation process induced by radiation did not occur instantaneously. The single-celled organism *Paramecium* has proved useful for studying at Oak Ridge National Laboratory the time course of postirradiation processes. In this organism, the rate of mutational damage is gradually reduced until a certain stage in the growth leading to cell division is reached. At this stage the remaining damage leads to final mutation. Reduction of damage can persist for at least a day or probably longer in paramecia that are not growing and dividing. This reduction seems to involve repair or removal of damage by the cell's own metabolic processes, since the rate is greater in paramecia that are metabolizing rapidly than in those metabolizing slowly. About 60 percent of the mutational damage can be averted in this way after irradiation.

In another phase of research at Oak Ridge National Laboratory (dealing with enigmatical alterations caused by mutual genes), starch gel electrophoresis is being employed to screen a series of mutants in

maize which affect starch synthesis. Since the starch gel is the substrate upon which these enzymes act, their rate of migration is dependent upon substrate affinity as well as charge and size. The enzymatic activity of the bands is determined directly on the gel by the iodine test. The banding patterns in sugars and non-sugars show striking differences.

In order to gain information on the processes involved in the repair of radiation induced genetic damage, the effect of protein synthesis inhibitors on the rejoining of chromosome breaks was studied in *Vicia faba*. It was found that high concentrations of chloramphenicol or aureomycin prevented rejoining. Biochemical studies have indicated that these compounds inhibit the incorporation of carbon 14-labeled glycine into the proteins of the bean, but do not inhibit the incorporation of phosphorus 32 into the nucleic acids. These results suggest that protein synthesis in the cytoplasm is involved in the repair of chromosome breaks.

Other fundamental research at Oak Ridge National Laboratory has centered primarily around efforts to determine the radiation sensitive sites in the cell and the ways in which these sites contribute to the activities of the unirradiated as well as the irradiated cell. With an ultraviolet microbeam, it has been possible to demonstrate that the nucleolus in cells of grasshopper embryos is intimately related to the cell's ability to divide and that the nucleolus is a very sensitive site for radiation damage (a high dose delivered to one nucleolus results in cell death). That interference with cell division during development has a significant role in radiation damage is further suggested by genetic studies in the wasp *Habrobracon*.

Nucleic Acid Chemistry

There is now fairly convincing evidence that radiation-induced genetic changes are the result of alterations in the deoxyribose nucleic acid (DNA) of the chromosomes. Further, it appears tha DNA specifies the formation of ribose nucleic acid (RNA) and RNA then participates in protein formation. The proteins through their ability to catalyze chemical reactions control cellular metabolism so that eventually they are involved in duplication of the DNA incorporated into new chromosomes, thus completing the cycle which can be represented in a greatly oversimplified fashion as DNA→RNA→Protein→DNA.

Radiation received during that portion of the cell lifetime prior to the protein→DNA part of the cycle is reportedly the most effective in initiating damage. However, under *certain conditions* appropriate

treatments *can alter* the number of aberrations and "mutations" which are eventually expressed. These treatments include: the use of drugs to delay or depress protein and DNA synthesis; changes in the nutrients available to the cells; addition of metabolic inhibitors; administration of bursts of heat; changes in the water and oxygen content of the irradiated cells; and exposure to red light of a wavelength comparable to that which is instrumental in triggering such diverse biological events as plant growth, the moulting of birds, and shedding of hair by cows. In order to better understand and expand the above information it will be necessary to unravel the specific steps involved in the above cycle. The necessary studies range from the synthesis of the building blocks for DNA, RNA and protein to the development of the most exacting tests for detecting subtle molecular changes. Progress on a number of such studies are described here.

A minor constituent of ribonucleic acids that has eluded identification for several years has finally been identified at Oak Ridge National Laboratory as 5-ribosyl uracil. This is the first carbon-carbon ribofuranosyl compound to be found in nucleic acids.

An enzyme isolated from mammalian liver has been shown to catalyze the formation of deoxyribonucleic acid in amounts greater than that added as a primer. Such "net synthesis" heretofore had been shown only by enzymes from bacteria.

Disrupted *Chlorella* cells, analyzed by differential centrifugation, show the presence of RNA (ribonucleic acid) and of DNA (deoxyribonucleic acid) in both the supernatant and the chloroplast fractions, and each differs from the other in its composition. The intermediate particulate fraction contains only a small amount of the total RNA of the material.

The growth cycle of *E. coli* bacteria and the growth of bacterial viruses (bacteriophage) in the host coliform bacteria afford ideal model systems for studying nucleic acid function and metabolism. An important aspect of the work is concerned with characterizing metabolically active RNA unique to these systems. In the bacteriophage infected system, a hitherto unknown RNA has been discovered. This RNA exhibits a rapid metabolic turnover rate, has an apparent composition similar to the infecting phage's DNA and is formed in the infection cycle when phage-specific proteins are synthesized. These findings have been made possible largely through the availability and use of isotopic tracer compounds.

Hydrogen Peroxide-Decomposing Enzymes

Biological mechanisms which decompose peroxides are of interest to radiation biologists. Radiation produces peroxides in aqueous

systems and the peroxides are implicated as causative agents of radiation damage. Catalase is a hydrogen peroxide-decomposing enzyme, and has been under investigation at Oak Ridge National Laboratory through the "induced" synthesis of catalase in the photosynthetic bacterium, *Rhodopseudomonas spheroides.* Synthesis of catalase in this organism is induced upon contact with air. The actual "inducer" was found to be hydrogen peroxide, which is generated intracellularly when air is present. Additional studies have shown a *de novo* synthesis of the enzyme (protein).

Studies of Effects of Internal Radiation

In this section, the Commission describes studies under way to increase knowledge of the pathways of radioactive materials incorporated into the body either by ingestion or inhalation. Radioactive materials encountered in atomic energy operations—plutonium, strontium, cesium, yttrium, zinc, radon, iodine, polonium, ruthenium and others—as well as nonradioactive toxic materials such as mercury, have been studied. Studies have been made of the distribution of these materials in the body as well as the pathways of excretion and methods of increasing excretion or removing them from the body before serious effects result.

A later portion of this section deals with controlled low level background facilities, often called "whole-body counters." Such counters are useful tools for measuring accumulation of naturally occurring radioisotopes in the body such as potassium 40 and radium, and effects of fallout, as well as in controlling internal exposures in laboratory and industrial uses of radioisotopes.

Radioelement Toxicity—Strontium 90

Age-dependence of strontium retention. Young growing laboratory animals are known to retain a higher proportion of administered radioelements, such as strontium 90, than do adult animals, but the quantitative effects of the growth rate have not heretofore been described adequately. At Argonne National Laboratory the age-dependence of strontium retention has been studied over its entire range of significance in both rats and dogs. Rat data are more nearly complete, but results so far from the dog studies appear quite similar.

Strontium 85 was used in the studies since it is a gamma-emitter which can be traced and measured in the living animal over extended periods of time. The beta emissions of strontium 90 do not have sufficient range to be easily traced or measured in the same way.

Strontium 85 was injected into rats varying in age from 4 to 428 days at the time of injection. As expected, the observed retention patterns varied with age at injection but, by 200 days after injection the coefficients of elimination (fraction of the body burden excreted per day) were the same in all animals within statistical limitations. This indicates that the rat injected at an early age may be expected, after reaching adult life, to treat his strontium burden in the same manner as an animal that received strontium in adulthood. Thus, the mechanisms involved in retention in adult life have not been seen to differ with age at administration.

In rats more than 300 days old, retention of strontium is essentially age-independent, which corresponds to the observation that the rate of calcium deposition in older rats is nearly constant. It thus seems possible to predict, by references to differential growth rate, the strontium burdens which an animal will achieve under conditions of constant exposure.

In the analysis of mechanisms of skeletal biochemistry the assumption is usually made that the animal is in a steady state, that is, that on the average its daily absorption of food (or calcium) exactly equals excretion. In the rat, no steady state is ever reached: the animal grows steadily throughout adult life. From a study of existing literature it is impossible to state whether or not all species, including man, grow slowly during adult life. The possibility certainly exists, and the retention of strontium would be influenced to some degree by such a possibility.

Toxicity of strontium 90 in mice, dogs, and cats. The potential hazard of environmental contamination with strontium 90 is being examined by exposing large numbers of mice to a series of doses leading to acute lethal effects and to dosage levels comparable to 5 times the maximum body-burden deemed permissible for occupational exposure.

At Argonne National Laboratory one group of 960 mice received a single intravenous injection at approximately 70 days of age of a strontium 90-yttrium 90 equilibrium mixture. With the numbers of animals used, no significant changes in life expectancy or bone tumor incidence could be observed at doses below 10 μc/kg (microcuries per kilogram) of body weight, or, at half this dose, in tumors of blood-forming organs. Selection from among the many conceivable types of dose-response relationships will require studies on a much larger population.

A second group of 821 mice is receiving strontium 90 at several dose levels in a continuous feeding experiment. Approximately one-fourth of these were placed on the diet just before they were bred; they

produced 595 mice which have been exposed to a constant strontium 90 to calcium ratio since they were conceived.

Preliminary data indicate that a diet containing 10 μc strontium 90 per gram of calcium (10 million strontium units), the highest level used, did not interfere with conception, gestation, parturition or lactation. However, malignant bone tumors and an increase in the number of tumors of the blood-forming tissues have been observed among those mice maintained at this level since conception. One-half this dose, or 5 μc strontium 90 per gram of calcium has had no apparent effects to date on carcinogenesis. The incidence of osteogenic sarcomas is much lower than that following the administration of strontium 90 as a single intravenous injection. For example, 6.5 percent of the mice maintained since conception on the top-level diet had malignant tumors by 525 days of age. Those which received the same total amount in a single injection, showed an incidence of about 80 percent.

These experiments were supplemented by smaller series of exposures of dogs and cats to strontium 90. Bone changes resulting from a single intravenous injection of 150 μc/kg of body weight are being studied in one group of adult dogs and cats. Sixty-seven percent of the dogs so injected had osteogenic sarcomas (malignant bone tumors) at death, and 50 percent of the cats had tentatively-diagnosed hemangioendotheliomas of the bone. It was estimated that a comparable dose in mice would induce osteogenic sarcomas in 9 percent of the population and hemangioendotheliomas of bone in 6 percent.

The effects of age and uniformity of strontium 90 distribution upon bone pathology are being examined by comparing dogs that received a single injection with those that are receiving total doses of 15 or 150 μc/kg by fractionated doses, injected subcutaneously 5 times a week for 1 year, beginning at birth or later. Another group of dogs was treated before birth. The injection of one litter of dogs was discontinued at 4 months of age because of development of multiple bone fractures, most of which have healed, or are healing, normally. Several dogs of another litter died with hematologic symptoms of acute radiation injury. All the dogs at this level have shown abnormal development of the permanent teeth, and several malignant tumors have appeared.

Renal clearance of strontium and calcium. Renal clearance resulting in excretion in the urine of strontium 85, introduced into the body by injection, is being compared with that of calcium in female dogs in studies at the University of Rochester Atomic Energy Project. A double tracer experiment using strontium 85 and calcium 45 has been

conducted. From these experiments, it is clear that the kidney discriminates in favor of strontium 85 excretion by both (*a*) allowing a more rapid filtration of strontium 85 than calcium and (*b*) accomplishing less reabsorption of the strontium 85. This kidney discrimination seems to be an important part of the overall biological mechanisms by which strontium 85 and calcium are metabolized.

Strontium 90 versus calcium in body. In a continuing series of experiments at Hanford Atomic Products Operation with mature and growing rats, the biological discrimination between strontium 90 and calcium has been shown to vary widely as a function of dietary calcium level, the age of the animal, and the duration of the experimental feeding period. These experiments indicate the limitations of any system of hazard evaluation based solely on strontium 90-to-calcium ratios. A four-fold increase in total calcium intake of mature rats, over normally adequate levels, caused no decrease in strontium 90 deposition and retention in the bone during 100 days of chronic strontium 90 feeding.

Extensive work on uptake of strontium 90 into plants has provided several lines of evidence that a strontium 90/calcium ratio in the soil (and probably other ratios of this type) has limited application in evaluating hazards. Uptake of strontium 90 versus calcium is not uniform, and is influenced, for example, by the prolonged period before newly added strontium 90 attains a state of equilibrium with existing calcium in the soil. Also as strontium and calcium move through the plant their relative concentrations change in different plant parts so that the hazard, if based on the ratio, is dependent on the part of the plant eaten. Contamination by direct fallout on vegetation is of greater significance than soil ratios at the present time.

Ecological studies of fission products. The kinds and amounts of fallout radioisotopes found in plants and animals from major, ecologically different habitats in Washington State were compared at Hanford. Highest concentrations of radioisotopes were found in specimens collected from the highest elevations with the heaviest rainfall. Lowest values occurred in samples from the arid plateau of eastern Washington.

Accumulation of cesium 137 was compared in plants growing under aquatic, semiaquatic, and terrestrial conditions and experiments to define better the effects of environmental factors upon the accumulation of cesium 137 by organisms in an aquatic system were carried out. Zinc 65 was introduced into aquatic communities to study its accumulation and transfer within the total environment. There was

a rapid accumulation of the isotope by plants and animals during the first day followed by a gradual uptake that continued beyond 3 weeks.

Studies of Other Toxic Elements

Biological effects of radon inhalation. Radon gas and its associated decay or daughter products are present in the air in uranium and some other mines. A series of studies has been conducted at University of Rochester, using principally mice and rats, to determine the biological effects of inhaling these substances. Early experiments used acutely toxic concentrations. At levels of 0.2 millicurie per liter, given in single doses of a few hours duration rather than by continuous exposure, and in an atmosphere containing few daughter products, the changes are comparable to those seen after whole-body external radiation. Specific organ damage may be quite extensive. particularly in the kidney.

Later experiments have used concentrations some 10 times greater than the highest found in poorly ventilated mines. An experiment just completed utilized almost continuous exposure for 7,300 hours to a level of 0.4 microcurie per liter. The life span of the test animals was found to be reduced to one-half the control median life span of the controls. The radiation dose to the lungs was some 10,000 rad, while that to the rest of the animal was about 100 rad. Extensive pulmonary damage occurred, but there was a notable absence of lung cancer. Studies of the detailed distribution of the daughter products formed in the living animal are under way.

Plutonium and fission products. In inhalation studies at Hanford, dogs and mice inhaling relatively insoluble radiostrontium sulphate particles showed rapid translocation of the material to bone after both single and repeated daily exposures. Inhalation of relatively insoluble silver radioiodide particles by mice and sheep also translocated rapidly to the thyroid. In other studies with mice and sheep, thyroid tissue contained about 3 percent of total iodine 131 inhaled as vapor. Thyroid tumors were observed in 4-year-old sheep following daily administration of 1.5 μc per day of iodine 131. The total radiation dose to the thyroid gland, including *in utero* exposure, was about 5,000 to 10,000 rads. This is about one-third the dose previously observed to cause thyroid tumors in sheep when the iodine 131 was given acutely.

A 2-year study at Hanford using young miniature swine was performed to relate plutonium blood and excretion values to body burden

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as a function of different routes of administration. The percentage of the administered dose of plutonium 239 retained following intravenous administration was found to be 2,000 to 4,000 times greater than after intrapulmonary administration, and about 20,000 times greater than after oral administration. At autopsy, 30 and 600 days after plutonium 239 administration, the liver in all groups showed a higher concentration than bone. The rate of plutonium elimination was found to be dependent on the route of administration and was slowest after intravenous administration.

Gastrointestinal absorption of strontium 90 orally administered to mature swine essentially ceased within 10 hours after administration and less than 10 percent was absorbed. In miniature swine, over 20 percent of the administered dose was absorbed and the majority was deposited in bone. The percentage of absorption was dependent on the degree of maturity. These studies were preliminary to a long-term strontium 90 toxicity program in miniature swine receiving daily rations of strontium. This program was initiated this year.

Rats were shown to withstand remarkably high levels of chronic irradiation from ingested yttrium 90, a nonabsorbed, energetic beta-emitter. Animals surviving 2 months of daily ingestion of 0.5 mc yttrium 90 have been followed for 200 days without detrimental effects having been observed. The mechanisms of intestinal radiation damage are being studied in terms of effects of glucose transport on *DNA* and *RNA* levels (desoxyribonucleic acid and ribonucleic acid) and on the enzymatic processes involved in the control of these levels.

Plutonium and polonium studies. When a radioactive particulate is inhaled, its behavior in the body and its elimination may be quite different from that of an inhaled gas. As a corollary to work on radon, studies under way at the University of Rochester to determine the residence time in the lung, the excretion pattern and, in a few instances, the biological effects of such alpha emitters as polonium and plutonium when administered as aerosols. In addition, field experiments with exposure to fission product aerosols were carried out at the National Reactor Testing Station, Idaho.

Results to date indicate that the principal organs of deposition, the excretion pattern, and probable ultimate effects cannot be predicted with certainty from experiments utilizing injection rather than inhalation of a material. The information from inhalation experiments, of course, is in a form which is more directly useful for the calculation of various permissible air concentration values for these materials.

Using the autoradiographic method, it was found that appreciable radiation doses can be delivered to the bronchial tubes by movement

of radioactive materials over the surface within certain scavenging cells, or by action of the hair-like cilia of the mucous lining. Of particular interest is the demonstration of accumulations of radioactive materials at branchings in the bronchiolar tree, areas long ago found to be sensitive sites for cancer development in man. In general, the concentrations of radioactive materials used in these studies were sufficiently low to produce little or no biological action. However, in some experiments in which polonium was injected into the bronchi of rats, there is clear evidence for the production of lung tumors.

The lungs from a few animals 30 to 140 days after inhalation of aerosols of polonium 210 and plutonium 239 were found to have undergone some structural changes consistent with radiation effects. The total dose to the lungs was estimated to be between 1,000 and 2,000 rads minimum; however, the lungs from other animals receiving comparable exposures did not exhibit changes. Tentatively, it appears that alpha emitter exposures are effective for acute yet minimal damage. The production of other effects, including changes in the circulating blood, are being determined in experiments now under way.

Polonium 210 binding by blood constituents. A 3-year study on the *in vitro* binding of polonium 210 blood constituents was concluded in 1959. The filterability of polonium in mixtures containing various blood constituents at near blood pH (acid-alkaline balance) was determined with ultrafine millipore filter paper.

The conclusion was that, in tracer concentration, any polonium carried in blood in a diffusible form is probably bound about 75 percent to citrate and about 20 percent to bicarbonate, the remaining few percent being complexed by malate and phosphate ions. It was concluded further that the polonium-affinity should be relatively strong for most plasma proteins, since the binding is not limited to any one functional group. A practical byproduct of this study was a spontaneous-plating technique for polonium analyses refined to give 99 percent accuracy.

Other studies on plutonium and ruthenium. A preliminary study at Hanford of the pathologic effects of intratracheal injection of radioactive particles in lungs of mice was completed. Malignant tumors were observed after intratracheal deposition of 0.15 to 4.5 microcuries (μc) of insoluble ruthenium 106 dioxide and after deposition of 0.003 to 0.06 μc of insoluble plutonium 239 dioxide.

Deposition of 0.3 μc of plutonium 239 in a single inhalation exposure resulted in 80 percent mortality to mice after 9 months. Lesser quantities caused fewer deaths but gross examination of mice 500 days

after inhalation of plutonium or radioactive ruthenium showed large numbers with lymphatic damage and a few with pulmonary changes. Dogs retaining 25 to 50 μc 1 week after inhalation of plutonium 239 dioxide showed an early drop in total leukocytes, became pneumotoxic and survived only 3 to 4 months. Other effects observed in dogs with pulmonary deposits of plutonium 239 include a gradual decrease in circulating lymphocytes over a 2-year period.

Studies of the behavior of inhaled ruthenium 106 and plutonium 239 were completed. In mice, pulmonary clearance was rapid for all but about 3 percent of the total deposited aerosol; a biological half-life of 230 days was found for ruthenium 106 and 460 days for plutonium 239. Translocation of small percentages of ruthenium 106 and plutonium 239 to bone and several soft tissues was observed, but at the end of about 70 weeks 60 to 70 percent of the retained body-burden remained in the lung. In preliminary experiments with dogs much longer pulmonary retention was found. The concentration of plutonium 239 in the tracheobronchial lymph nodes of these dogs 40 weeks after inhalation was many times that of the lungs. Further studies are in progress to define the behavior and effects of inhaled plutonium 239 dioxide in dogs as a function of particle size and concentration after single and weekly exposures. A whole-body monitor capable of detecting gamma rays from plutonium isotopes is being used in these studies.

Liver lipid response to rare earths. Studies at the Oak Ridge Institute of Nuclear Studies have shown that intravenous injection of rare earths with low atomic numbers produces fatty infiltration in the liver of rats. This infiltration is maximal 48 hours after injection and is characterized by a marked increase in neutral fat esters. Total cholesterol and phospholipids of the liver in the treated rats were similar to those in control rats.

Cerium was found to be effective in producing extremely high levels of liver fat in female rats of the several strains tested. Male rats treated in the same way did not exhibit the consistent response or the high liver-lipid levels that were seen in the females.

After castration, the response of male rats resembled that of females. Injection of the male sex hormone, testosterone, caused a significant reduction in the fatty infiltration induced by cerium in both intact females and those with the ovaries removed. Removal of the pituitary gland prevented fatty livers in both females and males, whereas removal of the adrenal glands did so only in males.

Choline and methionine had no protective effect against cerium. Tracer experiments involving cerium 144 demonstrated that most of

the radioactivity appeared in the acid-soluble fraction of the liver and that the lipid fraction contained essentially no tracer.

Radiation and cell permeability. For many years it has been difficult to show that the biological effects of radiation noted *in vitro*—for example, using purified enzymes in dilute solutions—could be related to radiation effects in the intact cell. Some years ago, research at the University of Rochester showed that damage in certain cellular enzyme processes could be brought to light if the solution were depleted in electrolytes, or if starvation of the cell or treatment with ion exchange resin reduced the relative amounts of materials available to scavenge free radicals. More recently it was found that, in yeast cells at least, radiation produces a basic defect in the transfer of electrolytes across the cell membrane. For example, the cell loses its ability to retain potassium. This has been found both by measuring the appearance of potassium in the suspending medium and by measuring the rate of efflux of potassium from irradiated as compared with normal cells.

An extension of these studies, with yeast cells as the model system, has revealed certain interesting similarities between the acute effects of radiation, high oxygen tensions, and mercury poisoning. All three agents appear to have thresholds, that is, certain levels must be reached before any effect is noted. Each individual cell is either killed or unaffected by the dosages, but, with increasing dosages, a greater percentage of cells is killed. Certain sulfhydryl compounds and other redox dyes have an antidotal effect, which may indicate that cells die as the result of destruction of a structural substance (containing sulfhydryl) which is required for maintenance of an intact and normally functioning cell membrane.

Mercury program. Because the effects in man of chronic exposure to mercury are principally neurological in nature, a program of animal experimentation was begun, designed to detect behavioural changes resulting from low-level, chronic exposures to mercury vapor.

The "pecking pattern" of pigeons is currently under study because this approach has been successfully applied to the investigation of certain psychogenic drugs.

The metabolism of mercury in the rat has been followed at the University of Rochester using single and multiple, intravenous and intramuscular injection. The mercury is excreted in three phases. The first is rapid (half-time of a few days) associated with an initial high level of mercury in the liver which is excreted by the fecal route. The second and third phases are associated with accumulation of mercury in the kidney and its excretion in urine. The second phase

has a half-time of about 25 days. The third phase, a very slow excretion, is seen only after about 2 months when the mercury remaining in the body is reduced to about 15 percent to 20 percent of the original burden.

The equilibration of mercury vapor with blood proceeds quite rapidly in the presence of oxygen. The metallic mercury dissolves and then is oxidized to mercuric form. The latter is bound by serum proteins and red blood cells to the extent of 99 percent.

With perfused isolated rat kidney it has been demonstrated that 5 to 15 percent of the mercury in the blood is deposited in a single pass. Because less than 1 percent of the mercury is filterable, it is suggested that most of the mercury is cleared from the blood by tubular and interstitial cells, rather than by filtration.

Studies on Removal of Isotopes from Body

Various chelating materials for administration as therapeutic agents after accidental human inhalation of radioactive particles have been studied at Hanford with encouraging results. In experiments with mice, sodium chloride aerosol and several more noxious materials effectively increased whole-body clearance of insoluble ruthenium 106 dioxide.

Diethylenetriaminepentaacetic acid (DTPA), formerly reported as an effective agent for plutonium removal, has been further investigated in rats as to dosage requirements, routes of administration, and treatment modification. This agent was found superior to ethylenediaminetetraacetic acid (EDTA) and other agents in many respects.

Limited testing in humans indicates that DTPA may have promise as a practical therapeutic agent; also, it is the only agent tested, so far, that shows promise of being effective upon oral administration.

Screening test for protective agents. A radiation dosimeter, containing the dye erioglaucine has been developed at Hanford. It has a sensitivity such that 10 rads of radiation cause complete bleaching. The effect is independent of the energy of the intercepted X-ray photons and of the dose rate.

An important use of this dosimeter is to evaluate the ability of chemicals to protect other chemical systems from radiation damage. Some compounds added to the dosimeter solution decrease bleaching by competing with the dye for free radicals formed by radiation. This colorimetric test can rapidly screen numbers of potentially useful agents for radiation protection which then can be tried in experi-

mental systems. One of the best of these materials proved to be the dye itself (Erioglaucine A). Preliminary experiments indicated that the erioglaucine offers significant protection to mice and rats.

Whole-Body Counters

Biological data currently available clearly indicate that many radioisotopes encountered in atomic energy operations show different behavior in animals than in man. The whole-body counter is the key equipment used in planned studies in man and the further development and use of this equipment is being supported wherever the talents and interests of a group of investigators become available. Experiments over long periods should produce data, ratios, and factors correlating body burden in man with intake of radioactivity in foods and water and/or with rates and absolute amounts of activity in body wastes. Such figures are needed to specify realistic values for maximum permissible concentrations and levels as recommended by the National Committee on Radiation Protection and Measurements. The whole-body counter is rapidly taking its place as a research tool for study of metabolic disorders in human patients.

The Los Alamos Scientific Laboratory is constructing an improved model of the original liquid scintillation whole-body counter which has been in operation since 1955. This type of counter is extremely useful for screening large numbers of people for both natural and artificial radioactivity in a short period of time. The new instrument is expected to have considerably increased sensitivity and versatility, and will be used in a variety of research projects, including the utilization of radioisotopes in medical research and diagnosis.

The low level counting facility in use at Argonne National Laboratory,[40] currently is being improved. At present, it is able to measure in the human body 10^{-9} curie (1 millimicrocurie) equivalent of a gamma ray emitter if the energy is greater than 30 Kev.

This sensitivity will be increased through the use of construction materials with less inherent radioactivity, anticoincidence devices for reducing the cosmic ray background, and a new coincidence summing technique.

When these modifications are completed, the Argonne staff may be able to measure, for example, an amount of natural radium in the human body as small as 10^{-10} curie (one-tenth millimicrocurie).

This increase in sensitivity is expected to have practical application, as, for instance, in studies of individuals with low body burdens of radium.

[40] See pp. 161–162, Twenty-fourth Seminannual Report (January–June 1958).

The measurements possible with the improved techniques will enable investigators to study an additional 150 individuals with lower radium body burdens, bringing the total studied at Argonne to over 400.

Use is being made of the low level counting facility to study potassium content of human beings in relation to heart disease, cirrhosis of the liver, muscular dystrophy, and other metabolic states in which potassium is involved. One value of the Argonne techniques is that gamma emitters now can be used as tracers using about one one-hundredth to one one-thousandth the quantity formerly necessary.

The Los Alamos Scientific Laboratory and the Hanford Works also have crystal-type counters, similar to the one at Argonne. It is felt that such instruments will have increasing importance in the field of clinical medicine.

The 8-inch steel wall, low-level, counting facility at the Argonne Cancer Research Hospital has been completed and scintillation crystals are being installed. Studies on the metabolism of strontium 85 and other fission products in man will be carried out in this facility.

Construction of a "Shielded Personnel Monitoring Station" was completed at Hanford and the facility was occupied at the beginning of 1959. A 4 x 9⅜-inch sodium iodide scintillation counter and a 256-channel pulse analyzer were obtained. Resolution and background studies were made with different photomultiplier tubes in the scintillation counter, until there was obtained a counter with resolution as good as most smaller counters. People who risk being contaminated in plant operations are examined in the facility, and routine inspection was begun of a limited number of people at the background radiation level.

A similar facility has been constructed at the University of Rochester to measure gamma radioactivity of human subjects. This follows, in general, the Argonne design. The low background afforded by the iron shield permits the detection of cesium 137 and potassium 40 as they occur in man. This facility, located at the Medical School, is being used to aid research on obesity of children and in nutritional deficiencies by the measurement of body potassium. It is planned to extend its use into other areas of medical research where knowledge of the distribution and excretion pattern of key gamma emitting tracer materials may be important.

Counters are also under construction at the University of California at Los Angeles and at Berkeley. These facilities will be used to monitor the radioactivity in people and foods from the local geographical area. It will also be a valuable tool in studies of many human diseases utilizing small tracer doses of radioisotopes.

Another counter utilizing an 8 x 4-inch crystal and a 200 channel analyzer is under construction at the Oak Ridge National Laboratory. In addition to serving as a complement to the body fluids analysis program, it is anticipated that this counter will enable more determinations to be made in cases of exposure to insoluble gamma-emitting isotopes.

At the National Reactor Testing Station, installation of the scanning mechanism in the 11-inch thick armor plate, whole body counter was completed in November. When resolution and background studies are completed, determinations of gamma-emitting activity will be made in personnel who risk internal contamination at the Station.

A single 8 x 4-inch sodium iodide crystal will feed information into a 256-channel pulse analyzer. Provisions have been made to change to a series of smaller crystals if greater resolution is required. Although inherent background radiation of the whole body counter is low, as a result of using armor plate produced prior to 1945, triple distilled mercury will practically envelop the crystal and photomultiplier tube. Among other unique features, is a scanning crystal that will traverse a patient horizontal and longitudinal distances in discreet steps to establish a grid or histogram of activity in a body profile.

As operating knowledge is gained, use of the counter will be expanded to analyze large animals in the 94 x 53-inch diameter cubicle to better develop a correlation of body burden between man and animal.

Radiation Effects on Populations

In the continuing investigations of the effects of low-level radiation on human populations, the Commission has studied people who live in radioactive regions or drink radioactive water and people who were exposed to radiation at Hiroshima and Nagasaki and at Rongelap Atoll, as well as exposures related to research, industrial activities and medical therapy.

Radium Dial Painters

The Argonne National Laboratory, working with the Argonne Cancer Research Hospital, is conducting studies of individuals once employed as radium dial painters. The program, started 10 years ago at Argonne, has been enlarged in recent years to include studies being made, under contract with the Commission, at the Massachusetts Institute of Technology and by the New Jersey State Department of Health.

The Argonne work has led to devising the physical methods whereby quantitative measurements of the radium in the body may be determined, and the clinical criteria for detecting any indications of damage. Some 225 former radium dial painters, including 135 from the Ottawa, Ill., area, are under study at Argonne National Laboratory. The body burdens of radium and its daughter products is being measured in the Laboratory's low-level counting facility, while the degree of physical disability is being estimated from an X-ray survey of the patients' bones. To date, the radiographs of over 175 of the patients have been analyzed, and a third series of radiographs has been made of patients at Elgin State Hospital, Illinois.

Of especial interest is the increasing frequency of occurrence of epidermoid carcinomata arising in the mastoid air cells of patients carrying a body burden of radium. Two new cases of epidermoid carcinoma have been seen and proved by surgery in the past year and a third suspected on radiographic grounds. This brings the total to six (possibly seven) under cognizance of this group.

Special techniques have been devised for study of the intimate blood supply of bone to elucidate the mechanism of bone destruction in such cases. Histologic study of the bone and the epithelium in the mastoid process will continue, in order to understand better the mechanism of carcinogenesis in this specific site in radium patients.

Background Radiation Measurements

Water supplies. As part of a comprehensive program aimed at a detailed knowledge of the natural radioactivity present in the human body, Argonne National Laboratory has been surveying two of the isotopes of radium (radium 226 and radium 228) in certain water supplies in Illinois. About one-half the water supplies in 600 municipalities have been surveyed and plans have been made to accelerate the survey in the rest of Illinois and in pertinent areas of Iowa, Wisconsin, and Missouri. Thus far it has been shown that in about 10 percent of the localities surveyed the radium 226 content of the water is above 3 micromicrocuries per liter—about one-third the level deemed permissible.[41]

Radon. In order to correlate the normal radioactivity of the human skeleton with that of its water supply, an extremely sensitive method

[41] National Bureau of Standards Handbook No. 69 gives the maximum permissible concentration of radium 226 in water as 4×10^{-7} microcuries per milliliter of water for a 40-hour week, or 100 micromicrocuries per liter of water for a 168-hour week. The maximum permissible level for large populations is therefore 10 micromicrocuries per liter. The measured value of 3×10^{-9} micromicrocuries per milliliter of water, i.e., 3 micromicrocuries per liter, is 33⅓ percent or one-third of the large population maximum permissible level.

has been devised at Argonne National Laboratory to measure the radon produced from the radium in the human body. In view of this method's technical difficulties, other approaches to the problem are being investigated, namely, the measurement, when available, of bone samples secured at autopsy or surgery. Chemical techniques necessary to measure the amounts of radium 228, thorium 228, and radium 226 which may be present in specimens of normal bones have been developed. Since tooth surveys may be of questionable value, an investigation is under way to determine their validity.

Such findings will complement studies on long-term metabolic effects of radium 226 under natural conditions of intake. This work also will assist in extrapolation of the results of strontium 90 metabolism studies.

Acquired Radioactivity in Bone

The radioactivity of several hundred people who have acquired relatively high burdens of radium through industrial exposures is being studied to correlate the incidence of pathology with increased skeletal burden.

A national search for such individuals through the cooperative efforts of several laboratories thus far has located almost 1,000 individuals and more than 200 have been measured and examined medically.

Through the cooperation of medical institutions throughout the country, a survey has been started of radium 228 and thorium 228 content of the tissues of patients subjected to diagnostic procedures using thorotrast (a thorium contrast medium). Though far from completed, this study may identify a large number of people whose medical history and future health will assist in studies to establish maximum permissible limits of radioactivity in the human skeleton. Pertinent to metabolic aspects of the work have been two studies: a 6-year followup of one individual who inhaled a small quantity of radium; and a basic approach to the path and pattern of microscopic deposits of alkaline earths in bone. The second study will help in interpretation of bone pathology arising from incorporation of strontium 90 in bone under various conditions of intake.

Statistical Analysis of Data

Accurate figures concerning possible effects of radioactive fallout on human populations are subject to a number of possible errors. For

example, bone tumors and leukemia are two diseases often discussed as possible direct effects of radioactive fallout. But deaths from these diseases are relatively rare, the statistics on incidence are subject to serious question, and small increases, if they occurred, would be difficult to detect.

The average normal death rate from bone tumor in this country is reported at about 1.2 persons per 100,000 population per year; the rate of leukemia deaths is given as about 6.6 per 100,000 population per year. These represent an average of 2,000 and 10,000 deaths per year, respectively, in the United States. Since total deaths per year in this country from all causes average 1.5 million, bone tumor fatalities represent 0.1 percent of this total and leukemia deaths represent 0.7 percent.

Present increases in radiation from weapons tests fallout cause only a small increase in the background radiation normally present in the environment. The effects of added radiation above background levels—if any such effects are produced—might be to increase death rates from bone tumors and leukemia a small amount, assuming that a fraction of the incidences were specifically due to background radiation.

Two major areas of difficulty in obtaining accurate figures for bone tumor and leukemia death rates are: (*a*) the causes of death may not be correctly recorded on death certificates; and (*b*) death rates vary widely among populations depending on a large number of variables such as age, sex, racial composition, economic status, and occupation.

Argonne National Laboratory is studying the accuracy of death certificate reports on bone tumor as the cause of fatality. Early analysis of the data indicated that in up to 50 percent of the cases examined, deaths ascribed to bone tumors actually were not due to this cause. A study in England showed that, of 32 cases accepted as leukemia after careful study of pathological material, only 22 were reported as leukemia on the death certificate. Another 5 were classified as "suspicious," but did not have a final diagnosis.

Other difficulties arise in estimating exposure of a population resident in a given area because of the movement of people into and out of the area, because of wide variations in behavior, and because a population sample must be large to produce meaningful statistics.

Cancer Research

Much atomic energy work in the field of cancer research involves the therapeutic use of radiation. In this section of the report, the Commission describes some studies on mechanisms which produce

cancer as well as recent developments in using radiation for cancer treatment.

Therapeutic Linear Accelerator

A 50 Mev, moving-beam, linear accelerator for use in medical studies was placed in operation at the Argonne Cancer Research Hospital this year. Dosimetry of the linear accelerator has been worked out for a number of treatment possibilities and treatment of patients with different types of cancer was begun in mid-June 1959. Since that time, treatment of two patients has been completed and four others are currently undergoing treatment. Thus far, indications have been favorable.

The unit is very flexible in beam alignment, permitting adjustment to the needs of the patient. Fields of unusual shape are easily obtained to fit the peculiar requirements of the tumor being treated. Studies of various energies, field sizes and shapes of radiation have demonstrated a sharper end point to the dose distribution in depth and sharper definition at the edge of the field than had been expected. Stray radiation to the patient outside the treated area is very low—of the order of only 2 to 3 times the permissible dose set for workers occupationally exposed to radiation.

Studies of Liver Tumors

At Argonne National Laboratory, mechanisms of carcinogenesis are being investigated in a biochemical and cytological study of rat liver during prolonged administration of 2-acetylaminofluorene (AAF) which produces cancer of the liver. Other workers have shown that grossly recognizable tumors do not appear until 200 or more days after the start of administration. AAF must be continuously administered about 50 to 75 days since further administration does not greatly increase the incidence of tumors. This suggests, first, that malignant cells are not produced unless administration of the carcinogen is continued beyond the time required to produce a significant threshold effect of an undefined nature; and, secondly, when the transformation does occur, it takes place within a relatively short period of time. The present experiments were designed to study these possibilities further.

Rats continuously fed AAF grew at a reduced rate; liver weight increased after a relatively brief initial decrease. Determinations of total cells per liver revealed a characteristic pattern: an initial period in which no change appeared, followed by a rapid increase as the

carcinogenic period progressed. The curves for different rat strains and different starting weights were similar in form, but the time of onset of rapid cell proliferation occurred later in larger livers. Regardless of the time of onset, the period was associated with a number of deaths limited to this period.

These and related findings suggest that a crisis was precipitated by a decrease in the functional capacity of the liver, that the crisis necessitated a rapid proliferation of liver cells to maintain life. This critical period, defined in physiological terms, apparently corresponds to the critical period through which administration of the carcinogen must be continued to produce tumors.

It seems probable that the malignant change occurs during the period of cell proliferation and that, once the change has been initiated, further administration of the carcinogen is unnecessary to the production of cancer. It is estimated that to produce 100 tumors in a liver, such a malignant change would have to occur in only one in a million of the new cells produced. The malignant change appears to be sudden and complete, possibly taking place within one- or two-cell generations.

Treatment of Patients with Advanced Cancer

Studies of marrow autografts. Preliminary work indicates that it is possible to remove marrow from a patient, store it while the patient is treated with irradiation or an anticancer drug, and then reinject the marrow. A graft of the patient's own tissue is referred to as an "autograft." Such a technique might furnish undamaged compatible cells which could serve as a basis of recovery of the blood-forming tissues from the damaging effects of irradiation or drugs and thus allow these agents to be used in higher dosages than formerly.

Bone-marrow therapy. Autologous bone-marrow has been used to treat a patient with an inoperable carcinoma at Argonne Cancer Research Hospital. The marrow was withdrawn from the patient and stored prior to his exposure to 700 *r* (roentgens) of X-ray radiation from a 2 Mev (million electron volt) Van de Graaff machine. After exposure of the patient, the bone-marrow was reinjected. Studies are being made of the patient's progress.

An effort is being made at Oak Ridge Institute of Nuclear Studies to demonstrate the usefulness of an autograft of bone-marrow in conjunction with nitrogen mustard therapy. The methods of aspiration, dilution, and infusion of bone-marrow are the same used for total body irradiation and marrow treatment of patients with acute leukemia. A group of patients was selected whose disease had pro-

gressed beyond conventional therapeutic measures and who did not have demonstrable metastases of cancer of bone. They were given a large dose of nitrogen mustard intravenously under general anaesthesia. About 120 ml. of their own bone-marrow was withdrawn just before the drug was administered. The diluted bone-marrow then was infused intravenously after 4 to 6 hours later. No conclusions with regard to the success of the bone-marrow autograft can be drawn at this time. Two patients have responded encouragingly to the large dose of nitrogen mustard with marked regression of lesions.

Recent Developments in Thyroid Carcinoma

Refinements in use of radioiodine. Investigations at the Oak Ridge Institute of Nuclear Studies Medical Division have led to some improvements in the treatment of carcinoma of the thyroid. Emphasis has been placed upon improved techniques for locating and excising surgically the early metastases, particularly metastases to the lymphatics of the neck.

According to this plan the normal thyroid gland is removed as completely as possible, even if more than one operation is required. After an interval, as much as 10 millicuries of radioiodine are administered and very careful scanning techniques employed for locating areas of residual tumor even though they have little functional activity. Scans made several days after administration of the dose are more informative than those made early. This is because unbound radioiodine has left the body by this time and the "background" radiation level has fallen so that even a small amount of the radioisotope bound to the tumor can be located.

Improved scanning techniques, including use of a linear scanner, have helped in locating these small areas of tumor. Improved surgical techniques involve the use of a special surgical probe for locating and removing the residual areas of tumor. Preliminary results suggest that repeated conservative attacks based upon the known location of the tumor may be more valuable than radical surgery performed without the benefit of radioiodine localizing studies.

Supporting Laboratory Studies

Studies with mice. Preliminary work done at the University of California Medical Center, Los Angeles, has indicated an increased incidence of leukemia, a cancer of the blood, in newborn (C3Hf x AKR) F_1 hybrid mice when injected subcutaneously with

nucleic acids extracted from tissues of leukemic and normal AKR mice. No increased incidence of leukemia was observed in similarly injected C3Hf/Gs or C57BR/cd mice.

The results of intravenous injections of nucleic acids prepared from leukemic AKR mice spleens and lymph nodes in over 50 (C3Hf x AKR) F_1 hybrid mice indicate that preparations given by this route do not produce leukemia in animals up to 6 months of age.

To test the possibility of genetic transformations being involved in the first tests, similar preparations of AKR nucleic acids were administered intravenously to newborn C3Hf/Gs mice. At 6 weeks of age these animals then received injections of cell-free extracts of AKR leukemic tissues. This group also has shown no increased incidence of leukemia in animals up to 6 months of age.

The leukemogenic effects of cell-free filtrates of leukemic tissues combined with X-ray irradiation in adult mice of a low-incidence-leukemia strain also are being studied at the University of California Medical Center, Los Angeles.

Mice of the CF_1 strain, normally resistant to lymphatic leukemia of mice of the DBA/2 strain, will succumb to the disease if weakened with a low dose of X-rays. The histologic picture in the sensitive DBA/2 strain is that of an orderly series of stages through which the leukemia progresses. Irradiated CF_1 mice, on the other hand, showed a random pattern of spread due to variation in loss of resistance by each tissue. The liver of the irradiated CF_1 mouse never was infiltrated by leukemic cells, and the implications of this resistance are being explored at the Argonne Cancer Research Hospital.

Studies of radio-enhancing substances. Investigation of the effectiveness of triiodothyronine (T–3) (a thyroid gland regulator) in enhancing the biological action of ionizing radiation is continuing. The onset of spontaneous leukemia in the AKR mouse is speeded by low doses of irradiation, and T–3 further shortens the time of appearance of tumors, followed by death. On the other hand, administration of T–3 does not result in any additional depressing effect on the regression of thymus and spleen weight following total-body doses between 200 and 600 *r*; neither is the fall in peripheral blood elements following irradiation amplified. Experiments are in progress to determine whether the action of T–3 in enhancing radiation effect is due to increased metabolic rate and/or oxygen consumption, or increased cell division in the tumor at the time of irradiation.

The use of l-triiodothyronine in conjunction with radiation in the control and ablation of various tumors has been found to be effective

both in clinical patients and in experimental animals, although some toxicity has been noted in patients subjected to prolonged treatment. In an attempt to discover a method of eliminating the deleterious effects of prolonged continuous use of the drug, it was administered alternatively with X-rays at various intervals to treat various animal tumors, and results suggest that there is a definite relationship between times of administration of the drug and X-irradiation.

Research on Blast and Burns

The Commission has supported a small program on damage from burns and blast related to detonation of nuclear devices but this work is being transferred to the Department of Defense. Some of the accomplishments in these areas during the reporting period are summarized in the following sections.

Research in Blast Biology

Operation of the Commission-Lovelace Blast Facility located at Sandia Base, Albuquerque, N. Mex., by the Lovelace Foundation for Medical Education and Research has yielded data concerning primary (pressure) blast effects in four species of animals (mice, rats, guinea pigs and rabbits) exposed in a shock tube to overpressures of comparatively long duration in which the pressure increases consisted of single and double, sharp-rising steps. Some experiments also have included dogs. Biological tolerance was found to be least to single, fast-rising long duration pulses, intermediate to step increases in pressure, and greatest to slowly rising overpressures. Installation of an additional shock tube to allow more efficient investigations of short duration overpressures is under way.

Data from six projects during the 1957 Plumbbob Test Operation were analyzed. Among these were studies of the variations in velocity of blast-produced missiles as these varied with missile mass, yield and range, and the basic time-displacement phenomena (distance traveled, length of time in air, speed of acceleration) applicable to anthropometric dummies exposed at a 5 pounds per square inch station. A mathematical model which describes the physical behavior of missiles, including objects of the weight of man, has been constructed. With the help of machine computations, a theoretical formulation has yielded missile velocity predictions for simple circumstances involving wide variations in range, explosive yield, missile mass and missile shape.

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Flash Burns from Atomic Bomb Explosions

Laboratory experiments at the University of Rochester have made it possible to predict with some accuracy the burn casualties to be expected from a nuclear detonation. Studies on the protection afforded by summer and winter military uniforms have led to improved uniform design. How burns heal and how rapidly damaged tissue is repaired have been investigated.

Civil Defense Activities

In furtherance of the official policy of Federal leadership in civil defense announced by the Office of Civil and Defense Mobilization, the Commission has increased intra-Commission civil defense activities.

Major Commission programs are directed toward practical application of information on nuclear effects in the following fields: (*a*) internal environments of shelters, (*b*) development of a citizens' radiation detection instrument, (*c*) evaluation of protection in conventional structures against radiation, (*d*) and development of a mobile radiological measurement unit.

The Group Shelter

During the 1957 test series at the Nevada Test Site, the Commission sponsored an experiment [42] in which a 25 x 48 foot underground shelter was manned at the time of 2 detonations and afterward to collect data which would lead to better protection against fallout. This tested shelter, which will accommodate 100 persons for considerable periods under emergency conditions, will reduce fallout radiation intensity by a factor of 10,000 and will furnish substantial protection against blast, thermal radiation, and initial nuclear radiation.

A Commission contractor is preparing a brochure, drawings and specifications to permit local cost estimates on these shelters, designed to be tenable for a minimum period of 14 days for 100 persons.

The primary purpose is to prescribe an effective and biologically acceptable structure for protection of personnel as may be required at Commission sites. The shelter is adaptable for larger or smaller groups.

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[42] Reported in WT-1464, Operation Plumbbob Project 32.3, "Evaluation of Countermeasure Systems and Operational Procedures." Available from Office of Technical Services, U.S. Department of Commerce, price $3.00.

Citizens' Detection Instrument

In order to protect themselves in radiation-contaminated zones, people must have information on the degree of radiation hazard. One source of information would be a radiation detection and measuring instrument either in the hands of radiological defense personnel or of the individual. A combination radio and radiation detector would serve the family both for communication and for radiation detection.

The Commission has developed a combination portable radio-radiation dose rate meter and obtained 25 experimental models from a manufacturer for testing and study by persons having a background in radiation protection. Stimulated by Commission activity, electronic firms have developed other combinations. One type includes a radio and a radiation sensing device which gives an audible warning.

This work, which has been conducted in close cooperation with the Office of Civil and Defense Mobilization, has as its ultimate goal manufacturing, marketing and servicing of suitable combinations by the radio-television-electronic industry as a commercial enterprise.

Evaluation of Shielding

During 1958 the Commission conducted an experiment at the Nevada Test Site to determine the shielding afforded by typical residential structures. A large number of cobalt 60 sources were arranged to simulate the radiation field of fallout. The results of this experiment were published [43] during 1959 and show that:

a) The most effective shielding material is that which is in the direct line of radiation. For example, first floors of 2-story wood frame houses provide a reduction in radiation by about an average factor of two; the first floor of a 2-story brick house provides a reduction of about seven.

b) Reduction of radiation through openings into basements and openings in concrete, brick and block houses will increase the effectiveness of the home as a shelter. For basements of brick and wood frame houses, the reduction is about a factor of thirty.

c) Kitchen and bathroom fixtures cast radiation shielding "shadows" which give additional radiation protection. Location of shelter areas to include shielding from such furniture can increase the shielding potential of an ordinary house.

[43] CEX 58.1, "Evaluation of the Shielding Against Radiation Provided by Typical Residences." Available from the Office of Technical Services, U.S. Department of Commerce, price $2.75.

d) Dose rates behind chimneys and inside fireplaces are appreciably decreased.

e) An improved shelter consisting of a heavy table placed in the corner of a basement and covered with 7½ inches of concrete block provides a reduction of about 200 to 1,000.

f) The contribution of fallout on roofs of 2-story houses to the dose rate on the first floor is less by a factor of ten than for fallout on the ground outside.

A similar technique was employed to evaluate the radiation protection afforded by the Commission's headquarters building at Germantown. Measurements have shown that fallout radiation will be reduced by factors ranging up to 10,000 in the areas which would be used as a shelter. Results will assist in evaluating the fallout shelter existing in multistoried buildings and point toward design and modifications to enhance protection.

Mobile Radiation Measurement Unit

To extend the benefits of the technique for testing radiation resistance of structures, preliminary information on design of a survey vehicle was assembled during the 1958 experiment at the Nevada Test Site. The first component was built and used at Oak Ridge in 1959, following trial runs on typical residences. In initiation of the effort to raise the level of nonmilitary defense at Commission sites, a series of measurements of shielding characteristics of typical Oak Ridge homes against simulated fallout radiation were made during the summer of 1959. Specific objectives included the determination of the effects of irregular terrain and the shielding generally afforded by furnishings. The integrated exposure dose at points in the house was measured with ionization chambers and the readings compared with those made three feet above a flat area covered by the same radiation source. In practical application the radiation measurement unit will provide measurements in individual homes so as to locate the best shelter. Means for further improving the available protection then could be suggested and a nucleus of a home protection plan established. This mobile unit is to be used in the Commission and other community civil defense programs.

Radiation Instrumentation

In radiation instrument research, several unique devices were developed for use in biological and medical research projects and in the Commission's radiation safety program. The use of whole-body

counters was extended at Commission installations and is reported in an earlier section of this report.

Dosimetry

Thermal neutron chemical dosimeters. Chemical dosimeters have been produced at the University of California at Los Angeles which have been made sensitive to thermal neutrons while retaining their response to gamma rays and their original stability features. Thermal neutron sensitivity was produced by incorporating lithium 6 chloride in the dosimeter system. Such instruments when used in conjunction with similar gamma ray dosimeters provide a simple means for measuring the components of mixed slow neutron-gamma ray exposures by differential chemical dosimetry.

Geiger tubes as gamma-ray dosimeters. A gamma dosimeter with negligible neutron response is being developed at the Oak Ridge National Laboratory using commercially available miniature halogen-filled Geiger counters. This instrument will be useful in making measurements of gamma-ray dose in fields of mixed gamma and neutron radiation. Although the bare counter has a high energy dependence, with the proper amount of shielding it can be made to have a satisfactory energy dependence down to 150 Kev. It is adaptable to simple circuitry since it requires only low anode voltage, has large output pulses, and exhibits good stability and reproducibility.

External sources of radiation. Accurate measurement of the photon energy absorbed by different body tissues requires the use of ionization chambers with walls of special composition. Through a cooperative study between Argonne National Laboratory and the Physics Department of St. Procopius College, satisfactory wall materials for ionization chambers have been developed and tested.

Dosimetry for radiation accidents. The Oak Ridge National Laboratory is obtaining several hundred improved dosimeter units that they developed capable of measuring both gamma and neutron doses resulting from possible criticality accidents. The Commission is making these units available where the possibility of accidental radiation bursts exists.

Personnel Monitoring for Radiation Protection.

At Hanford, techniques of X-ray spectroscopy have been successfully applied to evaluation of duPont 510 emulsion film exposed to

gamma radiation doses in the range of about 20 to 2,000 roentgens where optical evaluation methods have not proved adequate. The new techniques and the associated instrumentation have been developed to provide rapid and accurate evaluation of large gamma radiation doses recorded by personnel badge film. At present, evaluation can be completed in about 90 minutes.

A personnel monitoring film badge for slow neutrons now has replaced the pencil dosimeters formerly used at Hanford. This badge uses a cadmium and tin shield which yields film densities that can be interpreted as a slow neutron dose. The badge can be used to evaluate: (*a*) slow neutron doses as large as three rems in the absence of gamma radiation and (*b*) slow neutron doses in gamma radiation fields, provided the sum of the slow neutron dose and the gamma dose to the badge does not exceed 3 rems.

Extended application of the current-pulse ionization dosimeter reader is providing information concerning radiation rates in Hanford environs. The method has been applied to measuring the gonad dose received during various diagnostic X-ray examinations where the very low rate requires the ultimate in sensitivity. With appropriate chambers, gamma radiation doses as low as 10 microroentgens have been measured. The full sensitivity of the system has not been fully determined.

Continuous Air Monitor for Aerosols

Radiation exposures can be cut to insignificant levels if warning devices can tell instantly that an exposure has started. If the radioactivity and radiation levels in the environment are known, and they can be controlled, it is possible to live and work very safely with very large quantities of radioactive materials. A good radioisotope-handling facility, for instance, leaves man in control even in emergencies.

One of the most difficult problems is that of providing instantaneous information continuously on low levels of airborne radioisotopes (vapor, gases, fumes, dusts), particularly in the case of such alpha emitters as plutonium, because the short-lived alpha activities of the radon and thoron daughters may vary from 50 to several hundred times the permissible levels of plutonium.

To make an immediate determination of low and moderate levels of alpha aerosols, radon-thoron daughter activity must be eliminated. Three methods can be used to do this. Impactor collecting permits selective counting when particle sizes of plutonium versus radon-thoron daughters differ significantly. A pulse analysis method has

also been reported. A third method is to count simultaneously both the alpha and beta activities of the radon-thoron daughters. Any unusual variation in the alpha-beta ratio is indication of presence of other alpha or beta emitters.

A satisfactory counter of the third type has been built at Argonne National Laboratory. Aerosols are collected on a filter paper screening at a rate of 15 cubic meters of air per hour. While collection is taking place, a thin-windowed proportional alpha counter counts the alpha activity. Riding on the alpha counter is a beta proportional counter which counts betas which come through the one-half-inch deep alpha counter. The beta counter window stops alphas from entering the beta counter. Both counters use argon-methane gas at atmospheric pressure. Nylon alpha counter windows of 0.9 mg/cm^2 were used since the more usual weight of 0.2 mg/cm^2 proved too flexible for the pressure and air steam.

Internal Dosimetry

When a radionuclide enters the body, the gonads may be irradiated and the dose to the gonads may be separated conveniently into two parts: (*a*) the dose due to the presence of the radionuclide in the gonads, and (*b*) the dose absorbed in the gonads due to the presence of the radionuclides in the bladder, the gastrointestinal tract, or the blood. The latter dose generally will be small except for gamma emitters. The extent to which many radionuclides concentrate in the gonads has not been determined; however, experimental values for some of the isotopes generally considered as potentially a genetic hazard are available. The gonad dose delivered by gamma rays originating outside the gonads is estimated by calculations being carried out at the Oak Ridge National Laboratory. The dose to the gonads from the contents of the gastrointestinal tract exceeds the dose from the contents of the bladder in most cases, both because of the greater length of time required for passage through the tract and because many materials are only slightly absorbed into the blood.

Other studies at Oak Ridge National Laboratory are directed toward supplying more accurate estimates of the parameters needed to calculate the maximum permissible concentrations of certain radionuclides in air, water, and food. Dogs exposed to a single inhalation of uranium oxide fume have been found to retain approximately 25 percent of the inhaled material. About half the lung burden is cleared rapidly with a biological half-life of 6 days, while the remainder is eliminated at the rate of half every 100 days. The concentration of uranium in the tracheobronchial lymph nodes increases, while the

amount in the lung decreases so that after about 4 months the uranium concentration in the lymph tissue exceeds that in the lung.

Carbon Dioxide in Expired Air

The majority of chemical compounds that are important for human (or animal) metabolism contain carbon, and can be prepared for tracer studies using a carbon 14 label. Following the administration of a tracer dose of C^{14}-labeled material, radioactive carbon dioxide is eliminated in exhaled air. It is believed that the pattern of elimination (that is, the specific activity vs. time curve for $C^{14}O_2$) is characteristic for each metabolic substance, and has a typical configuration in healthy subjects. In the case of disease, or other abnormal states, it is assumed that the pattern will deviate significantly from the normal or usual one. Prior to the development of automatic equipment for the measurement of radioactive carbon dioxide, it was necessary to collect a series of samples of exhaled air and analyze each one by conventional methods. Such procedures were time-consuming and there was a limit to the number of studies that could be performed in the average laboratory.

Automatic instruments were developed by the group at the University of California's Donner Laboratory, and the group at the Argonne Cancer Research Hospital, working independently. The Argonne instrument uses a special Geiger-Mueller counter, operating in anti-concidence as a radiation detector, while the Berkeley instrument uses an ionization chamber. Both employ an infrared absorption meter to measure the amount of carbon dioxide ($C^{12}O_2$) in expired air; and both have devices to measure the volume of air breathed by the subject. In both instruments, all data are recorded on the chart of a millivoltmeter, from which they can be transcribed for detailed analysis. At Argonne, computation of the kinetics of the carbon dioxide pool is performed routinely by a high-speed computer.

Programs are being developed to estimate the rate of oxidation of glucose, acetate, formate, and other metabolically-important compounds. The combination of automatic recording of experimental data, and machine-analysis of the results has eliminated two serious bottlenecks in the use of carbon 14 for large scale metabolic studies in man, and in laboratory animals.

Any study of the metabolism of a C^{14}-labeled substance (such as glucose, for example) requires prior knowledge of the behavior of the carbon dioxide pool, because the CO_2 produced from the substance must pass through this pool before it is eliminated. Some fraction of the CO_2 passing through the pool is reutilized by the body, and the

remainder is eliminated principally in exhaled air. The fraction reutilized varies from person to person; but is comparatively constant for each individual. Some of this carbon dioxide is used by the body to synthesize other chemicals, and the majority is in some sort of equilibrium with the carbonate portion of bone. Information on the fraction of CO_2 that is recycled provides a correction factor which is applied to data on the oxidation of a substance such as glucose, so that variations in the percent of dose recovered as $C^{14}O_2$ can be adjusted accordingly.

The Argonne group is studying various aspects of glucose metabolism in healthy subjects, and in patients with diabetes, cancer, and drug-induced hemolytic anemia. Variations in the rate of oxidation of each of these carbon positions are being evaluated in an attempt to develop better methods to study disease states in man.

Fallout Studies

Beginning with the first test in 1945, the United States has conducted 16 series of weapons tests. This country announced the first nuclear detonation by the Union of Soviet Socialist Republics in 1949, and the United Kingdom initiated its series of weapons tests in 1952 (see Appendix 15 for list).

With the exception of the first test during the war, the United States has announced each series publicly in advance. Before being authorized, each shot fired by this country was evaluated individually for its contribution to the advancement of nuclear weapons technology, or to important gains in knowledge about weapons effects. A major associated effort in United States tests has been to obtain information for the protection of the civilian population in event of nuclear warfare.

Approximately 20 percent of the United States detonations have been of high-yield thermonuclear designs and 80 percent of fission devices. The first test—TRINITY at Alamogordo, N. Mex., July 16, 1945—demonstrated the feasibility of an atomic weapon. In July 1946, two devices were fired in Operation CROSSROADS at Bikini Atoll in the Pacific Ocean for information on the effects on ships of atomic bursts. Subsequent United States tests were:

Operation SANDSTONE, spring of 1948, Eniwetok Proving Ground EPG).

Operation RANGER, early 1951, Nevada Test Site (NTS).

Operation GREENHOUSE, spring of 1951 (EPG).

Operation BUSTER-JANGLE, fall of 1951 (NTS).

Operation TUMBLER-SNAPPER, spring of 1952 (NTS).

Operation IVY, fall of 1952 (EPG).
Operation UPSHOT-KNOTHOLE, spring of 1953 (NTS).
Operation CASTLE, spring of 1954 (EPG).
Operation TEAPOT and WIGWAM, spring of 1955, NTS and off the coast of California.
Operation REDWING, summer of 1956 (EPG).
Operation PLUMBOB, summer of 1957 (NTS).
Operation HARDTACK, summer and fall of 1958 (EPG and NTS).
Operation ARGUS, fall of 1958, South Atlantic.

Radioactive fallout from detonation of nuclear weapons has been identified since the first test explosion. Its importance increased with the greater number of devices set off, and with the advent of thermonuclear explosions—the first was fired in Operation *Ivy*, 1952—since these fusion devices hurled debris into the upper regions of the atmosphere and this has resulted in more widespread distribution of fallout. Strontium 90, one of the more troublesome fallout products because of its long continued radioactivity and its assimilation in food chains where it competes with calcium, is a product of atomic fission, but not of fusion.

Studies of the distribution and possible effects of radioactive fallout began with the first nuclear detonation in 1945. Initially, this work was limited to relatively high-intensity radioactive areas near detonation sites. Wind drift of radioactivity from test detonations was traced regularly by plane until the clouds dispersed, and readings were taken in and near the test sites. As the problem increased, monitoring stations were set up, and programs of sampling and analysis undertaken. The Commission has engaged continuously in studies of the biological effects of all important types of radiation, as did the wartime operator of Federal atomic energy activities, the Manhattan Engineering District, Corps of Engineers, U.S. Army. The results of this broad work on radiation effects and radiation protection, like the results of fallout studies, have been reported regularly and fully to the public and the Congress. This report, in another section, describes the progress of research related to these problems.

On fallout and its possible consequences, the Commission constantly makes new information available as rapidly as possible. Information on some aspects of fallout necessarily is held in secret since they bear directly on security and national safety. Decisions in this field are not made by the Commission alone, but in concert with the Department of State, the Department of Defense, and the Central Intelligence Agency. This special section of the Annual Report to Congress for 1959 reviews the history, and current status, of the fallout studies.

Chronology of Fallout Studies

The Commission's studies on fallout were initiated in 1947 through a small group from the University of California at Los Angeles. Beginning with a reconnaissance radiological survey of soil, animals, and vegetation at the *Trinity* (1945) detonation site near Alamogordo, N. Mex., this program had developed into an extensive research program by the time of the 1951 Nevada test series. These studies help delineate fallout patterns up to several hundred miles from a test site, determine soil-plant-animal relationship in uptake of weapons debris, and characterize various types of fallout material. Air, soil, plant, and animal samples are obtained and analyzed for a number of radionuclides under this program. Results of surveys made following the latest Nevada test series are given in Appendix 16.

The Naval Research Laboratory began an air sampling program for natural radioactivity measurements in 1948. Measurements of fission product radioactivity were begun in 1950. Daily air samples are collected at 21 stations along the 80th Western Meridian from Thule, Greenland, to Punta Arenas, Chile. Gross radioactivity measurements and radiochemical analyses of a number of radionuclides are made. This work is now a part of the Commission fallout monitoring program.

In 1951, rain samples taken in the northeastern United States and analyzed by the Commission indicated traces of fallout material from Nevada tests earlier that year. A sample collection network was established for subsequent tests at Eniwetok Proving Ground that year, and a nation-wide monitoring system was established under the direction of the Commission's Health and Safety Laboratory in New York.

During the spring 1952 Nevada test series, two-man mobile monitoring teams made measurements of external gamma radiation and airborne radioactivity at widely distributed locations within 200 to 500 miles of the Nevada Test Site. Gummed-film and air samples also were collected at 121 fixed monitoring stations set up with the United States Weather Bureau, Department of Commerce. Samples were analyzed for gross radioactivity, and later estimates were made of strontium 90 deposition. Other Federal and State agencies and private organizations assisted in making collections and analyses.

In October 1952, the network using gummed-film collectors was expanded to include a number of stations outside continental United States. Other foreign stations were added in February 1954, and an expanded monitoring network operated during the Nevada test series

of that year. This program continued through the test series conducted during 1958.

Two networks of air and external radiation monitoring stations were established prior to the 1957 Nevada test series. One comprised Commission installations—national laboratories and major research contractor sites where background radiation is measured routinely; the other was established in cooperation with the Commission during 1956 by the United States Public Health Service, Department of Health, Education, and Welfare. Both networks analyzed air samples for gross beta radioactivity and obtained on a daily basis measurements of total beta-gamma background activity. This network also has measured radioactivity in rainfall continuously since before the 1957 Nevada test series.

In 1953, after the Commission engaged the Rand Corp., to study the fallout problem, a review conference was held which led to the present program of worldwide fallout studies.

An extensive program of research to study the mechanisms involved in worldwide fallout was initiated in 1954 by the Commission through its Health and Safety Laboratory, and through the University of Chicago and Lamont Geological Observatory of Columbia University. These have collected and analyzed for radioactivity, particularly for strontium 90, samples of soils, air, water, milk and other foods, and animal and human tissues. Later the Department of Agriculture entered this program and, in 1955, initiated a program to determine levels of strontium 90 in soils on a worldwide basis. Other more limited sampling programs also were initiated. The Commission currently is assisting in training personnel of the Food and Drug Administration, Department of Health, Education, and Welfare, in the radiochemistry involved in such analyses. The current FDA program includes analyses of food samples for gross radioactivity.

Precipitation fallout collections at 13 stations in the United States and at 17 stations outside this country were begun in early 1954. Analyses of fallout samples, collected in stainless-steel pots, were made for strontium 90. Work was initiated in 1956 for sampling and strontium 90 analyses of precipitation at Mount Washington Observatory, New Hampshire. Stations were established at Pittsburgh, Pa., in 1955 and at Westwood, N.J., in 1958 to obtain precipitation samples which are analyzed for strontium 90, barium 140 and tungsten 185. This program was expanded in 1959 using an improved collecting method (a plastic funnel and an ion-exchange column). Samples also are obtained in the Atlantic Ocean aboard Coast Guard ships.

The Commission's high-altitude sampling program for fission product radioactivity began in 1956, using balloon-borne sampling devices at four locations in the United States, Brazil, and the Panama Canal

Zone. Samples were obtained at nominal 50,000,- 65,000,- 80,000- and 90,000-foot altitudes and analyzed for several radionuclides. The program since has been reduced to two sampling locations at Sioux City, Iowa, and San Angelo, Tex.

In 1956, the Los Alamos Scientific Laboratory began a program to measure radioactivity, especially cesium 137 and natural potassium 40 in milk and in man. Measurements have been made with a large scintillation whole-body counter. Measurements have been made of people from all over the world visiting Los Alamos.

In addition to the various sampling programs, many research activities are performed under the auspices of the Commission which contribute to basic knowledge of fallout and its effects in the overall fallout studies program. While most of these activities are described elsewhere in this report, a few of them are included in a later part of this section.

Standards for Radiation Protection

In evaluating the risk from fallout, the standards commonly used are largely based upon the recommendations of such groups as the National Committee on Radiation Protection and Measurements, the International Commission on Radiological Protection, the National Academy of Sciences, and the Medical Research Council of the United Kingdom. Some of these recommendations relate directly to questions of hazards from fallout; others may provide useful guidance. These standards generally are applied through establishing exposure levels designated by such terms as "maximum permissible dose" and "maximum permissible concentration." Maximum permissible exposures set for occupational activities, for individual members of the public, and for the general public, are neither absolutely safe nor dangerous. In the judgment of those making the recommendations, it is an exposure which represents the greatest hazard that, in their opinion, should be permitted under the conditions to which the recommendation is applicable. Under different conditions, either a lower or a higher permissible dose might be recommended.

The Federal Radiation Council, established by executive order of the President and by statute, September 23, 1959, has the responsibility for recommending to the President, among other standards, those which it judges should apply to environmental exposures from all sources.

Recommended values of maximum permissible doses of radiation generally involve the assumption that the hazard of some radiation is proportional to the dose. To the extent that this is true, doubling

the exposure stipulated as the recommended maximum permissible dose would mean increasing the hazard involved to twice the level which the recommenders considered justifiable under the conditions for which the recommendation was made. How great a hazard this may be depends, of course, upon estimates of the hazard that would result from the recommended maximum permissible dose. Hence, a recommended maximum permissible dose has no specific significance except that it marks the point at which an advisory group has agreed to draw the line in recommending the maximum degree of hazard that is appropriate under a given set of circumstances.

There is a sharp difference between permissible doses of radiation to persons and the maximum permissible concentrations of radioactivity in the environment.

The radiation dose actually received by persons is being measured. The best information on the uptake by humans of radioactivity from fallout in the environment is that being obtained by examinations of small children most nearly in equilibrium with the radiation in their environment. Measurements of this kind will assist in developing, within the next few years, realistic values for the maximum concentrations of radioisotopes resulting from fallout that should be permitted in the total food supply. Present standards for concentration have been determined on the basis of the best information and recommendations available, with the addition of a large safety factor.

In principle, establishing the best possible value for a maximum permissible exposure involves at least three independent evaluations: (*a*) estimating the total biological risk, (*b*) estimating the benefits to be gained from taking the risk, and (*c*) balancing the risk against the reason for taking the risk.

The uncertainties involved in estimating the biological risk are indicated in the research currently being carried on, as described elsewhere in this report. The uncertainties involved in estimating the benefits to be gained by taking the risk probably are much larger. The most difficult step is that of comparing biological risk to benefits which may be measured in economic or social gains, considering also that some or all of the benefits may not accrue to the person taking the risk.

In occupational standards, one criterion commonly used is that risks due to exposure to radiation should be small compared to other occupational risks. How small would depend upon the comparative ease of avoiding the risks, and the reasons for accepting a risk of any particular magnitude, which reasons are to be found in the difficulties—in the form of time, personal inconvenience, expense, or other reason—involved in avoiding the risk.

Reasons for acceptance of a risk are not the same, of course, as the

primary benefits to be derived from the activity in which the risk arises. These primary benefits may be sufficiently large to outweigh by far any risks involved, although it still may be desirable to reduce the risk by various possible means.

Standards of radiation protection, while based upon logical concepts, never can be ideal. This is not a condemnation of the standards nor of the system by which they are formulated, but rather a recognition that imperfections and compromises are inherent in most solutions to complex problems. In environmental health, radiation protection shares this difficulty with all other health standards.

Fallout Radiation Levels

Recent measurements of radioactive fallout in the soil, rainwater, surface air, upper air, milk and food under Commission and cooperative programs are summarized in this section.

Strontium 90 in Soils

Measurement of strontium 90 levels in soil sampled at 77 locations throughout the world, made by the Commission's Health and Safety Laboratory working with the Department of Agriculture, provide a good indication of current strontium 90 deposition. They help in estimating present and future levels of this radioactivity in man. Radioactivity levels in soil provide an indication of changes in the amount of strontium 90 which has fallen out, and the availability of this radioisotope for uptake in food plants and eventually in human bone. Of the total strontium 90 in soil at any time, only a small fraction will eventually reach human bone. On the other hand, some strontium 90 enters food crops and fodder directly from the air and rain without first entering the soil.

The following table gives total strontium 90 levels in soils as collected in October 1958. Soil samples usually are taken at several depths down to 6 inches, or, in some cases, 12 inches.

Location	*Sr 90 millicuries per square mile*	*Location*	*Sr 90 millicuries per square mile*
Albuquerque, N. Mex	27	Memphis, Tenn	37
Atlanta, Ga	37	New Orleans, La	34
Binghamton, N.Y	40	New York, N.Y	37
Boise, Idaho	38	Philadelphia, Pa	44
Des Moines, Iowa	56	Rapid City, S. Dak	74
Detroit, Mich	40	Rochester, N.Y	33
Grand Junction, Colo	39	Salt Lake City, Utah	78
Jacksonville, Fla	36	Seattle, Wash	30
Los Angeles, Calif	19		

The average level of strontium 90 in soils collected in October 1958 in the United States between latitudes 40° and 50° North was 46.9 millicuries per square mile (mc/mi^2), while the average between 30° and 40° North was 32.6 mc/mi^2. The levels in the United States appear to be 10 to 15 mc/mi^2 higher than the world average because of tropospheric fallout from weapons tests and higher rainfall rates, except that, west of the Rocky Mountains, levels are about the same as the world average. This may be due to lower levels of rainfall. Analysis of 1959 soil samples has not been completed. Data already collected indicate substantial increases over 1958 levels of strontium 90.

Fission product radioactivity analyses in monthly soil samples, using gamma ray spectroscopy, were continued at Argonne National Laboratory during 1959. Analyses for the gamma emitters include zirconium 95, niobium 95, cesium 137 and 144, ruthenium 103, and cerium 141. Monthly total levels in the spring of 1959 of 4,000 to 5,000 millicuries per square mile were remarkably consistent for a period when the fallout was relatively heavy. Individual radionuclides showed peak activities at various times, depending on half-lives, from March to July.

Monthly Fallout Collections

Monthly fallout collections are made through the worldwide network of stations [44] set up by the Commission and analyses are made for strontium 90, strontium 89 and tungsten 185. These data provide information concerning the rate of fallout and its accumulation. During the United States' tests at the Eniwetok Proving Ground in 1958, tungsten produced in some devices provided a tracer material for fallout collection studies. Tungsten was partially transformed into radioactive tungsten 185 (74-day half-life) which provided additional information on the world-wide fallout pattern from equatorial tests.

The monthly data during late 1959 indicate a decrease in the rate of fallout in the United States after generally rising rates from January to May. The highest rates generally appeared to occur during February and March on the west coast and Hawaii, and in April and May on the east coast with a range between these for other areas,

[44] Includes 35 steel pot and ion-exchange stations and 3 precipitation stations in the United States, 4 Coast Guard (ship) rain collecting stations in the Atlantic, and 28 steel pot and ion-exchange stations in 14 foreign countries.

reaching 6 millicuries of strontium 90 per square mile per month in some places. Monthly fallout rates during 1959 in the United States have been higher than during 1958, but since mid-year have decreased to much lower levels. It is expected that the rate of fallout from past tests generally will decrease further in subsequent years, although temporary seasonal increases would, on some hypotheses, be expected.

Surface Air Monitoring

The surface air monitoring networks indicated generally rising levels of gross radioactivity in the atmosphere during the early months of 1959, a continuation of the rising levels noted in November and December of 1958. The levels reached their highest in the spring of 1959 and decreased to one-half to one-third of the peak values by June and July. The levels in the Southern Hemisphere were 50 to 100 times lower than those in the United States. Levels in Alaska and Hawaii also were lower than in continental United States.

Stratospheric Monitoring

High-altitude air sampling was continued at Sioux City, Iowa, and San Angelo, Tex., during 1959. The Sioux City Station ceased sampling late in the year. Sampling at Sao Paulo, Brazil, was discontinued in February. At each site sampling was carried out between 50,000 and 90,000 feet altitude. Samples also were obtained from Denver, Colo., at altitudes greater than 90,000 feet. Some balloon-borne sampling research flights were made at Minneapolis, Minn., by General Mills, Inc. and Chicago Midway Laboratory.

High altitude samples are analyzed for barium 140, zirconium 95, cerium 144, cesium 137, strontium 89, strontium 90, and tungsten 185. These data are of value in studying meteorological and fallout phenomena, especially in material balance studies.

Studies of Uptake in Foods

The Commission's Health and Safety Laboratory continued to obtain milk samples for strontium 90 analyses at Mandan, N. Dak. and Perry and New York, N.Y. Levels in milk for the first 9 months

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at these locations, micromicrocuries per gram of calcium, were as follows:

Sampling month	New York, N.Y. (liquid milk)	Perry, N.Y. (powdered milk)	Mandan, N. Dak. (powdered buttermilk)
January	8. 2	8. 1	20. 8
February	8. 4	7. 6	18. 4
March	8. 1	6. 6	23. 9
April	7. 7	7. 2	27. 8
May	13. 4	8. 9	47. 5
June	26. 2	8. 9	37. 9
July	14. 4	7. 0	22. 2
August	10. 7	7. 8	24. 0
September	9. 8	6. 1	16. 6

The June sample from New York City, reported as 26.2 micromicrocuries per gram of calcium, was higher than any previously reported for that station. The value for New York City liquid milk reported by the Public Health Service for June was 14.0 micromicrocuries per liter, very nearly equal to 14 micromicrocuries per gram of calcium. This difference is possibly due to the difference in source of the two samples. The Health and Safety Laboratory sample for New York City dropped to 9.8 micromicrocuries per gram of calcium in September, about half the June value. The May sample for Mandan is the highest value reported for milk in the United States, as far as Commission records show. By September, however, the level had dropped to 16.6.

Samples of wheat harvested in 10 Minnesota areas from 1956 to 1958 were provided by the University of Minnesota for analysis by the Health and Safety Laboratory and the analyses for strontium 90 were completed in early 1959. Strontium 90 levels ranged from 17 to 76 micromicrocuries per kilogram in 1956, 47 to 112 in 1957, and 35 to 60 in 1958. Similar samples of 1958 wheat from the major wheat-producing states also were furnished by the University of Minnesota, the levels ranging from 21 to 133 micromicrocuries of strontium 90 per kilogram. North Dakota wheat samples from the August, 1958, crop furnished by the North Dakota Agricultural College and the United States Department of Agriculture's Mandan Agricultural Experiment Station contained 29 to 54 micromicrocuries of strontium 90 per kilogram. Minnesota seed corn yearly samples for the years 1945 to 1958 indicated levels too low to be quantitatively detected.

Data for strontium 90 in flour and bread samples were collected in New York City during February and May 1959. The May data indicate that strontium 90 levels in two samples of whole wheat bread (37 to 59 micromicrocuries per kilogram) were about five times the levels in two white bread samples (12 micromicrocuries per kilogram) obtained at the same time. The level in a single sample of whole wheat

flour was 189, compared to 12.8 in a sample of white flour. The values for the white bread sampled in May are somewhat higher than the February figures; however, the values for the whole wheat bread sampled in May are considerably lower than the February values. The levels in the flour samples in May differed little from those sampled in February. Samples of whole wheat bread collected in June, July, and August showed 29, 27, and 52 micromicrocuries per kilogram while white bread showed about the same value as for May.

As has been previously reported,[45] the relationships between strontium 90 levels in foods and maximum permissible dosage involve the entire diet over a matter of many months. The significance of concentrations in single items of food, such as whole wheat bread, depends upon the extent to which these contribute to the total diet.

Other uptake studies of radioactivity involved analyses of other foods, human bone, soils, and animals. Human bone samples from the New York City area analyzed by the Lamont Geological Observatory showed levels of 0.53 to 2.62 micromicrocuries of strontium 90 per gram of calcium for children (fetus to 11 years) and 0.43 to 1.19 for adults.

Investigators at the University of Nevada, under contract with the Commission, and the Nevada Test Organization have reported strontium 90 levels in milk and bones of cattle collected in Nevada during 1958. Nevada samples were collected at Knoll Creek, and Delamar Valley in the Southeastern part of the State, and the Nevada Test Site. Cattle bone levels at these locations ranged from 3.7 (rib) to 44.8 (femur) micromicrocuries of strontium 90 per gram of calcium, both extremes were from the Nevada Test Site samples. Milk levels determined in Knoll Creek and Delamar Valley samples in May and November, 1958, showed a value for May at Knoll Creek of 5 micromicrocuries of strontium 90 per gram of calcium to be the highest. Studies conducted in other areas of the United States have suggested that human bones accumulate less strontium 90 than animal bones under the same exposure conditions. The Nevada milk and bone data also suggest that values to be expected in persons living in that State would be well below the values that have been measured in cattle.

Data for cesium 137 in more than 273 people from 25 States, and in more than 1,364 samples of milk from 37 locations in 28 States, was collected for 1958 at the Los Alamos Scientific Laboratory. Because of the biochemical similarity of cesium and potassium, cesium 137 levels are conveniently expressed as micromicrocuries of cesium 137

[45] See HASL–65, John H. Harley, "Dietary Strontium 90 Estimates for the United States," Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. $3.50.

per gram of potassium. The samples of nonfat dry milk ranged from 7 to 297 micromicrocuries of cesium 137 per gram of potassium. During 1958 the average milk value was 50 such units with some samples as high as about 250. The 1959 levels in people ranged from 12 to 170 units. The 1958 average for the United States was 67 units.

Research Findings on Fallout

Pattern of Distribution of Radioactive Fallout

Measurements of fallout on the ground and of radioactivity in the troposphere and stratosphere have made apparent some of the complexities of the true patterns of global transport and mixing, as contrasted with idealized models. Knowledge about the distribution of weapons debris in the atmosphere has been greatly improved by data from Department of Defense programs, augmented by Commission stratospheric balloon data for the upper atmosphere and by other Commission data for air, water and soil at the earth's surface.

Commission and Department of Defense upper atmosphere data have demonstrated in the tropical latitudes a well-defined drop in atmospheric radionuclide concentration from the stratosphere into the troposphere. These data also suggest strongly the lack of any prompt uniform mixing in the stratosphere, either horizontally from pole to pole or vertically. Reliability of the balloon data, while improving, is not yet sufficient to warrant their use alone with any great assurance, but as a supplement to Department of Defense data they are valuable and confirmatory.

One important prediction has been verified: A substantial reservoir of longer lived fission products does exist in the stratosphere. The exact inventory still is in some doubt. Various estimates based on measurements just before the Soviet Union October test series in 1958 ranged from 600,000 to about 1,800,000 curies of strontium 90.

The information available about debris thrown into the stratosphere is subject to large uncertainty. In addition to knowledge of the total and fission energy yields of all weapon explosions it would be necessary to know whether they were land, water or air bursts. Even then it is difficult to estimate the fractions of the debris produced that come out as local fallout relatively near the site of detonation, tropospheric fallout, and stratospheric fallout. This information is obtainable only from actual measurement taken on some United States shots at the time of testing. These measurements may or may not be applicable to other shots under differing test conditions. Ta-

bles of yields of nuclear weapons detonated during tests are included in Appendix 15.

Estimates of stratospheric inventory based on measurements in the stratosphere can be combined with other information such as input rates and fallout rates to provide estimates of the length of time various radioactive materials may remain in the stratosphere. Predictions of the consequences of testing or of nuclear war depends in large part upon what can be determined about this residence time in the stratosphere.

The concept of stratospheric residence time as being a single figure applicable to all stratospheric debris has been modified. The first large injections of debris in 1952 and 1954 were placed high in the equatorial stratosphere. Vertical exchange of air is especially slow in these latitudes because of the intensity of the stratospheric temperature inversion, and because seasonal rearrangements of the atmospheric circulation are at a minimum. Many subsequent high-yield tests have not placed debris so high in the stratosphere.

During 1958, a number of tests were made by the Soviet Union north of the Arctic Circle. There, vertical mixing and entry into the lower atmosphere are more rapid, particularly in winter and early spring. In the polar regions, the stratosphere's altitude also is much lower than in the tropics. In the middle-latitudes so-called "double tropopauses" occur, where the higher tropical stratosphere overlaps the lower polar stratosphere. These overlaps, or breaks, are thought to provide an opportunity for horizontal movements of air out of the stratosphere.

These variabilities in stratospheric conditions complicate estimates of strontium 90 inventories and rates of deposition. Regardless of the actual pattern or residence time of debris in the stratosphere, it is clear that the debris does not fall out uniformly on the earth's surface. Strongly defined North-South irregularities exist.

For purposes of predicting and estimating hazards, the observed North-South fallout patterns must be separated into components representing stratospheric and tropospheric fallout. Since some weapons have been fired which yielded only tropospheric debris, it should be easier, in principle, to study these shots and arrive at an understanding about tropospheric debris patterns. Assuming an estimate of the location and amount of world-wide tropospheric fallout, subtracting this from the total should indicate the location and amount of stratospheric fallout.

Knowledge about the tropospheric fallout from small shots is limited however, and the applicability of this knowledge to tropospheric fallout from large yield shots is even more limited. Tropospheric

fallout is to be thought of in terms of masses of debris distributed vertically and horizontally in the lower atmosphere (where the weather is), and presumably subject to spreading and mixing, and wanderings as buffeted by winds. Tropospheric fallout does not descend in an even band about the earth. Weather trajectories of debris from both Pacific and Nevada shots strongly support this interpretation. Actually, tropospheric winds at the Eniwetok Proving Ground tend to blow in nearly opposite directions at different altitudes.

In different places different amounts and rates of fallout are found reflecting the global variations in stratospheric and tropospheric transfer, and the variations in location of tropospheric debris. Good evidence indicates that debris introduced into the upper stratosphere just north of the equator at about 10°N has a mean residence time in the stratosphere of several years, and perhaps as much as one-third of it will descend in the Southern Hemisphere. If introduced in the lower stratosphere at the same latitude, the debris' mean residence time will be not more than two or three years.

If the debris is introduced in the North Temperate Zone or farther north the mean residence time appears to be of the order of a year or less with very little mixing across the equator. In either hemisphere the debris appears to be falling out preferentially between 30° to 60° latitude, regardless of the latitude of injection. Relatively little fallout occurs near either pole or the equator. This phenomenon seems to be related to preferential leakage through the break between the high tropical tropopause and the lower polar tropopause in North and South Temperate latitudes.

Differences in the rates of fallout, and the rates of world-wide spread between equatorial and polar tests, now are appearing as the debris from Operation Hardtack of 1958 tagged with tungsten 185, and the fresh debris from the Soviet Union series of October 1958, are being sampled and measured.

Weather also is a factor in determining places where debris may fall out. Local inequalities in fallout are in great part determined by rain, the chief vehicle for its deposition. This holds true for debris filtering down from the stratosphere.

Local conditions also may produce variability in measurement since forests do not behave like meadows nor mountain-tops like valleys as repositories of fallout. Cyclonic and orographic (mountain) rainfall will behave differently as scavengers. Soil samples cannot be expected to contain the same amounts of strontium 90 as rainwater collections or collections on gum paper.

As further experimental data are obtained some fallout puzzles undoubtedly will be solved, but new ones may well arise. There is no

reason to expect the global atmospheric circulation to behave in a simple manner.

Discrimination Against Strontium 90

Research here and in the United Kingdom indicates that plants show no consistent discrimination against strontium 90 in the soil. No plant is known which has the remarkable capacity that some mollusks and diatoms have of being able to discriminate almost totally against strontium in favor of calcium. Strontium 90 uptake from soil can be reduced by existing methods of treatment with simple chemicals (containing, for example, calcium or potassium) by at most one-half.

Mechanisms exist also for strontium 90 and cesium 137 to enter plants either by direct uptake through the leaves, or by uptake in the grass mat through the base of the stems. British research demonstrated that the cereal grasses readily absorb soluble strontium 90 salts into the grain if the salts are sprayed on during the formative stage of the grain. These mechanisms seem to account for the fluctuation in strontium 90 content of food from month to month and year to year as seen in milk and wheat. The low points seem more likely to represent uptake from soil.

These findings do not resolve, however, the question of whether the peaks result from stratospheric or tropospheric fallout. Milk collected by the Mandan Agricultural Experiment Station reached a peak value of 33 micromicrocuries of strontium 90 per gram of calcium in the summer of 1957. A relatively heavy rainout of tropospheric fallout from United States 1957 Nevada tests probably was responsible for this peak. On the other hand, even higher levels of strontium 90 in milk observed during early 1959 must be attributed to stratospheric fallout.

Effects vs. Radiation Dose

The Commission has no new evidence clearly indicating that effect is directly proportional to dose regardless of dose rate, but no conclusive evidence has been found pointing to a true threshold below which effects do not occur. Effects versus radiation probably is best represented by a series of curves, one for each of a number of situations involving a given dose rate and dose schedule, i.e., the matter of divided doses as incurred with diagnostic X-rays as opposed to the more uniformly incurred exposures from fallout.

Data on internal emitters in humans and experimental animals

point to a sharp break in the curve representing bone tumor formation which occurs well above any recommended permissible levels. This indicates that, even though a threshold may not exist, very few bone tumors will result from low body burdens of strontium 90. The data for leukemia induced in mice from internal radiation sources are not so clear. Data on life span effects from fallout have not been clarified.

Research Programs

Somatic effects. Information still is meager on the effects of low levels of chronic radiation exposure and low total doses. The United Nations Scientific Committee on the Effects of Atomic Radiation, for example, found that after reviewing all available data, it was unable to make a categorical statement on leukemia and radiation exposure. The data indicated a threshold for radiation-induced leukemia as high as several hundred roentgens. On the other hand, the Committee estimated the number of cases of leukemia which might occur should the effect of radiation be directly proportional to radiation dose regardless of dose rate. The Committee made similar calculations for bone cancer, but at the same time noted that, whereas X-ray radiologists appear to have a higher incidence of leukemia than do nonradiologists, no corresponding increase in bone cancer has been observed. Nevertheless, the absorbed dose of radiation in bone that could be affected by tumors probably was greater than the dose to the bone-marrow which is involved in leukemia.

At hearings held on fallout before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy of the Congress May 5–8, 1959, a panel of 22 scientists was convened to attempt predictions of exposures which, in their opinion, would result from fallout from all weapons testing to date and to estimate the strontium 90 accumulation in soil and in humans. The panel estimated that in the United States the genetically significant dose from tests to date would be about 0.05 rad while the average body burden of strontium 90 would be about 6 micromicrocuries per gram of calcium. Commission staff made estimates of the possible effects of fallout to date based on an average body burden of strontium 90 of 10 micromicrocuries per gram of calcium and on a genetically significant exposure of 0.15 rads.

Figuring from the higher dose estimates, it can be estimated on the basis of one current theory that the maximum number of additional

cases of bone cancer that could occur per year in the next 70 years would be 50 to 100, and for leukemia as much as double that figure. There may be no additional cases at all, as the United Nations Scientific Committee was so careful to point out.

Genetic effects. On this same basis, genetic effects during the next 30 years would average not more than 20 persons born each year with tangible genetic defects and several times that number with lesser genetic defects, stillbirths and the like. In this country there would occur not more than 500 greater or lesser tragedies of this nature to add to the some 1,400 fatalities and a large number of serious injuries each year readily identifiable with other aspects of our defense efforts. If weapons tests that produce fallout are not resumed, these rates, if realized at all, would subside gradually with succeeding generations.

While the statement "no radiation exposure to the gonads without some genetic effect" seems to still hold, work at Oak Ridge National Laboratory and in the United Kingdom clearly demonstrates that mutations depend on the rate at which radiation exposure occurs. Whether these new data mean that the true doubling dose for man or mice—the dose of radiation that will cause the spontaneous genetic mutation rate to double—is the 40 *r* taken by the United Nations Scientific Committee or is higher remains to be resolved. Certainly the new evidence would suggest the 40 *r* figure is not too high for exposure incurred at very low dose rates.

Current Research Activities

The Commission keeps informed of the vast amount of information being developed for other purposes and has concentrated its own research efforts on completing the picture of fallout.

Some of the most valuable information the Commission has on the movement of fission products in the air or the soil and the deposition on vegetation and soil of particulate or gaseous radioactive material comes as a byproduct of operating production and processing plant sites and conducting weapons test sites.

The Commission-sponsored program of research directed specifically into the nature and hazards of fallout has grown steadily during the past 2 years. Table VI, showing a budgetary increase of nearly 130 percent in this category, outlines the extent of this research and in closely related activities.

TABLE VI.—SUMMARY OF FALLOUT RESEARCH AND RELATED ACTIVITIES

	Actual fiscal year 1958	Actual fiscal year 1959	Estimated fiscal year 1960
FALLOUT SAMPLING AND ANALYSIS	$1, 708, 573	$2, 396, 726	$3, 952, 000
PROGRAM ACTIVITIES RELATED TO THE DEVELOPMENT OF RADIATION STANDARDS	25, 155, 251	30, 263, 566	34, 832, 000
Research Related to Radiation Standards of Permissible Exposure (Radiation Biology)	15, 738, 263	18, 794, 742	21, 188, 000
Research Related to Radiation Standards Involving Environmental Contamination and Waste Disposal	2, 708, 122	3, 861, 282	5, 025, 000
Research Related to Prophylaxis and Treatment of Radiation Injury	3, 150, 623	3, 301, 844	3, 397, 000
Dosimetry and Instrumentation	2, 027, 703	2, 115, 831	2, 497, 000
Radiation Protection—Physical	867, 616	1, 138, 489	1, 205, 000
Radiation Measurements—General	662, 924	1, 051, 378	1, 520, 000
PROGRAMMATIC NOT DIRECTLY RELATED TO THE DEVELOPMENT OF RADIATION STANDARDS	8, 474, 246	9, 347, 465	10, 216, 000
Total Biology and Medicine Program	35, 338, 070	42, 007, 757	49, 000, 000

The problem of rate and pattern of transport of fallout and its final distribution over the surface of the earth is primarily meteorological. The closest possible liaison with the Weather Bureau, the Air Force and the Defense Atomic Support Agency personnel and their related studies has been essential and has been successfully achieved. The Commission has encouraged, and where appropriate or necessary, supported financially those groups, both in and out of government best qualified to work on various aspects of the problem.

For instance, the best evidence as to the ultimate resting place of global fallout is to collect and to analyze soil for strontium 90 on a global basis. This has been done by the Department of Agriculture with analytical support by the Commission. The Commission made arrangements with scientists in Australia, New Zealand, and other countries to participate in this program.

Scientists of the Lamont Geological Observatory, Columbia University, have for several years assumed responsibility for our national and world-wide human bone studies. They also have made studies in soil uptake of strontium 90 and collected and analyzed a variety of foods from many places in the United States and abroad. The food collection program has cooperation from the Interdepartmental Committee on Nutrition which assisted in procuring food from South America and other areas. Recently with Atomic Energy Commission support the United States Public Health Service has undertaken a regional study of strontium 90 in humans in the vicinity of the Nevada Test Site.

One of the critical parts of the program has been the analytical work. The Commission's Health and Safety Laboratory has been responsible for developing methods and procedures for analyzing strontium 90 in a variety of materials, soil, grass, water, air samples, etc. It has worked with the several contract laboratories on methods, standardization of procedures, and most important and at times most discouraging of all, the matter of quality control which has plagued those who have worked at the low levels dealt with in fallout studies.

The program of fallout sampling and monitoring supported by the Commission during the fiscal year 1960 will include the following work:

Development of Stratospheric and Ground Level Sampling Devices by Armour Research Foundation, Atlantic Research Corp., Del Electronics Corp., General Mills, Inc., Georgia Institute of Technology, and Meteorology Research, Inc.

Stratospheric and Surface Air Sampling and Analysis by the Air Force, Public Health Service, AEC Health and Safety Laboratory, and Naval Research Laboratory.

Measurement of Fallout Deposition on Earth's Surface and Measurement of Fallout in Plants, Animals and Man by the Department of Agriculture, Air Force, Air Research and Development Command, University of Arkansas, University of California at Los Angeles, Columbia University Lamont Geological Observatory, General Electric Co. at Hanford, National Institutes of Health and Bureau of State Services, Department of Health, Education and Welfare, AEC Health and Safety Laboratory, Geological Survey, University of Michigan, Mount Washington Observatory, University of Washington Laboratory of Radiation Biology, and Woods Hole Oceanographic Institute.

Compilation and Meteorological Interpretation of Fallout Data by U.S. Weather Bureau, Nuclear Science and Engineering Corp., and Isotopes, Inc.

This program has been primarily a scientific research program with the purpose of understanding the factors that influence the patterns and rates of fallout onto the earth's surface whether the debris is tropospheric or stratospheric in origin and whether the fallout material originates near the equator or at some other latitude. What has been demanded is four dimensional sampling, in two dimensions over the surface of the earth, a third dimension out to 100,000 feet or more in the earth's atmosphere and a fourth in time.

As long as radiochemical analysis for strontium 90 remains as expensive and difficult as it is today, enough sampling and analysis to answer everybody's questions will be impossible. Each year several million samples of milk are analyzed for bacterial count. To do the same for fallout would cost several hundred million dollars a year. However, an occasional item in the diet that is relatively high in strontium 90 carries none of the consequences of a batch of milk contaminated with hemolytic streptococci or tubercle or diphtheria bacilli. It is the average strontium 90 intake over the year which will be reflected in the bone, not peak values nor lowest values. With all the milk sampling locations averaging well under 30 micromicrocuries of strontium 90 per liter to date it is unlikely that in the United States the average level of radiation to the bone from strontium 90 from weapons tests detonated to date will equal the sea level "natural background" exposure.

The Commission's experimental and laboratory research in biology and medicine related to the problem of fallout falls naturally into two major categories.

First is the movement of fallout into and in the food chain and water supplies, once it has been deposited on the earth's surface, and, in addition, the matter of absorption by man from food, water or air and the deposition and ultimate fate of different isotopes in the human body. Table VII—Sampling Systems Related to Radioactive Fallout gives details.

Second is the work aimed at determining the effects of ionizing radiation on the human body and on human germ cells in order to gain a more precise knowledge of the hazards of fallout, some of which is described later in this section.

The Commission-supported work on soil chemistry and movement of strontium 90, cesium 137 and other nuclides from soils and plants into the food chain includes 25 projects in the fiscal year that will end June 30, 1960 (see Appendix 15). Additional projects are under way at Commission installations.

Some results of Commission-sponsored and United Kingdom studies of soil and pasture have been cited earlier, the lack of important discrimination by plants against strontium 90, the importance of direct uptake that bypass the soil, the limited value of liming, or similarly treating acid soils, to reduce uptake. Other facts brought out by the studies include:

a) The levels of strontium 90 fluctuate month to month, season to season, but soil levels and bone levels have risen slowly and steadily.

b) There is evidence for some slow fixation of strontium 90 in some soils.

c) Strontium 90 is slowly moving downward in unplowed soil.

In the Commission's research program in molecular biology, fundamental work is aimed at unravelling the mechanisms and the several steps involved in production of radiation injury at the molecular level. It may short cut the direct approach to the problem involving hundreds of thousands of laboratory animals, and provide leads to methods for forestalling or correcting radiation injury.

Summaries of Research Results

A few examples of work aimed at measuring the biological effects of low-level radiation are described in the following pages. Other studies related to the fallout problem are covered in the preceding portion of this report devoted to progress in research in the life sciences.

Long-term studies in animals. The Radiobiology Laboratory of the University of Utah under contract with the Commission has been carrying out long-term studies on dogs to determine the distribution, excretion rate and pathological effects of chronic dosages with five radioisotopes of interest to the Commission. These studies have been under way for 7 years, and are to continue until the experimental animals die. Some 300 young beagle hounds have received single injections of radioactive strontium, radium, plutonium, radiothorium, or mesothorium. Physical examinations are carried out periodically to assess biological damage. Of equal importance are determinations of the body burdens of isotopes using a whole body counter designed especially for dogs. Without this instrument, a much greater number of dogs would have had to be used to establish rates of elimination. Upon death, each dog will be given extensive pathological, radiochemical, and autoradiographic studies.

TABLE VII.—SAMPLING SYSTEMS RELATED TO RADIOACTIVE FALLOUT

Samples drawn from—	Sampling system	Samples collected by—	Samples analyzed by—	Number of stations	Frequency of sampling	Year established	Radiation analysis				
							Gross radiation	Fission products	Tracers	Natural activities	Supplementary analysis
Upper air	Project Ash Can	AF Hq Com	Contractor	2	4 per mo	1956	β	Sr^{90}, Sr^{89}, Zr^{95}, Cs^{137}, Ba^{140}, Ce^{144}.	Rh^{102}, W^{185}.		
Do	Experimental sampling (GMI, CML, Del, 110th BAG, etc.).	Contractors	do	2	Irregular	1953	β	Sr^{90}, Sr^{89}, Zr^{95}, Cs^{137}, Ba^{140}, Ce^{144}.	Rh^{102}, W^{185}.	H^3, C^{14}	Particle size, ozone.
Do	Research sampling.	AFCRC	AFCRC	Variable	do		β	Sr^{90}, Sr^{89}, Ba^{140}, Ce^{141}, Ce^{144}.	Rh^{102}, W^{181}.	H^3, C^{14}, Pb^{210}.	Particle size, total mass,
Surface air	National Surveillance Net.	USPHS	USPHS	44	Daily	1956	β				
Do	80 Meridian Net	USNRL	USNRL	21	do Monthly	1956	β	Sr^{90}, Sr^{89}, Y^{91}, Cs^{137}, Ce^{141}, Ce^{144}.	W^{185}	Pb^{210}	
Do	AEC Site Net	Contractor	Contractor	11	Daily	1953	β, γ				
Do	Research and development (ARF, Scripps, ANL, UCLA).	Contractors	Contractors	3	Irregular		β	Sr^{90}, various others.		C^{14}, Rn^{222}	Particle size.
		AFCRC	AFCRC	1	Daily	1958		Sr^{90}, various others.	Rh^{102}, W^{181}.		
Do	Carbon dioxide sampling.	USWB	Contractor	5–10	Few per yr	1958		C^{14}			
Deposition	Gummed film Net.	HASL	HASL	197	dup. Daily	1951	β, est. γ	est. Sr^{90}			
Do	Pot and funnel net.	HASL	HASL, contractor.	67	Monthly	1954	β	Sr^{90}, Sr^{89}	W^{185}		
Do	"Washtub" Program.	Contractor	Contractor	5	Each rain	1955	β	Sr^{90}, Sr^{89}, Ba^{140}, (Cs^{137} New Zealand only).	W^{185} (except N.Z.).		Solubility.
Do	National Surveillance Net.	USPHS	USPHS	44	Daily	1956	β				
Do	80th Meridian Net.	AFCRC	AFCRC	6	By-weekly	1956		Sr^{90}, various others.	Rh^{102}, W^{181}.	H^3, Pb^{210}	

Do	U.S. Soil Program	HASL	HASL	17	dup. Annual	1955		Sr^{90}			
Do	Foreign Soil Program.	USDA	do	60	dup. 2-yr	1955		Sr^{90}			
Do	Tritium projects	Contractors	Contractors	3	Each rain	1958				H^3	
Do	Research sampling (Mt. Wash., BNL, MIT, U of MICH., UCLA).	do	Various	5	Various		β	Sr^{90}, various others.	Various	Various	Natural salts, radar cloud data, snow, crystal structure, drop size, etc.
Biosphere	Ocean sampling	Contractors	Contractors	10–15	Wkly to Quarterly.	1948		Sr^{90} various	W^{185}, Co^{60}, Zn^{65}.	C^{14}	Various chemical and biological data.
Do	Tap water	HASL	HASL	2	Monthly	1953		Sr^{90}			
Do	HASL Pasture Program (soil, vegetation, animal bone).	USDA	do	6	dup. Annual	1955		Sr^{90}			Stable Ca.
Do	Chicago Pasture Survey (soil, vegetation).	USDA	do	8	do	1953		Sr^{90}			Do.
Do	Los Alamos C^{14} Program.	Contractor	Contractor	50	1-3 yrs	1956				C^{14}	C^{12}, C^{13}.
Do	Food sampling	HASL and Contr.	HASL	Variable	Total 150/yr	1957		Sr^{90}			Stable Ca.
Do	HASL Milk Program.	HASL	do	4	Monthly	1954		Sr^{90}			Do.
Do	Los Alamos Milk Program.	Contractor	Contractor	67	Wkly to Quarterly.	1956		Cs^{137}, Ba^{140}, La^{140}, some Sr^{90}.		K^{40}	Stable K.
Do	Lamont Milk Program.	do	do	30	Total 200/yr	1954		Sr^{90}			Stable Ca.
Do	HASL Background Survey.		HASL	400	Semi-annual	1957	γ				
Do	Research projects	Contractors	Contractors					Sr^{90}, I^{131}, others			
Man	Lamont Human Bone Program.	Contractor	Contractor	30	Total 1500/yr	1954		Sr^{90}			Stable Ca.
Do	Urine	HASL	HASL	Variable	Total 30/yr	1954		Sr^{90}			
Do	Whole Body Counting.		Contractor	2	Some wkly	1956	γ	Cs^{137}		Ra^{226}, K^{90}.	

A project at the University of California at Davis, Calif., began in July 1951 with the objective of ascertaining the effects of whole-body X-irradiation on work capacity and longevity in beagle hounds. At present, the average age of the dogs is 6 years and approximately 10–12 percent of the colony has died. Although no major differences in the time of death is yet evident among the three groups—one a control group, two others receiving exposures of 100*r* and 300*r*—the irradiated animals are showing a higher incidence of neoplastic diseases, principally as adenocarcinomas of the mammary gland. One-half the animals in each group have been bred, but this does not seem to influence markedly the probability of death from mammary tumor. The results of breeding of the irradiated dogs are essentially normal.

The death rate in the colony is rising and the next several years should produce information as to the effects of the initial radiation exposure on life expectancy and cause of death, as well as on detrimental effects that might arise from a combination of irradiation exposure and reproductive activity.

At the Veterinary School of the University of California at Davis, Calif., a long-term project is being developed using dogs to determine the relation between effects of radium 226 and strontium 90. The figures are known for radium 226 in man, and ratios obtained from this experiment can be extrapolated back to man.

Strontium 90 will be fed at five systematic dose levels to pregnant and nursing females so that the pups, on weaning, will have specific levels of strontium 90 in their bones. They then will receive similar graded amounts of strontium 90 in their food until they reach 18 months of age. These animals then will be observed until their deaths. The strontium 90 series will be paralleled by a similarly treated group of dogs receiving radium 226.

To care individually for some 450 radioactively contaminated animals, it was necessary to devise a sound decontamination system for the waste, to design easily decontaminated metabolism cages, and to build holding pens adapted to the normal needs of the animal. Live trial-runs of all procedures are being carried out. It is known already that the highest dose level of strontium 90, some 125 times the maximum permissible concentration, produces leukemia in the dog, together with serious pathological changes in bone.

Dietary studies in animals. The assimilation of fission products in man and animals is known to be closely dependent on such dietary factors as nutrition, vitamin and hormone action and on such physiological factors as growth, gestation, and lactation. To obtain addi-

tional data concerning these factors, New York State Veterinary College, Cornell University, is investigating fission product metabolism and response in laboratory and domestic animals, and consequent movement of these nuclides through the food-chain to man. Factors governing relationships between dietary intake, retention and elimination of radioisotopes of strontium, cesium, iodine and barium have been studied. Experiments using radioactive isotopes of strontium and calcium have revealed such findings as a strontium-calcium ratio in milk of 0.09 to 0.16 to that present in the ration being consumed by the animal. It also has been shown that the stable calcium level in blood plasma may be elevated from a normal level of about 12 milligrams percent to about 22 milligrams percent without show of outward distress by the animal.

Strontium 85 studies in man. Since the long half-life of strontium 90 precludes its use in clinical investigations with volunteers, radioactive strontium 85, with a relatively short half-life of 65 days, is being used extensively in studies of the metabolism of radiostrontium in man.

Studies of the metabolism of strontium indicate a preferential urinary excretion, higher renal clearance, and lower body retention of strontium 85 than of calcium 45 following an intravenous injection of the tracer isotopes; the average ratio of Sr^{85} to Ca^{45} is 2.8. With oral administration, it was found that strontium 85 was poorly absorbed from the gastrointestinal tract when compared to calcium 45, approximately 3 times more calcium than strontium being absorbed. Thus, due to the poor gastrointestinal absorption of strontium and to the preferential urinary excretion of the absorbed radiostrontium, the body burden of strontium 85 is considerably lower than that of calcium 45.

Another study indicated that at 30 days 50 percent of the administered dose of strontium 85 remains in the body and that subjects with skeletal abnormalities such as multiple myeloma, hyperparathyroidism, or osteoporosis tend to retain strontium with great avidity, in one case in the face of great calcium loss.

These results in man confirm the earlier studies in animals. The reasons for these discrimination differences are as yet unknown.

Radioactive decontamination of milk. Although not necessary under current conditions, removal of radioactive contamination from foods was being studied to provide basic information against possible emergencies. A series of laboratory scale studies carried out at the University of Tennessee-AEC Agricultural Research Laboratory, Oak Ridge, Tenn., demonstrated that up to 94 percent of contained stron-

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tium can be removed from milk without appreciable alteration of the milk. The most useful technique involved separating the milk (the cream fraction contains very little strontium) and treating the skim milk with the calcium form of a cation exchange resin. Studies in Canada also have indicated the feasibility of removing both strontium and cesium from milk, while work in the United Kingdom demonstrated removal of strontium and iodine from milk.

The Commission has joined in a cooperative program with the U.S. Department of Agriculture and the U.S. Public Health Service to examine the feasibility of removing strontium from milk on a pilot plant scale. These studies will be carried out at the United States Department of Agriculture, Agricultural Research Center at Beltsville, Md.

Iodine 131 uptake in animals and man. Research conducted at the University of Tennessee School of Medicine during the past several years has used selective uptake of iodine by the thyroid to assess the contamination of the environment by studies in man, sheep, cattle, and swine. Samples for assay have been collected from the United States, Canada, Australia, Japan, Republic of China, the United Kingdom, and the Federal Republic of Germany. Assay data are available from January 1956 for most of the specimen classes. During October and November 1959, increases in uptake of iodine 131 in the thyroids of cattle and sheep have been noted both in the United States and the United Kingdom.

Estimates have been made based on iodine concentrations in milk which suggest that a few children in the United States may have received 1.8 rads to the thyroid gland.

Fallout Information for the Public

In order to keep the Congress and the public currently and fully informed on the subject of fallout and its possible consequences, the Commission publishes new facts as rapidly as possible. Some information that bears directly on security and national safety is held secret. The Commission does not carry exclusively the responsibility for decisions on what must be kept secret. Other agencies, including the Department of State, the Department of Defense, and the Central Intelligence Agency are directly concerned.

The Commission issued the Health and Safety Laboratory Report No. 42 in October 1958—a 359-page summary report entitled "Environmental Contamination from Weapon Tests." Subsequent quarterly technical reports on world-wide fallout have been distributed

to news media and made available for sale through the Office of Technical Services, U.S. Department of Commerce. Many other reports originating in various Commission laboratories (examples are UCRL-8083, "Estimation of Turnover Equation of Strontium-90 for Human Bones," by P. K. Kuroda; and BNL–496 "The Distribution of Fallout Activity in Rainfall at BNL, June–September 1957," by F. P. Cowan and J. Steimers) also are made available for sale.

From time to time the Commission issues special fallout reports through the Government Printing Office (examples are "Some Effects of Ionizing Radiation on Human Beings," 1956, by E. O. Cronkite, V. P. Bond and C. L. Dunham; and "Radioactive Contamination of Certain Areas in the Pacific Ocean from Nuclear Tests," 1957, by G. M. Dunning). In 14 Semiannual Reports to Congress, sections on fallout problems were included, for example, in the Fourteenth, Sixteenth, Nineteenth, Twenty-second and Twenty-third Semiannual Reports. Scientific papers prepared by biophysical, biological and medical scientists supported by the Commission appear in technical journals throughout the world, as have papers specifically on world-wide fallout prepared by members and staff of the Commission.

The United States has been the principal source of fallout information provided to the United Nations Scientific Committee, largely because of the extensive data made available by the Commission. In addition, the Commission issues regular quarterly public information summaries on fallout, the first being released September 8 and October 9, 1959.

The Commission is continuing to declassify fallout information which might concern the public health and welfare, and making the data available as soon as possible after its collection. A concerted review was made throughout the Commission to find classified reports in this area and a special declassification team was organized. A total of 2,160 documents were identified as containing some information relating to the radioactive content of the atmosphere in fallout. Some 501 of these had been previously released or duplicated in other reports. Of the remaining 1,659 reports (1,033 unclassified and 626 classified) 84 unclassified reports were found to contain information useful to the public for evaluation of radioactive hazards. Of the 626 classified reports in this group, 79 were declassified, most without deletions, and prepared for distribution to the public by sale through the Office of Technical Services, Department of Commerce. Previously declassified and unclassified documents are available in the same way, and all will be summarized in the Commission's regular publication, *Nuclear Science Abstracts*.

The published reports of the 1959 Hearings on Fallout by the

Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, to which the Commission submitted a large number of summaries and reviews will provide a broad survey of up-to-date knowledge. Individual papers submitted for the Hearings have been published separately by the Commission and made available to the public.[46]

A scientific meeting of major importance, the University of Minnesota Symposium on Radioisotopes in the Biosphere, was held in October under joint sponsorship of the Commission, the National Science Foundation and the Agricultural Research Services, U.S. Department of Agriculture. Held in Minneapolis the symposium drew approximately 150 scientists from the United States, Canada, Norway, Sweden, the United Kingdom, New Zealand and Australia. The printed proceedings of the symposium will be given wide distribution.

Health and Safety

As a means of centralizing its responsibilities in the field of radiation protection, the Commission, on September 12, 1959, established within its headquarters an Office of Health and Safety. The new organization was assigned primary responsibility, in cooperation with other Commission offices and divisions, for: (*a*) developing and recommending health standards for protection of the public from atomic energy-induced radiation; (*b*) serving as a focal point for Commission relationships with State Governments in the area of radiation protection; and (*c*) developing policies and recommending standards for protection of Commission, and contractor, personnel from nonnuclear as well as radiation hazards.

Actions Under New Law

Cooperation With States

Public Law 86–373, effective September 23, 1959, further amended the Atomic Energy Act of 1954 by adding a new section 274, "Coop-

[46] Available through the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. One of the important publications is TID–5550, "Radioactive Fallout—A Two-Year Summary" by C. L. Dunham, M.D., Director, Division of Biology and Medicine, AEC. Price $1.25. A "Summary-Analysis of Hearings," prepared by the Commission and Joint Committee on Atomic Energy staffs is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

eration with States." The Commission's program to carry out the provisions of section 274 will be a responsibility of the new Office of Health and Safety.

Essentially, the amendment provides procedures and criteria whereby the Commission may turn over to individual States, as they wish to do so and become prepared for the task, the responsibility for regulating source material (natural uranium and thorium), by-product material (radioisotopes), and small quantities of special nuclear material (uranium 233, uranium 235, and plutonium).

Under the amendment, before the Commission may enter into an agreement with the Governor of State providing for discontinuance of the regulatory authority of the Commission, the Governor must certify that the State desires to assume the regulatory authority and has a program for the control of radiation hazards adequate to protect the public health and safety. In turn, the Commission must determine whether the State's program is compatible with the Commission's program for regulating nuclear materials and is adequate to protect public health and safety. The Act also authorizes the Commission to assist the States—through training and other services—in preparing themselves to assume independent regulatory jurisdiction. The Federal Government retains areas of regulatory jurisdiction in which interstate, national, or international considerations are paramount. These areas include: construction and operation of nuclear facilities, such as reactors and other facilities using or producing large quantities of special nuclear material; the import and export of nuclear facilities and materials; the disposal into the ocean or sea of nuclear materials; and the distribution of manufactured articles containing source, by-product or special nuclear materials.

The Commission is developing the criteria necessary to determine the adequacy of proposed State programs, including the formulation of suggested statutes and regulations which may be used as guides for State action. A training program for personnel is being developed jointly with the United States Public Health Service. Some work already under way in this field is described in the section of this report dealing with Education and Training. Informal discussions on the criteria and other aspects of cooperation with the States have been held by the Commission with the Council of State Governors, the States Attorney General Association, regional and other representatives of individual State Governors, representatives of individual State organizations, as well as with other Federal agencies concerned in the program.

Federal Radiation Council

The amendment to the act establishes a Federal Radiation Council to advise the President on radiation matters. This Council, similar to that established by Executive Order 10831, August 14, 1959, consists of the Secretary of Health, Education, and Welfare, the Chairman of the Atomic Energy Commission, the Secretary of Defense, the Secretary of Commerce, the Secretary of Labor, or their designees, and such other members as shall be appointed by the President. The Special Assistant to the President for Science and Technology, or his designee, also is authorized to attend meetings, participate in deliberations, and advise the Council.

On August 22, the President designated the Secretary of Health, Education, and Welfare as the current Chairman of the Council. With the aid of a technical committee consisting of designees of the Council members and an appointed Secretary of the Council, the Council has begun a study of current standards of radiation protection in relation to public health. These exploratory studies are expected to form the basis for defining the immediate program of the Council, and will eventually effect policies for the control of sources of radiation by the Federal Government.

Radiological Assistance Plan

The Commission, upon request, provides assistance during radiological incidents through a Radiological Assistance Plan. The plan was formulated in 1957–58, and is presently administered through eight Commission Operations Offices, New York, Oak Ridge, Savannah River, Albuquerque, Chicago, Idaho, San Francisco, and Hanford. Each office is responsible for a specific region of the United States (see Table VIII Regional Areas for Radiological Assistance Plan). Through the plan, Commission Radiological Assistance Teams are available from 35 locations scattered through 22 States plus 1 team located in Puerto Rico. Team capabilities may include alpha, beta, or gamma monitoring; air, water, and food sampling and monitoring; medical advice and assistance; decontamination assistance; and the use of laboratory facilities to perform radiochemical analyses of samples.

The Operations Offices managers, in cooperation with Governors in the various regions, have worked out detailed plans for informing civil authorities of the types of radiological assistance available from the Commission in case of radiation incidents and the procedures to be used for requesting assistance.

TABLE VIII.—REGIONAL AREAS FOR RADIOLOGICAL ASSISTANCE PLAN

Region area No.	Regional office address	Telephone No.	States and Territories in regional area
1	New York Operations Office, 376 Hudson St., New York 14, N.Y.	YUkon 9-1000	Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, and Delaware.
2	Oak Ridge Operations Office, P.O. Box E, Oak Ridge, Tenn.	Oak Ridge 5-7486 or 5-8611; extension 7607.	Virginia, West Virginia, Kentucky, Tennessee, Missouri, Arkansas, Mississippi, Louisiana, Puerto Rico, and Virgin Islands.
3	Savannah River Operations Office, P.O. Box A, Aiken, S.C.	Aiken, S.C., MIdway 9-6211; or Augusta, Ga., PArk 4-6311, extension 3333.	North Carolina, South Carolina, Georgia, Alabama, Florida, and Panama Canal Zone.
4	Albuquerque Operations Office, P.O. Box 5400, Albuquerque, N. Mex.	ALpine 6-4411, extension 38267.	Kansas, Oklahoma, Texas, New Mexico, and Arizona.
5	Chicago Operations Office, P.O. Box 59, Lemont, Ill.	CLearwater 7-7711	Ohio, Indiana, Illinois, Michigan, Minnesota, Wisconsin, Iowa, North Dakota, South Dakota, and Nebraska.
6	Idaho Operations Office, P.O. Box 2108, Idaho Falls, Idaho.	JAckson 2-6640	Montana, Idaho, Wyoming, Utah, and Colorado.
7	San Francisco Operations Office, 518 17th St., Oakland, Calif.	TEmplebar 2-4282	California, Hawaii, and Nevada.
8	Hanford Operations Office, P.O. Box 550, Richland, Wash.	RIchland 2-1111, extension 6-5441.	Alaska, Washington, and Oregon.

Managers of Operations having responsibilities for regional radiological assistance have established liaison with field offices of other Federal agencies, including the Coast Guard, Army, Air Force, and Navy; United States Public Health Service; Office of Civil and Defense Mobilization; General Services Administration; Federal Bureau of Investigation; and the Department of Defense Atomic Support Agency Field Command.

Since early 1958, the Commission and Defense Department have had a formal agreement for joint action in handling accidents involving nuclear weapons. That agreement has been extended to include radiological incidents which do not involve weapons, and operates through a Joint Nuclear Accident Coordinating Center presently established at Sandia Base, Albuquerque, N. Mex.[47] Department of Defense assistance is available at more than 400 military installations.

[47] A technical information bulletin, "Atomic Weapon Accident Hazards, Precautions and Procedures", prepared by the Department of Defense and Atomic Energy Commission, Sept. 30, 1958, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., for 10 cents.

To date, requests for radiological assistance made under the joint Commission-Defense Department agreement have been for specialized technical advice and assistance rather than the services of teams.

A survey of written inquiries from the inception of the plan (June 1958) to the end of 1959, shows that Commission Regional Offices have replied to about 1,000 requests for information, 86 for radiological assistance, and 13 for advice in establishment of radiation monitoring teams. Radiological assistance personnel were sent in response to 67 of the 86 requests received. Full radiological assistance teams were sent on request to the sites of 22 incidents; one man was sent to each of 45 incidents. Radioactive materials were found to be actually involved in 42 incidents.

Test exercises for Commission radiological assistance teams are conducted periodically to test improvements in the plan and to provide training.

The *Interagency Committee on Radiological Assistance*, organized in May 1958, is composed of representatives from 13 Federal agencies. This committee has prepared a proposed Mutual Radiological Assistance Plan (MRAP) intended to establish a basis for integrating Federal agency capability to render advice and assistance in response to requests for radiological assistance; to provide a radiological training program for public safety and public health personnel at the Federal, State and local levels; and to provide a means whereby the participating Federal agencies may coordinate their activities with those of State and local health, police, fire and civil defense agencies. The MRAP provides that the Atomic Energy Commission be designated the agency responsible for administration and implementation of the policy with the cooperation of other participating Federal agencies. Presently operating radiological assistance capabilities of the Federal agencies, including the Commission and Department of Defense systems, are not intended to be replaced or changed by the proposed plan.

Occupational Safety

Radiation Exposure Summary

During early 1959, the Commission completed the first of its new annual surveys [48] on radiation exposure levels for personnel employed

[48] Under regulations published on Oct. 10, 1958, as AEC Manual Chapter 0523, field Operations Offices will submit by February 28 of each year a summary of external and internal occupational radiation exposures for Commission and contractor personnel under their jurisdictions. Exempted from the reports are certain types of research contractors who would not be expected to have significant personnel exposures.

in its operations. The survey covered personnel at 117 Commission- and contractor-operated activities for the calendar year 1958 and showed a downward trend in exposure levels over previous surveys.

Annual accumulated external whole-body penetrating radiation exposures were reported for 65,907 individuals, or about 53 percent of the 124.499 individuals employed during calendar year 1958. About 99.7 percent of external radiation exposures accumulated were less than 5 rem [49] which is the recommended maximum permissible annual average dose for occupational exposure. About 90 percent of all annual exposures were less than one rem total dose. Although 181 individuals accumulated more than the 5 rem average permissible dose, their total exposure has not exceeded the level allowable at their present age.

There were 12 exposures reported to be equal to, or greater than, the recommended maximum yearly permissible dose of 15 rem.[50] These exposures resulted from radiation accidents which have been investigated and reported in detail. In one case, there is some doubt as to whether the dose in fact exceeded 15 rem.

Reports also are required of any case in which an individual has accumulated an amount of radioactive material in his body estimated to be more than half the permissible quantity as recommended by the National Committee on Radiation Protection and Measurements (NCRP), and if this amount has persisted for a period of 6 consecutive months.

Additional information is required for all reportable internal radiation exposures and follow-up is provided for by the Operations Office with jurisdiction over the installation at which the exposure occurred. During 1958, only two individuals were in this category.

Nineteen hundred and fifty-eight is the first year for which the Commission received annual radiation exposure information under present reporting requirements. Radiation exposures of Commission, and its contractor personnel, were reported to the Congress for the period 1947–55, and for 1955 alone.[51] Exclusive of accidental exposures of 15 rem and larger, the percentage of annual accumulated radiation exposure in 1958 below the 5 rem average permissible dose is greater than was the case in 1955. In general, the 1958 information shows that

[49] "Rem" stands for roentgen equivalent, man; the dose of any ionizing radiation that will produce the same biological effect as that produced by one roentgen of high-voltage X-radiation.

[50] The maximum permissible radiation dose from external whole-body penetrating radiation was recommended to be reduced to 12 rems by the NCRP in its statement "Maximum Permissible Radiation Exposures to Man", April 1958.

[51] See pp. 162–168, Twenty-first Semiannual Report (July–December 1956).

the Commission's operations are keeping occupational radiation exposures to minimum dosages consistent with effectively carrying on the Commission's programs.

Safety and Fire Protection

Fire protection. Over the past 3 years, work has been proceeding to develop fire-resistive filters for radiation containment in event of fire. About 95 percent of all flammable filters in Commission plants and laboratories have been replaced.

AEC respirator committee. A committee of Commission contractor representatives, formed to consider breathing mask problems, has recommended performance criteria for respirators used in atmospheres containing particulate matter "significantly more toxic than lead." All major Commission contractors, as well as manufacturers of respiratory equipment, were consulted in compiling the report. These criteria will be submitted to the United States Bureau of Mines Health and Safety laboratory for inclusion in future manufacturing approval schedules for respirators.

The Commission is financing a study at the Harvard School of Public Health to develop a quick, accurate method for evaluating the peripheral leakage of filter respirators. With good criteria and good test methods, approval schedules may result in manufacture of respiratory equipment that will offer better protection against radioactive particulates.

Industrial safety experience. During 1959, for the second consecutive year since the record low in 1957, the frequency of disabling work injuries has declined. The Commission program experienced 436 disabling work injuries through November 1959—lower than in the same period last year. The increase in fatalities from 5 in 1958 to 12 in 1959 was due largely to a nonnuclear explosion which occurred at Los Alamos Scientific Laboratory on October 16, 1959 in which 4 men were killed.

The rate of lost-time accidents per million man-hours worked for the total program of the Commission was 2.03—7.4 percent below the preceding year—as compared to an all-industry rate, as reported by the National Safety Council, of 6.17 lost-time accidents per million man-hours. Frequency rates for various types of activities for the past two years are given in the following table:

NUMBER OF LOST TIME ACCIDENTS PER MILLION MAN-HOURS WORKED

Activity	*Nov. 1959 frequency*	*1958 frequency*
Operation	1.50	1.75
Production	.99	1.47
Research	1.93	1.98
Services	3.21	2.47
Construction	7.67	6.08
AEC (Government)	2.17	1.53
All operations	2.03	2.18

Safety performance awards. Twenty-one Awards of Merit and 10 Awards of Honor were made to Commission contractors and Operations Offices during 1959. Among the Awards of Honor was one presented to Dow Chemical Co., Rocky Flats Plant, employees who at the present time have worked more than 7 million man-hours since their last lost-time injury. Twelve contractors and three Commission offices received the General Manager's Commendation for 200,000 or more injury-free man-hours.

Nuclear Materials Management

Material Transfers to Private Industry

With the increase in the number of transfers of source and special nuclear materials between the Commission and private industry or foreign governments, increased emphasis was placed during 1959 on measurement of these materials and resolution of measurement differences between the parties involved.

Recommended measurement methods. Through a special Advisory Committee and through seminars, the Commission is establishing suitable methods for measuring the properties and quantities of source and special nuclear materials transferred between the Commission and private industry or foreign governments.

Measurement methods now in use for atomic energy operations are being reviewed and evaluated at a series of technical seminars among recognized authorities in the various fields of measurement. The first seminar was held at the Argonne National Laboratory on November 17–18. The Advisory Committee for Standard Reference Materials and Methods of Measurement, formed in 1958, will review results and advise the Commission in selecting Commission-recommended methods for publication or for initiation of methods of research and development.

Resolution of measurement differences. Even with recommended measurement methods established, differences will occur between the results of measurements made by the parties involved in transfers of source and special nuclear materials. Culminating several years' study to establish principles and procedures for resolving these differences, new standard lease agreements and contracts for processing irradiated fuel now include procedures for resolution of measurement differences. The cold scrap processing contracts, first negotiated this year, also contain procedures for resolving differences in measurement of material properties and quantities.

Standard Reference Materials

Five additional uranium isotopic standards were made available to complete the series of 15 standards prepared under the Commission-National Bureau of Standards cooperative program. Since the initial availability of these standards and the normal uranium chemical standard was announced in October 1958, an average of 20 uranium isotopic standard samples and 30 normal uranium chemical standard samples per month have been distributed to domestic private industry and to foreign governments. Among the foreign governments to which standards have been sent are Canada, Great Britain, The Netherlands, Belgium, France, Sweden, and Japan.

Several hundred grams of high purity plutonium metal have been prepared for evaluation for use as plutonium standard reference material. The plutonium standard is scheduled to be available from the National Bureau of Standards by February 1960.

Statistical Manual

To enable users of the uranium isotopic standard reference materials to obtain the maximum information from a minimum quantity of reference material, a manual entitled, "The Use of Uranium Standards in Isotopic Analysis," is being prepared. The manual will contain discussions of the philosophy and objective of standard reference materials, the statistical principles applicable to their use, and specific application of the uranium standards. Its preparation is being coordinated by the Commission with the recognized authorities in the fields of statistics, standards, and analytical measurement methods.

Annual Meeting

The annual meeting of Commission and contractor personnel concerned with nuclear materials management was held May 25–28. Two

panel discussions were held and some 20 papers presented. Approximately 200 people attended.

Construction and Supply

Construction

As of December 31, the Nation's investment in atomic energy facilities had increased to $7.4 billion, before depreciation reserves.

Costs incurred by the Commission for new plant and equipment during fiscal year 1959 amounted to $299 million, the fourth successive year that atomic energy construction activity has approximated the $300 million annual level to which it declined in 1956. It is expected that activity during fiscal year 1960 will continue at about this level.

Construction of new reactor facilities accounted for about 40 percent of the total costs incurred during fiscal year 1959. The $118 million incurred during the fiscal year for these facilities represents a 15 percent increase over the previous fiscal year, and an almost 300 percent increase since 1956.

Mobilization Planning

Participation in the mobilization and continuity of Government programs of the Office of Civil and Defense Mobilization (OCDM) has been augmented. A Commissioner served as Commission representative on the Civil and Defense Mobilization Board which advises the OCDM Director; Commission representatives were appointed to OCDM's eight Regional Boards; and representation is being provided on a 24-hour, 7-day-week basis at the OCDM Main Relocation Site.

Several groups from OCDM have visited the Commission Headquarters Emergency Relocation Center for briefing on emergency plans and a tour of the Center.

Participation in the OCDM program for national damage assessment after an enemy attack has been expanded as a readiness measure and in preparation for Operation Alert Exercises. Headquarters and field emergency operations from relocation centers were fully tested during the Civil Defense Alert Exercise in April. The Commission also participated in the Regional Phase of the Local, State, and Regional Exercise during July, and the National Relocation Exercise of Operation Alert 1959, during August.

The Commission is complying with the National Shelter Policy, as directed by the President, to provide Federal leadership and ex-

ample in incorporation of fallout shelters in appropriate new Federal buildings.

Small Business

Small business received a significantly increased share of the total Commission subcontract awards during fiscal year 1959, totaling $220.5 million or 41.6 percent of the $530.3 million total subcontract awards. By comparison, the small business share for fiscal year 1958 was 39.3 percent and for the 9-year period, 1951–59, the average share was 38.7 percent. At the prime contract level, the small business share also increased. Total prime contract awards amounted to $2,346 million, and the small business share was 6.1 percent or $144.5 million compared with the 4.3 percent average for the 9-year period, 1951–59.

Records Management

During fiscal year 1959, the Commission and its cost-type contractors disposed of more than 89,000 cubic feet of records having no further value. Additional emphasis was placed on removing semiactive records from office space to records centers. At the end of the fiscal year, 214,000 cubic feet, or about 39 percent, of Commission records were housed in records centers or other low-cost storage areas.

Freight Rates

Negotiations with the three major railroad associations resulted in substantial reductions in rail freight rates applicable to shipments of excess scrap armor plate and obsolete lead dummy bombs. These reductions were a significant factor in the economy of converting and utilizing the materials involved for shielding and other construction purposes at various Commission locations.

Rail Classification Ratings

By June 15, 1959, rail classification ratings had become effective on many radioactive materials and related items. This completed about 2 years effort by the rail carriers' Uniform Freight Classification Committee, working with Commission and industry representatives on the development of descriptions and ratings for nonirradiated materials and related items.

The publication of these ratings for the first time provides a means whereby many of the materials peculiar to atomic energy use can be

specifically described and shipped by rail at published tariff rates which are applicable to those specific descriptions. Previously, the alternatives for rail movement have been to ship either (*a*) at tariff rates applicable to "reasonably analogous" commodities, e.g., "Chemicals, Not Otherwise Indexed by Name," or (*b*) under special agreements entered into with the carriers.

Community Activities

Oak Ridge and Richland

Progress of property sales at Oak Ridge, Tenn., and Richland, Wash., during 1959 was as follows:

	Dec. 31, 1958		Dec. 31, 1959	
	Units offered	Percent sold	Units offered	Percent sold
	Oak Ridge [a]			
Single and duplex houses	4,360	98	4,360	99
Apartments (4 or more family units)	221	17	248	100
Residential lots	1,591	40	1,593	66
Commercial properties	103	87	103	97
Nonprofit	33	91	33	100
	Richland			
Single and duplex houses	4,806	93	4,806	99
Apartments (4 or more family units)	0	0	17	0
Residential lots	203	38	293	71
Commercial properties	0	0	231	42
Nonprofit	0	0	13	69

[a] 453 garden and brick apartments have not been offered for sale to date. It is estimated that these will be sold by Mar. 1, 1960.

Municipal government. In December 1958 Richland residents formed an incorporated city government under the laws of the State of Washington and elected a city council. Police, fire, engineering, and city clerk functions were transferred to the city of Richland on June 1, 1959; other municipal functions, including health and welfare, were transferred on September 1. Utilities, including water, waste removal and sewerage, were transferred on October 1. The electric utility was transferred November 1. This completes the transfer of all municipal functions and utilities to local entities.

In May, Oak Ridge residents voted to incorporate under provisions of a law adopted 2 years ago by the Tennessee State Legislature. On June 2, a city council was elected, and on June 16 it formally took over the duties of city government. From 34 city manager applicants,

the city council selected Fred E. Weisbrod of Painesville, Ohio, as the new Oak Ridge city manager on September 3. He was sworn in on October 30. Transfer of the balance of municipal facilities, including schools, the city water distribution system and the electric distribution system will be made to the city of Oak Ridge on or by June 30, 1960. The roads and streets within the minimum geographic area were transferred June 25, 1959, by fee simple deed from the Commission to the city of Oak Ridge. This transfer started the 10-year financial agreement period with the Commission under Public Law 221 and entitles Oak Ridge to share in the street aid revenue from State gasoline money.

Schools. Richland school facilities were transferred to the Richland School District in December 1958. The Commission is providing financial assistance to the Richland School District in an amount equal to that which the district would otherwise receive under provisions of Public Law 81–874. Oak Ridge schools will be the responsibility of the municipal government, when transferred in early 1960, through an elected school board rather than being operated by a separate school district as at Richland.

Hospitals. Oak Ridge residents selected the Methodist Church as the agency to own and operate the new hospital, which is expected to be completed by February 1960. The Atomic Energy Community Act of 1955 permits the residents to select the municipal or nonprofit agency to receive government-owned facilities such as the hospital.

Los Alamos

Arrangements are being made for development and sale by the Commission of the remaining 47 residential lots in the Barranca Mesa Subdivision No. 1 for privately owned homes.

Bids are being solicited on long-term leases covering unimproved commercial real estate to enable private enterprise to construct business buildings which will augment the limited commercial facilities operating in Government-owned buildings in Los Alamos.

Studies have been undertaken to arrange for private development of the White Rock area.

Personnel

Personnel Changes

During the January–December 1959, reporting period, the following major personnel changes took place:

Commissioner Harold S. Vance died on August 31.

Commissioner John S. Graham was renominated by the President and confirmed by the Senate for a 5-year term expiring June 30, 1964. Mr. Graham first was appointed in 1957 to fill an expired term.

Dr. Willard F. Libby, Commissioner, resigned effective June 30, to enter employment with the University of California.

Dr. John H. Williams, formerly Director, Division of Research, was appointed and confirmed by the Senate August 13, as Commissioner for the unexpired term of Commissioner Libby, ending June 30, 1961.

Dr. Paul W. McDaniel, Deputy Director, Division of Research was designated Acting Director of the Division, effective August 13.

Paul F. Foster, Deputy General Manager, resigned May 25 to accept appointment as the U.S. Representative to the International Atomic Energy Agency in Vienna.

Robert E. Hollingsworth, formerly Assistant General Manager for Administration, was appointed Deputy General Manager, effective August 28.

Dwight A. Ink, former Special Assistant to the Chairman, was appointed Assistant General Manager for Administration, effective October 9.

Edward J. Bloch, formerly Director, Division of Production, was appointed Assistant General Manager for Manufacturing, effective September 29.

George F. Quinn, formerly Deputy Director, Division of Production, was appointed Director of the Division, effective September 29.

William H. Slaton, formerly Assistant Manager for Administration and Construction, Albuquerque Operations Office, was appointed Deputy Assistant General Manager effective August 16, 1959.

Edward H. Glade, formerly Assistant Director for Headquarters Operations and Services, Division of Construction and Supply, was appointed Director of the new Office of Headquarters Services, effective September 29.

Myron B. Kratzer, formerly Assistant Director for Program Development and Liaison, Division of International Affairs, was appointed Deputy Director of the Division, effective November 10, replacing Clark Vogel, who resigned.

Dr. Nathan Woodruff, formerly AEC Scientific Representative, Buenos Aires, Argentina, was appointed Director, of the new Office of Health and Safety, effective October 19.

Jon D. Anderson, Manager, Schenectady Naval Reactors Operations Office, resigned effective June 12, to enter the employment of the New York State Atomic Energy Commission.

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Dr. Eugene P. Wigner, Palmer Physical Laboratory, Princeton University, was appointed to the General Advisory Committee, effective December 18.

Dr. Robert A. Charpie, Assistant Director, Oak Ridge National Laboratory, replaced Dr. Jane H. Hall as Secretary to the General Advisory Committee.

Stanley W. Nitzman, formerly Director, Plant Engineering and Construction Division, Schenectady Operations Office, was appointed Manager, Schenectady Operations Office, effective October 9.

John R. Moore, formerly Director, Contract Division, Oak Ridge Operations Office, was appointed Director, Office of Contract Policy, effective November 16.

Joel V. Levy, formerly Director, Industrial and Technical Services Division, Savannah River Operations Office, was appointed Area Manager, Canoga Park Area Office, effective November 30.

William F. Finan, formerly Assistant Director, Office of Management and Organization, Bureau of the Budget, was appointed Assistant General Manager for Regulation and Safety, effective December 12.

Howard G. Hembree, formerly Chief, Reactor Safety Section, Engineering Development Branch, Division of Reactor Development, was appointed AEC Scientific Representative, Chalk River (Canada) Office of the Division of International Affairs, effective May 3.

John K. Rouleau, formerly Chief, International Atomic Energy Agency Branch, Division of International Affairs, was appointed as AEC Scientific Representative, Paris, France, effective August 2.

Dr. Merril Eisenbud, Manager, New York Operations Office, resigned effective September 11.

Joseph C. Clarke, formerly Deputy Manager, New York Operations Office, was appointed Manager, effective October 9.

Willis B. Creamer, formerly Chief, Industrial Relations Branch, Division of Organization and Personnel, Albuquerque, was appointed Area Manager, Dayton Area Office, effective March 8.

Organization

Effective September 12, 1959, the Office of Health and Safety was established. The Office is responsible for developing and establishing health standards for the protection of the public from atomic energy-induced radiation and for policy and standards for the protection of

personnel in Commission operations from nonradiation hazards. The Office also serves as the focal point for relationships with officials of State governments in these areas. The functions and personnel of the Health Protection Branch and the Radiation Effects of Weapons Branch, Division of Biology and Medicine, and the Safety and Fire Protection Branch, Office of Industrial Relations, were transferred to the Office of Health and Safety.

Effective September 29, 1959, the headquarters housekeeping functions and activities were transferred from the Division of Construction and Supply and established as an Office of Headquarters Services, reporting to the Assistant General Manager.

Effective September 29, 1959, the Office of Operations Analysis and Forecasting and the Office of Industrial Relations were assigned to report to the Assistant General Manager for Manufacturing instead of to the General Manager.

Effective November 16, an Office of Contract Policy was established reporting to the Assistant General Manager for Administration. The principal functions of this Office are the development and maintenance of the AEC-wide policies and standards for contracting; the review of contracts to be awarded in headquarters; the review of all contractor selections requiring headquarters approval; and the review of conflicting staff recommendations and positions and resolutions of such conflicts, or recommendation of resolution to the General Manager. Contract functions of the Procurement and Contracts Branch, Division of Construction and Supply, were transferred to the Office of Contract Policy.

A position of Assistant General Manager for Regulation and Safety was established effective December 7. The position is responsible for the functions assigned to the Division of Licensing and Regulation, the Office of Health and Safety, and the Division of Compliance.

The functions involving direct inspection of licensees will be placed under the new Assistant General Manager for Regulation and Safety by transfer from the Inspection Division, which retains its overall statutory authority.

The Clarksville (Tenn.) Branch Office of the San Antonio (Tex.) Area Office was established March 30, 1959, to administer a contract with Mason & Hanger-Silas Mason Co., Inc. for operation of a production plant located at Clarksville. The San Antonio Area Office reports to the Albuquerque Operations Office.

Industrial Relations

Technical Manpower

The Commission's 1959 review of technical manpower indicated that the labor market has tightened considerably. Some contractors reported delay in certain programs due to inability to recruit qualified personnel. Half the reports indicated that recruitment procedures had been revised and activity increased in an effort to obtain additional competent personnel. Many cited an increased scarcity of candidates with advanced degrees.

Shortages continue in all disciplines, with electrical and electronics technicians high on the list of hard-to-recruit skills. Physicists, some types of engineers, metallurgists and mathematicians remain scarce. Increased competition with space and missile programs, and increased research and development activity in all phases of industry, were cited with a decrease in scientific and engineering graduates as reasons for the change reported during 1959.

Radiation Disease and Workmen's Compensation

The Commission worked with the Bureau of Labor Standards, U.S. Department of Labor, during 1959 in assisting the Council of State Governments in developing the Council's 1959 Program of Suggested Workmen's Compensation Legislation.

The Council's efforts were directed at substantive improvements in those State laws deficient by the Council's recommended standards. The major areas of concern to the Council—and to the Commission, since these deficiencies also operated to limit protection of workers in atomic energy—were: lack of reciprocal arrangements for extraterritorial coverage; absence of full coverage for all occupational diseases in many States; limited medical benefits payable in many States; broad coverage under second injury funds; lack of maintenance benefits payable during rehabilitation; and unrealistic, inflexible time limits for filing claims.

This last item is of especial concern to the Commission in view of the characteristics of diseases induced by exposure to radiation. Because the symptoms of such diseases may not become manifest immediately, the statutory time limit under many State laws may elapse before a worker knows he is suffering from a radiation disease.

Although the Council recognized the lack of reciprocal arrangements for extraterritorial coverage in most State laws, it made no specific legislative recommendation dealing with this subject this year

pending further consideration by the Committee on Suggested State Legislation.

During 1959, a number of States made substantive changes in their laws in keeping with the objectives set forth in the Council's suggested program. With respect to coverage of radiation disease, four States—Iowa, Maine, Montana and New Hampshire—added radiation disease to the schedule of compensable diseases; Kansas, Ohio and Missouri clarified their laws specifically describing radiation disease as compensable. This leaves three States—Wyoming, Alabama and Mississippi—without coverage of radiation disease.

Time limits for filing claims were liberalized in nine States during the current year—Alaska, Iowa, Kansas, Maine, Missouri, Montana, Ohio, Oregon, and Texas. This improvement, which applies to occupational disease generally and therefore to radiation diseases, is mitigated by the fact that 6 of the 9 States added or retained time-limit provisions which could restrict a worker's eligibility to receive compensation for a radiation disability. For example, although the Iowa law provides that the time limit for filing claims does not begin to run until after disablement or death, or until after the employee should reasonably have known of his disablement and its relation to employment, another provision of the law exempts the employer from liability for radiation disease unless disability occurs within 2 years after the last injurious exposure.

At the close of the 1959 legislative year, only two States—California and New York—substantially met all the standards recommended by the Council of State Governments.

Collective Bargaining Settlements

Approximately 32,000 or 75 percent of the production and manual employees of the more than 40 cost-type operating contractors at Commission-owned installations are represented under collective bargaining agreements. Through December, there were 53 negotiated settlements, resulting from either the negotiation of initial labor agreements or from contract renewals or reopeners, affecting approximately 20,100 or 65 percent of the contractor work force covered by union agreements.

Nearly all the settlements were concluded without work stoppages. Principal among these were those involving Goodyear Atomic Corp. and Oil, Chemical and Atomic Workers Union, AFL–CIO; Sandia Corp. and Atomic Projects and Production Workers Metal Trades Council, AFL–CIO; National Lead Co. and Fernald Atomic Trades and Labor Council, as well as the Office Employees International

Union, AFL–CIO; Union Carbide Nuclear Co. and the Atomic Trades and Labor Council (ORNL and Y–12) and the Oil, Chemical and Atomic Workers (K–25 and the Paducah plant); Dow Chemical Co. (Rocky Flats, Colo., plant) and Denver Metal Trades Council, AFL–CIO; Phillips Petroleum Co., and the Oil, Chemical, and Atomic Workers International Council, AFL–CIO, and Eastern Idaho Metal Trades Council and affiliated local unions.

Of the 53 settlements, only three were accompanied by strikes. These were of varying duration effecting approximately 2,800 employees. There was a work stoppage of 44 days at ACF Industries, Albuquerque, N. Mex., involving approximately 1,200 members of IAM Lodge No. 794, and a 28-day strike of the Oil, Chemical, and Atomic Workers Union representing approximately 320 production and maintenance workers employed at the Mound Laboratory, Miamisburg, Ohio.

The third work stoppage arising out of contract renewal negotiations occurred in June and involved bargaining units of maintenance crafts employed by Mason Hanger-Silas Mason Co., contractor for the Iowa Ordnance Works in Burlington, Iowa. A 2-day strike was terminated at the request of the Atomic Energy Labor-Management Relations Panel. The parties thereafter accepted the recommendation of the Panel as a basis for settlement of the wage dispute which caused the strike.

Panel Activities

The Atomic Energy Labor-Management Relations Panel was officially involved in 2 disputes between Commission contractors and unions representing their employees during the calendar year.[52]

Contractor Employment

The following table reflects employment of Commission prime and subcontractors employing five or more persons in 1959 as compared with 1958:[53]

[52] The Panel's report to the President on its activities since July 1, 1956, the date on which it was transferred to the Commission for Administrative purposes, will be published early in 1960.

[53] Excluded are AEC Headquarters-designated research contractors and supply contracts.

Contractor grouping	1958	1959 (through November)	Percent of change
Total	114, 665	113, 656	−0. 9
Production	51, 263	51, 175	−0. 2
Research and development	46, 642	47, 624	+2. 1
Maintenance and service	5, 721	5, 125	−11. 6
Construction	11, 039	9, 732	−13. 4

Total contractor employment reflects a decrease in 1959, from 1958, primarily resulting from a change in the method of reporting employment by a major research and development contractor. Even with this change, employment of research and development contractors showed a net increase attributable to increased Commission emphasis in research and development for peace-time uses, particularly reactors. A slight decrease in production contractor employment occurred.

Maintenance and service contractor employment declined sharply over the period because of the curtailment of town services following incorporation of Richland, Wash., and Oak Ridge, Tenn., communities. Construction contractor employment similarly declined during 1959 due principally to suspension of nuclear weapons tests which was reflected in reduced activity at the Nevada Test Site and at Eniwetok Proving Ground and completion of the major part of a facility improvement at the Savannah River Plant.

Considering the total work force employed by cost-type operating contractors at Commission installations with 50 or more employees, a gradual shift has been noticed in the composition of this work force since the inception of these statistics in 1952, indicating a trend toward an increasing percentage of employees in the executive, administrative and professional category. This trend continued during 1959 while the percentage of white collar nonprofessional employees appears to have stabilized for 1959 following a generally declining trend since 1952. A similar trend toward a generally declining percentage of manual employees continued in 1959. In all sectors, however, an absolute increase in the number of employees occurred. These trends are reflected in the following tabulation:

Category	1952		1959 (Jan.–Aug.)	
	Number	Percent	Number	Percent
Total contractors	52, 235	100. 0	91, 181	100. 0
Executive, Administrative and professional [a]	13, 124	24. 7	27, 471	30. 1
Clerical and other office [b]	14, 329	26. 9	22, 080	24. 2
Production and manual [b]	25, 782	48. 4	41, 630	45. 7

[a] Exempt employees under the overtime provisions of the Fair Labor Standards Act.
Nonexempt employees under the overtime provisions of the Fair Labor Standards Act.

The shifts observed appear to be due, in part at least, not only to the increasing emphasis placed on Commission research and development activities—creating the need for proportionately more high-level professional employees—but also to such technological developments as increased use of electronic data processing equipment in the preparation of payrolls, mathematical computations, etc., as well as the installation of improved methods, machinery and facility modifications all of which tend to hold constant or diminish the proportion of white collar clerical and production and other manual workers employed in the total work force.

Employee Earnings

The total straight-time average hourly earnings for manual employees engaged in such operating contractor activities as production, research and development, services, etc., for November 1959 were $2.79 an increase of $0.14 or 5.3 percent over the November 1958 figure. The contractor average continues to fall between comparable November earnings of $2.60 for Industrial Inorganic Chemical Industries and $2.84 for Products of Petroleum and Coal Industries up respectively 3.6 percent and 4.4 percent over November 1958 figures. This relationship in which Commission earnings fall between Petroleum and Chemical earnings continues a trend which has prevailed since this comparison was begun in 1952.

Base monthly earnings of executive, administrative and professional employees in November 1959 average $778 per month which was a 5.4 percent increase over the November 1958 level while straight-time earnings of contractor clerical and office employees [54] were $2.65 in November 1959, up 6.0 percent over November 1958.

Nondiscrimination

The Commission continues as one of five participating agencies on the President's Committee on Government Contracts established by Executive Order to improve the means for obtaining compliance with the nondiscrimination provisions of Federal contracts. During the year the Commission investigated complaints alleging discrimination by 2 contractors and conducted surveys of the operations of 17 contractors, pursuant to the Committee's compliance survey program. No evidence was developed to support the complainants' allegations and the surveys disclosed that the contractors were in compliance with the nondiscrimination provisions of their contracts.

[54] Exempt from the overtime provisions of the Fair Labor Standards Act.

Part Three

Management of Radioactive Wastes

I

RADIOACTIVE WASTES—SOURCES AND PROBLEMS

Protection of the public health and safety against radiation originating in atomic energy activities is a paramount responsibility of the Atomic Energy Commission. Safe management and disposal of wastes originating in Federal operations, and effective control over waste handling by private users of atomic energy products and facilities, is a major aspect of this responsibility. This special report of the Atomic Energy Commission summarizes the problems, the way in which they are solved in Federal programs, and the standards and methods applied to regulating private management of wastes.

The problems have increased in scope, though very little in kind, with broadening uses of isotopes and radiation in science, medicine and industry, and with the rising private interest and participation in the atomic energy industry. The multiplication of reactors for research and testing, for power and propulsion, is swelling the volume of man-made radiation, and this total must be expected to mount as power reactors become competitive producers of electricity.

Waste problems have proved completely managable in the operations of the Commission and of its predecessor war-time agency, the Manhattan Engineering District, Corps of Engineers, U.S. Army. There is no reason to believe that proliferation of wastes will become a limiting factor on future development of atomic energy for peaceful purposes. Effective, safe management will require continued broad programs of research and development—both in waste handling and in the effects of radiation on man and his environment—and it will demand disciplined execution of careful routines in laboratory and plant.

The Commission and its contractors have developed and enforced these disciplined routines in Government programs. Commission regulations, licensing, and inspection methods and practices are designed to accomplish equal efficiency in safe private management of wastes without unduly limiting private exploitation of atomic energy for human betterment.

Some atomic wastes are highly poisonous, and all can be harmful in high concentrations or long exposures, as is true of many other conventional industrial wastes. Key factors in the hazards of atomic

wastes are that radiation is not detectable by the unaided human senses, except at extremely high levels;[1] that only time can destroy radioactivity; that toxic effects often are cumulative; and that injuries resulting from radiation may not become evident for some time.

The most dangerous wastes are stored in Government-controlled and policed reservations. Selected radioactive wastes may be released to the earth, to the air, or to the water, under rigorous control. Under such conditions, the concentrations released are extremely low, the release is usually gradual, and the dilution to safe tolerance levels is assured. The restrictions on which the Commission insists for released wastes provide a wide margin of safety, and life-long human consumption of the resulting fluids would not result in exceeding exposures which research and experience indicate are tolerable. This control of radiation release to the environment applies to fallout from the weapons tests the United States has conducted as well as to industrial and laboratory wastes. In this special report, only the last two are considered; fallout research and current measurements are described in Part II of this annual report to the Congress.

What are termed atomic energy wastes cover a wide range of substances, from the laundry wastes resulting from washing atomic workers' uniforms to the crude fission products remaining after removal of plutonium and uranium from fuel elements of the production reactors at Hanford or Savannah River. They also include contaminated paper towels, broken glass ware, carcasses of animals used in experiments, dismantled reactors or other machinery, gases or coolants from reactors, and the detritus of a hundred different laboratory experiments or industrial processes. Some of the wastes may be themselves radioactive; others may be substances or equipment contaminated with radioactive materials beyond economic cleansing.

The substances that are radioactive may have been exposed to reactor neutrons—the chief source of radioactivity, other than nature itself—or may be normally radioactive, like uranium or a natural form of phosphorus (see table 1—Naturally Occurring Radionuclides; and table 2—Principal Fission Products in Waste-Disposal Operations). The radiation produced by these substances may be of three kinds—alpha, beta, or gamma rays, or combinations of these. Alpha and beta emitters are essentially of small hazard unless they enter the body in excessive amounts, although concentrated beta-emitters can cause severe burns. Gamma rays are penetrating and can cause damage from

[1] *Cherenkov effect*—Water and other transparent substances, such as glass and mica, emit a bluish-white glow when exposed to *gamma* radiation. The glow arises when electrically-charged particles travel through a medium with a velocity greater than that of light in that particular medium. This glow is most frequently noted in pool research reactors, where fuel elements are visible through shielding water.

outside the body, as X-rays can in cases of large exposures. Some of the radioactivity dies out very rapidly—with a half-life of hours or days.[2] Some radionuclides remain radioactive for years, or decades, or even thousands of years. The Commission's management of wastes is geared to these various physical facts, as well as to the specific chemical or radioactive toxicity of the separate chemicals and their compounds.

Sources of Wastes

Although wastes are generated to some extent wherever radioactive elements are worked with, the cycle of fuels for reactors is the largest source. It includes mining uranium, milling, preparation of feed materials for gaseous diffusion plants, fuel fabrication, processing of scrap, reactor operation, and spent fuel reprocessing, and research associated with each step. The amount and level of radioactivity range from fractions of millicuries[3] in the handling of raw ores, to hundreds of curies[3] per liter as fission products from reactor operations, or in the dissolved fuel elements being processed for recovery of fissionable uranium.

Wastes created in activities not associated with the nuclear fuel cycle generally are much lower in radioactivity and volume. Educational, industrial, and medical laboratories, hospitals, and industrial firms that use radioactive materials all fall generally into this category.

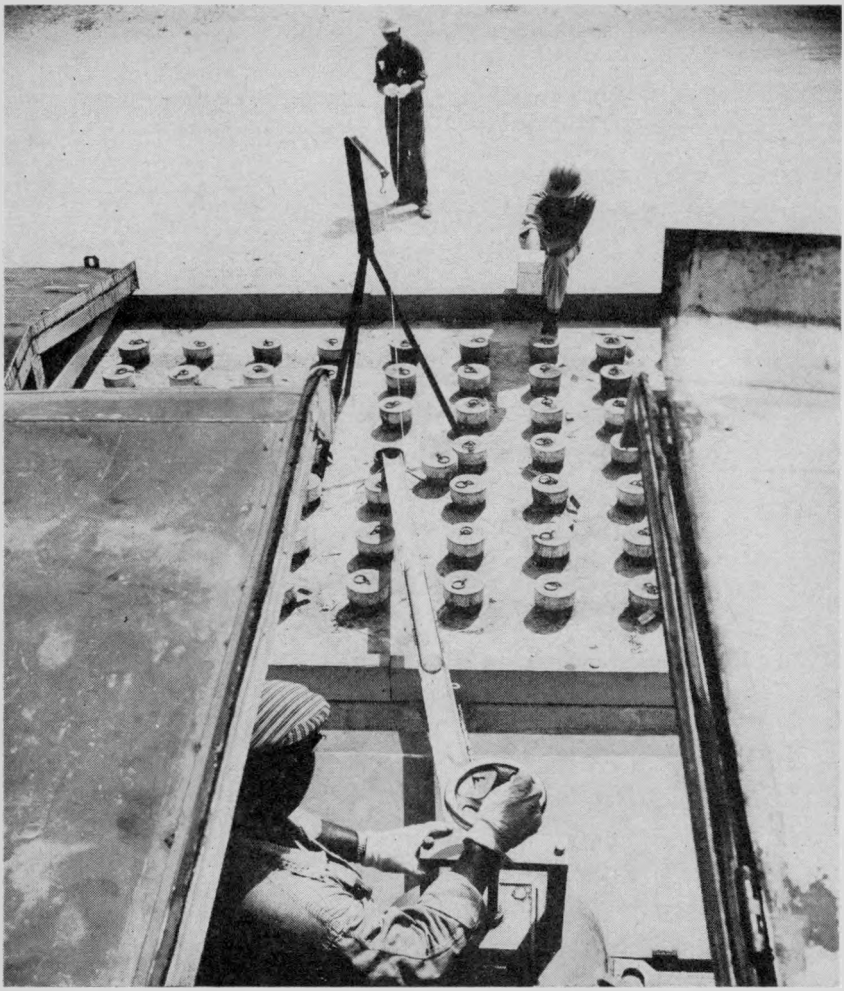
Origins of radioactive wastes in the nuclear fuel cycle are summarized in the following sections.

Mining. Some 500 mines in the United States produce uranium ores and the waste products of these operations are not a major problem. While some radioactive dust and radon gas—produced by the naturally-occurring radium associated with uranium ores—results from mining operations, harmful concentrations of these airborne radioactive materials can be prevented by sufficient ventilation. Air exhausted from the mines does not present a problem of general atmospheric contamination. Most of the shafts are dry, so liquid wastes are rarely a problem. Where mine water pumping is required, such as the Ambrosia Lake area in New Mexico, the water removal presents no disposal problem since the radioactivity is so low that the wastes can be allowed to seep into the desert-like soil.

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[2] The period of time during which any quantity of a radioactive substance will lose half of its radioactivity through radioactive decay of atoms.

[3] A curie is a measure of gross radioactivity, without regard to the kind of radiation or its intrinsic energy. It represents some 3.7×10^{10} atomic disintegrations per second—about the same number occurring in a gram of radium. A millicurie is one thousandth as much, about 3.7×10^{7} disintegrations per second.



Temporary waste storage. Small amounts of high-activity wastes generated at the Commission's Argonne National Laboratory are held until radioactive decay makes them safe for off-site shipment. In photo, "map tube" cannister (center of photo) is transferred to storage vault by remote handling devices. The extensive shielding necessary to make such small amounts safe for immediate shipment would not be economical. Man on right monitors radiation level of tube for safety of others.

Milling. Twenty-three mills concentrate uranium oxide from the ores. Together, they handle approximately 22,000 tons of ore a day, containing less than 100 curies of activity. From this they extract approximately 50 tons of concentrates.

The uranium mills produce several types of wastes that are dispersed to the environment. Radioactive dusts and radon gas are handled

TABLE I.—NATURALLY OCCURRING RADIONUCLIDES

Radionuclide	Natural Abundance in Nature	Half-Life [1]	Radionuclide	Natural Abundance in Nature	Half-Life [1]
	(*Percent*)			(*Percent*)	
Uranium 238	99.28	4.5×10^9 y	Thorium 232	100	1.4×10^{10} y
Thorium 234	[2]	24.5 d	Radium 228	[4]	6.7 y
Protactinium 234	[2]	6.7 h	Thorium 228	[4]	1.9 y
Thorium 230	[2]	8.0×10^4 y	Radium 224	[4]	3.6 d
Radium 226	[2]	1,600 y	Radon 220	[4]	54.0 s
Radon 222	[2]	3.8 d	Bismuth 212	[4]	1.0 h
Uranium 235	[3] 0.71	7.1×10^8 y	Polonium 212	[4]	Very short
Uranium 234	[3] 0.005	2.5×10^5 y	Thallium 208	[4]	3.0 m

[1] s=second, m=minute, h=hour, d=day, y=year.
[2] More important decay products of U 238.
[3] Decay products of U 235 and U 234 not very important due to low concentration of parent.
[4] More important decay products of Th 232.

TABLE II.—PRINCIPAL FISSION PRODUCTS IN WASTE-DISPOSAL OPERATIONS

Radionuclide	Half-life [1]	Maximum allowable concentration [2]		Approximate percent of total activity decrease after decay of—		
		In body μc	In water μc/ml	100 days	3 years	30 years
Strontium 90 [3]	28.0 y	2.0	1.0×10^{-7}	[4] <2	15	[5] ~49
Cesium 137 [3]	26.6 y	30.0	2.0×10^{-6}	<2	15	~49
Promethium 147	2.6 y	60.0	2.4×10^{-4}	3	15	<1
Cerium-praseodymium 144	290.0 d	5.0	1.0×10^{-5}	45	50	----
Krypton 85 (gas)	10.3 y	----	----	<1	1	<1
Iodine 131 (gas)	8.1 d	.7	2.0×10^{-6}	<1	----	----
Zirconium-niobium 95	63.0 d	20.0	6.0×10^{-5}	33	----	----
Barium-lanthanum 140	12.8 d	4.0	3.0×10^{-5}	<1	----	----
Ruthenium-rhodium 103	41.0 d	20.0	8.0×10^{-5}	5	----	----
Ruthenium-rhodium 106	1.0 y	3.0	1.0×10^{-5}	2	3	----
Strontium 89	54.0 d	4.0	3.0×10^{-5}	7	----	----
Xenon 133 (gas)	5.3 d	----	----	<1	----	----

[1] d=days, y=years.
[2] Commission Manual, chapter 0524.
[3] Because of their long half-lives, neither strontium 90 nor cesium 137, even though they may occur in low- or intermediate-level wastes, is not normally released to the atmosphere by the Commission, or its contractors; they are held in storage in the same way as high-level wastes.
[4] < symbol for "less than."
[5] ~ symbol for "about."

within the mill, and their discharge is rarely a problem. Contaminated water from milling operations averages approximately 865 gallons per ton of ore treated, a daily total of about 18 million gallons. About 60 gallons per ton remains with solid tailings; the rest runs into large retention ponds and overflows to streams, if available, or is allowed to percolate into the ground.

Liquid tailings of the mills contain large quantities of chemicals, some of which present problems, but the radioactive constituent of major concern is radium. Recent information from one mill [4] indicates that the greatest percentage of the radium in the wastes is associated with suspended solids in the tailings. During the latter half of 1959, the Commission issued letter orders to 11 uranium processing mills to take corrective action regarding the amount of radioactivity released as atmosphere or water pollutant. (See section on *Compliance Actions* in Part Two.) An "industrial waste guide" for the uranium milling industry is being developed by the U.S. Public Health Service, Department of Health, Education and Welfare for the Commission.

Feed material preparation. In the next step of the fuel cycle, ore concentrates containing about 70 percent uranium oxide (U_3O_8) are chemically purified to produce uranium salts that are fed to the gaseous diffusion cascades for the separation of uranium 235 from uranium 238; or reduced with calcium or magnesium to uranium metal; or converted to uranium compounds such as uranium dioxide to be used as power reactor fuels. The refining of ore concentrates produces, like the mines and mills, radon and uranium dust, which can be handled within the mill. The radiochemical nature of the liquid wastes is similar to that at the mills. For each ton of uranium processed, approximately 1,000 gallons of solvent extraction liquids are produced; if recycled uranium from within the feed materials complex is added, the volume of liquid may be on the order of 1,500 gallons for each ton of concentrate processed. This waste is reduced in volume and stored long enough for it to decay to a safe limit. Only condensate of acceptable low-activity is discharged into water ways without a storage period.

Additional volumes of liquid wastes containing only minor quantities of radioactivity result from preparation of "green salt" (uranium tetrafluoride, UF_4), which then is used as uranium hexafluoride (UF_6) as an intermediate feed material for gaseous diffusion plants. Product gases must be scrubbed to remove chemical fumes and entrained uranium. Scrubber effluents are monitored for radioactivity and discharged to streams or rivers at safe low levels.

Waste materials from uranium metal production are leached to remove contained uranium; the leach liquors are treated by solvent extraction or ion exchange. Fluids from these operations are discharged at safe levels to the environment.

[4] Survey of Interstate Pollution of the Animas River (Colorado, New Mexico, U.S., H.E.W. (P.H.S.) May 1959.

Diffusion plant feed is prepared from mill ore concentrates and uranium recovered from the fuel elements of production reactors. Waste management on handling mill concentrates has been described. Recycled uranium is decontaminated at separation plants before being recycled. Wastes from gaseous diffusion feed plants are treated, monitored, and discharged at below tolerance levels. These wastes are characterized by large volumes of liquid containing low concentrations of radioactive materials.

Solid wastes, such as uranium-contaminated ore drums, used equipment and piping, filter cakes from scrap; magnesium fluoride and dolomite liners from metal reduction, and other solid residues from the feed material operations contain only small quantities of naturally-occurring radioactive contaminants and are disposed of by burial in Commission-supervised reservations.

TABLE III.—COOLANT AND IMPURITY PRODUCTS

Radionuclide	Half-Life	Mechanism of Formation [1]
Water reactors:		
Coolant activity:		
Nitrogen 16	7.0 s	$O^{16}(n,p)N^{16}$
Nitrogen 17	4.0 s	$O^{17}(n,p)N^{17}$
Oxygen 19	30.0 s	$O^{18}(n,\ )O^{19}$
Fluorine 18	1.9 h	
Impurity activity:		
Sodium 24	15.0 h	$Al^{27}(n,\gamma)Na^{24}$
Aluminum 28	2.0 m	$Al^{27}(n,\gamma)Al^{28}$
Argon 41	110.0 m	$A^{40}(n,\gamma)A^{41}$
Manganese 56	2.6 h	$Fe^{56}(n,p)Mn^{56}$
Cobalt 58	71.0 d	$Ni^{58}(n,p)Co^{58}$
Cobalt 60	5.2 y	$Co^{59}(n,\gamma)Co^{60}$
Iron 55	2.9 y	$Fe^{54}(n,\gamma)Fe^{55}$
Iron 59	45.0 d	$Co^{59}(n,p)Fe^{59}$
Chromium 51	27.0 d	$Cr^{50}(n,\gamma)Cr^{51}$
Copper 64	12.8 h	$Cu^{63}(n,\gamma)Cu^{64}$
Tantalum 182	111.0 d	$Ta^{181}(n,\gamma)Ta^{182}$
Tungsten 187	24.0 h	$W^{186}(n,\gamma)W^{187}$
Sodium reactors:		
Sodium 24	15.0 h	$Na^{23}(n,\gamma)Na^{24}$
Sodium 22	2.6 y	$Na^{23}(n,2n)Na^{22}$
Rubidium 86	19.5 d	$Rb^{85}(n,\gamma)Rb^{86}$
Antimony 124	60.0 d	$I^{127}(n,\gamma)Sb^{124}$

[1] This, and other formulas in this column, indicate first the chemical substance affected (oxygen 16), then the impinging particle (a neutron), then the radiation resulting (a proton), and the chemical substance resulting from the reaction (nitrogen 16). Other symbols in column: α, alpha; γ, gamma.

Fuel element fabrication. In the manufacturing of fuel elements, the uranium used has an extremely low specific activity. It would require, for example, nearly 17 kilograms of uranium which has been enriched in excess of 90 percent to produce one curie of radioactivity. Fuel elements customarily are fabricated from uranium, uranium

alloys, and uranium oxide (UO_2). Processes include melting, casting, rolling, machining, and metal cleaning and produce varying quantities of uranium-bearing wastes as scrap, liquids, contaminated metal and trash, and a certain amount of airborne dust. Fuel manufacturing at a typical plant generated 5,000 gallons of liquid wastes in a year—a dilute acid containing small amounts of dissolved uranium. The level of radioactivity is so low that the waste can be monitored, diluted, and discharged to a river. At the same plant, 7,000 pounds a year of slightly contaminated copper and steel wastes were produced. The contamination was approximately three parts of uranium per million parts of steel, or about one-half part uranium per million parts of copper. The uranium was removed with acid and the waste liquid diluted, neutralized, and held in tanks until the radioactivity level dropped to the point where the liquid could be discharged to the river. The cleansed steel and copper could be used as nonradioactive scrap.

Nuclear reactor operation. Waste problems vary somewhat with each reactor type. In the following chapter on Waste Management, and in the later chapters on Research on Wastes, and Environmental Research, the production and disposition of wastes, and the results, are described for the Hanford complex of production reactors in Washington, for the large electricity-producing Shippingport Atomic Power Station in Pennsylvania, and for a research reactor at Brookhaven National Laboratory on Long Island, N.Y. Although reactors produce considerable volumes of radioactivity in their fuel elements, this is not a waste problem until the elements are processed. Wastes during reactor operation are handled at the site and do not create major problems as handled by the Commission and its contractors. Typical radioactivity in wastes from reactors are described in table III—Coolant and Impurity Products. Methods of handling wastes depend largely on the location of the reactor with reference to population density and geological and meteorological conditions. At Hanford the rainfall is low, the water table far below the surface, the soils highly useful as an ion exchange medium, the reservation large and isolated, and large volumes of water are available for dilution of discharges. Waste management takes advantage of these factors. At Brookhaven National Laboratory conditions are quite the reverse of these, and disposal methods are consistent with this fact, as the following chapters make clear.

Processing irradiated reactor fuels. The greatest volumes of highly radioactive wastes in all atomic energy operations result from the chemical processing of irradiated reactor fuels to separate plutonium

from uranium and fission products. A number of different processes are used, according to the type of fuel element. The following table gives characteristics of different solvent extraction processes:

Process	Application	Selective solvent	Salting agent	Approximate volume untreated high-activity waste
Purex	Pu-natural Uranium	TBP* in hydrocarbon	HNO_3	990 gal/metric ton U
Redox	----------	Hexone	$Al(NO_3)_3$	1,000 gal/metric ton U
Hexone 25	Enriched U-Al alloys	Hexone	$Al(NO_3)_3$	700 liters/kg enriched U
TBP 25	----------	TBP in hydrocarbon	HNO_3+ $Al(NO_3)_3$	670 liters/kg enriched U
Thorex	Th-U233	TBP in hydrocarbon	$Al(NO_3)_3$	1,360 gal/metric ton Th

*TBP—tributyl phosphate.

While the processing details vary with the type of fuel being worked and the plant performing the operation, the basic principles are the same. Solid fuels, which have been stored 90 to 120 days after removal from the reactor to permit decay of short-lived fission products, are dissolved in nitric acid. The solution is fed to a column where a solvent selectively extracts the uranium and plutonium. An aqueous salt solution scrubs the traces of fission products from the solvent extract before it leaves the column. This solution containing more than 99.9 percent of the dissolved fission products, and inert materials in the feed and scrub solutions, is drawn off for treatment and storage as highly radioactive wastes. The uranium and plutonium are separated and further decontaminated. This batch of wastes from further decontamination contains very small amounts of activity and, in some cases, is recycled to the process.

Table IV gives the characteristics and approximate values of high-activity wastes produced by the various processes in use. Besides the concentrations of inert chemicals, all wastes contain fission products and minimal amounts of uranium, plutonium, and other heavy elements.

All the high-level liquid wastes are stored on Commission-owned and policed reservations in buried tanks. The kind of tanks, the methods and conditions of storage, and the method of discharge to the environment of low and intermediate wastes resulting from later stages in the chemical processing of fuel elements are described in the next chapter.

High level wastes in storage at the Commission's major processing plants currently total some 67 million gallons. In all, there are some 170 tanks with a total capacity of 110 million gallons.

TABLE IV.—CHARACTERIZATION OF FIRST CYCLE HIGH LEVEL AQUEOUS WASTES FROM SELECTED SOLVENT EXTRACTION PROCESSES

Process	Chemical Properties, Constituents (M), Approximate Exclusive of Fission Products and Heavy Elements														Waste Volume gal/g U235 Consumed	Approximate Specific Gravity	Approximate Concentration of U in Feed g/liter	Waste Activity [2]		
	H	Al	Fe	Cr	Ni	Zr	Na	NH_4	Sn	Mn	Hg	NO_3	F	SO_4				Curies/gal	Total watts/gal [3]	BTU/hr/gal
Redox	−0.2	1.2	-----	-----	-----	-----	0.46	-----	-----	-----	-----	4.1	-----	-----	0.27	1.18	450	1720	8.6	29.4
Purex	2.5 to 7.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2.5 to 7.0	-----	-----	0.34	1.07	300	1320	6.7	22.7
Thorex	−0.1	0.5	-----	-----	-----	-----	-----	-----	-----	-----	0.01	1.4	0.05	-----	0.34	1.12	350 (Th)	81	0.4	1.37
Hexone–"25"	−0.2	1.5	-----	-----	-----	-----	-----	0.5	-----	-----	0.01	4.5	-----	-----	0.31 to 0.13	1.23	2–5	1620 to 3940	8.1 to 20.2	27.7 to 69.0
TBP–"25"	0.5	1.6	-----	-----	-----	-----	-----	-----	-----	-----	0.01	5.5	-----	0.02	0.22 to 0.11	1.29	3–6	2580 to 5160	12.9 to 26.0	44.1 to 88.6
Zirconium-HF for enriched U	0.8 to 2.0	0.8	0.1	-----	-----	0.5	-----	-----	0.02	-----	-----	2.3	3.0	-----	−1.50	1.1	0.3	350	1.75	6.0
Stainless Steel-H_2SO_4 for enriched U-235	2.6	0.25	0.05	0.01	0.003	-----	-----	-----	-----	0.001	-----	2.4	-----	0.30	−0.35	1.3	2–3	1500	7.5	25.

NOTES: (1) Wastes are untreated; they are essentially as they leave the solvent extraction plant and are subject to further treatment such as evaporation, neutralization' chemical treatment for fission product removal, etc.

(2) Basis for activity numbers: Irradiation period 4000/Mwd/t for natural uranium
5×10^{13} n/(cm)^2(sec)
4000 grams U233 chain per ton of thorium
53 percent burnup for U235 in enriched fuel elements
100 days decay cooling from time of reactor discharge

(3) After 100 days' decay, the distribution of energy is approximately 50 percent γ and 50 percent β.

(4) Waste volume per gram U235 consumed is an inverse function of burnup; i.e., for hexone 25 at 20 percent burnup, the gal/g U235$=\left(\frac{53}{20}\right)$ (0.14).

(5) Waste activity varies approximately as the (irradiation level)$^{0.2}$

Gases, vapors, and aerosols or minute particles released in processing are controlled by filtering and scrubbing. Iodine, for example, is 99.9 percent eliminated from off-gases.

For the foreseeable future, the Commission will continue to store high level wastes from its chemical separation plants in tanks. At the present time, no private concern handles chemical separation, and the Commission has announced its intention to provide for the processing of fuel elements from private reactors until such time as this service is available in commercial facilities at reasonable prices.

During October 1959, the Commission assigned the responsibility for chemically reprocessing the spent fuel elements from 17 specific power and experimental reactors, as well as those research and test reactors using uranium-aluminum alloy fuels, to four of its major facilities—Hanford, Oak Ridge, Savannah River, and the Idaho Chemical Processing Plant. The assignments were based on the type of fuel reprocessing technology developed and the facilities available at each site, as well as the site's capability for handling radioactive wastes generated by the reprocessing operation (see table V—Commission Fuel Processing Assignments).

Problems of Waste Management

The problems of waste management are essentially those of all atomic energy activities—to minimize exposures of workers and the general public so that they are kept within safe bounds—with the added factor that the costs involved in assuring safe management of wastes will influence the degree to which this country, and the world, put atomic energy to work for mankind's betterment, and the rate of that progress.

The results of the Commission's research and development programs, and the engineering development in its plants, have been made broadly available to assist in control of atomic energy hazards wherever they may arise. The Commission's exceptional industrial record of safety indicates the feasibility of this control.[5] Currently, the Commission is directing programs of scientific and engineering research and development, described elsewhere in this report, aimed specifically at reducing the costs of waste management while continuing to assure the public safety.

The Government has invested some $200 million in waste management facilities, and has annual operating costs in this field of about

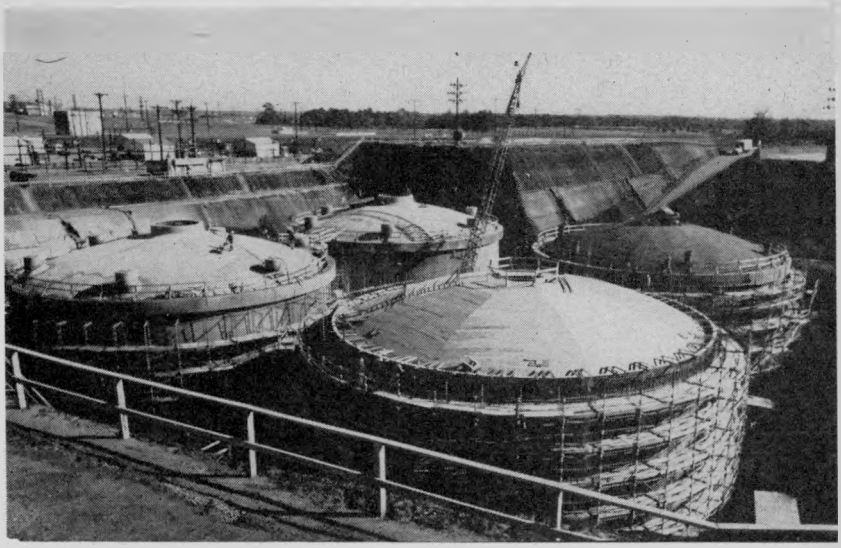
[5] The Twenty-first Semiannual Report to Congress (July–December 1956) describes this record, the means of its achievement, and the background of research involved in a special supplement, "Radiation Safety in Atomic Energy Activities," pp. 109–260.

TABLE V.—COMMISSION FUEL REPROCESSING ASSIGNMENTS

AEC Installation; Reactor Name and/or Owner	Type of Fuel Element	Initial Uranium Enrichment
		(Percent)
HANFORD		
Dresden Nuclear Power Station (Commonwealth Edison Co., Morris, Ill.).	UO_2 in Zr tubes	1.5
Yankee Atomic Electric Co., Rowe, Mass.	UO_2 in SS (stainless steel) tubes	2.6
Shippingport Atomic Power Station (blanket only) (AEC and Duquesne Light Co., Shippingport, Pa.).	UO_2 in Zr tubes	Natural
Pathfinder Plant (Northern States Power Co., Sioux Falls, S. Dak.).	UO_2 in Al-Ni plates	1.8
Piqua (AEC and city of Piqua, Ohio)	U clad with Al-Ni	1.8
OAK RIDGE NATIONAL LABORATORY		
Enrico Fermi Atomic Power Plant (blanket only) (Power Reactor Development Co., Lagoona Beach, Mich.).	U-Mo alloy in SS tubes	Depleted
Hallam Nuclear Power Facility (AEC and Consumers Public Power District, Hallam, Nebr.).	U-Mo alloy in SS tubes	3.5
N.S. Savannah (AEC and Maritime Administration)	UO_2 in SS tubes	4.1
Consolidated Edison Thorium Reactor (Consolidated Edison Co. of N.Y., Indian Point, N.Y.).	ThO_2-UO_2 in SS tubes	90
Elk River (AEC and Rural Cooperative Power Assn., Elk River, Minn.).	ThO_2-UO_2 in SS tubes	90
BORAX IV—Boiling Reactor Experiment No. 4 (AEC, NRTS, Idaho Falls, Idaho).	ThO_2-UO_2 in tubed Al plates	90
EBWR—Experimental Boiling Water Reactor (AEC, Lemont, Ill.).	U-Zr alloy in Zr plates	1.5
SRE—Sodium Reactor Experiment (AEC and Southern California Edison Co., Santa Susana, Calif.).	U rods in SS tubes	3.5
Research reactors (foreign)	U-Al alloy	20
SAVANNAH RIVER		
Enrico Fermi Atomic Power Plant (core only)	U-Mo alloy clad with Zr	27
IDAHO CHEMICAL PROCESSING PLANT		
Shippingport Atomic Power Station (core only)	U-Zr alloy clad with Zr	90
OMRE—Organic Moderated Reactor Experiment (AEC, NRTS, Idaho Falls, Idaho).	U-SS mixture clad with SS	90
SM-1—Stationary Medium Power Plant [1] (AEC and U.S. Department of Army).	U-SS mixture clad with SS	90
VBWR—Vallecitos Boiling Water Reactor (General Electric Co. and Pacific Gas and Electric Co., Pleasanton, Calif.).	U-SS mixture clad with SS	90
SL-1—Stationary Low Power Plant No. 1 [2] (AEC)	U-Al-Ni in Al-Ni plates	90
Research and test reactors (*domestic and foreign*)	U-Al alloys	90

[1] Formerly called the APPR (Army Package Power Reactor) located at Ft. Belvoir, Va.
[2] Formerly called the ALPR (Argonne Low Power Reactor) located at the National Reactor Testing Station in Idaho.

$6 million. The major portion of the capital investment—$125 million—was expended for tank storage of high-level wastes primarily at the Hanford Works in Washington State, the National Reactor



Liquid waste storage tanks. Four 1,300,000-gallon storage tanks for high-level radioactive wastes are shown under construction at the Savannah River Plant. The concrete and steel tanks are 85 feet in diameter and 34 feet high, and rest upon a steel saucer which, in turn, rests upon a 6-inch concrete pad. There are about 20 such tanks, ranging in capacity from 750,000 to 1,300,000 gallons, at the Commission's South Carolina production facility.

Testing Station in Idaho, and the Savannah River Plant in South Carolina.

The major portion of the 67 million gallons of high-level wastes now held in tank storage is the result of weapons material production. It is estimated that by 1980 the wastes generated by power and test reactors will help raise the storage figure to 100 million gallons. It has also been estimated that if by the year 2000 there is a nuclear power industry capable of producing 200 million kilowatts of electricity (about one-fourth of that currently produced by conventional means), some 280 metric tons of fission products would also be produced. In liquid form this might be as high as 50 million gallons a year of high-level wastes, assuming current aqueous chemical reprocessing methods are used.

A problem in tank storage of high-level wastes is that the life-expectancy of these concrete and steel containers has not yet been fully determined, and estimates range from 10 to 20 years or more. In more than a decade of tank storage at Hanford no leaks have been detected. However, the stored wastes are extremely corrosive and at each of the Commission's tank farms a number of empty tanks are maintained—currently, the nearly 70 million gallons in storage utilizes only about 60 percent of the available storage capacity. The

contents of any tank can be pumped into one of the empty tanks if necessary.

The average cost for each of the Commission's 170 high-level waste storage tanks, and the equipment associated with each tank, has been about $730,000. One reason why this form of storage is expensive is because the metal liner for a tank must withstand high temperatures—the wastes have a high temperature when stored, and continue to generate heat by radioactive decay—and the highly acid, or in some instances the highly alkaline, condition of the waste. Although methods are used to draw off some of the heat generated within the tank, the bulk of it remains within the container. The special steel needed to resist the heat and corrosive condition is costly.

After about 11 years of storage, the remaining energy being emitted in the stored high-level wastes is due almost entirely to strontium 90 and cesium 137. The long half-lives of both, and the strong gamma emission of the cesium radionuclides, makes for a continuing storage problem since it is Commission practice that these two radioactive isotopes normally should not be released to the environment during waste disposal operations.

Disposal of radioactive wastes from fuel processing will be a significant element in the costs of nuclear power when it approaches levels competitive with energy from other sources. Based on a conservative estimated future burnup rate for power reactors of 10,000 megawatt days per ton of uranium, transporting the high-level fuel element wastes has been estimated at 0.04 mills per kilowatt hour (for a 500-mile transport), and storage at 0.02 mills per kilowatt hour. At present, costs would range about 10 times these figures. Higher burnup would reduce the costs.

Much of the Commission's research and development work deals with reducing the volume of high-level wastes for storage, which currently costs from less than $1.00 up to $4.90 a gallon aside from maintenance. The lower figure applies to the latest set of tanks installed at the Savannah River Plant.

Safe disposal of large quantities of low-level wastes generated as gaseous and liquid discharges from various types of reactors is an equally important problem, which is discussed specifically in later chapters. It adds both to capital costs and to operating costs for all major reactors. To date, the Commission has invested some $45 million in devices to remove radioactivity from gaseous discharges, and $30 million for the means to make it possible to discharge liquid reactor wastes to the environment. Research continues in all these fields.

The methods for handling low-level wastes, whether generated in

reactors, laboratories, hospitals or industrial processes, currently are on a routine and carefully supervised, basis.

The Commission has reported publicly and to the Congress on these operations on a current basis, and in periodic reports such as the Twenty-first Semiannual Report to Congress, listed earlier. During 1959, the Commission supplied detailed testimony and written reports for hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy which resulted in a comprehensive, five-volume report [6] on the subject.

This special section on waste disposal, submitted as part of the Commission's Annual Report to Congress for 1959, includes chapters on Waste Management, Research on Waste Disposal, Environmental Research, and on Licensing, Regulation, and Inspection.

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[6] Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

II

WASTE MANAGEMENT

The major objective of waste management in atomic energy operations is control over the radiation hazard that might be produced by these wastes, either in storage or in nature. This requires control not only during operations and discharge, but also over movement and distribution of the waste products in the environment. Two basic disposal concepts are applied:

Concentrate and contain. The radioactive materials may be confined or isolated within permanently maintained reservations, away from people and useful resources. Highly active liquid wastes originating from the chemical processing of irradiated fuels from reactors must be reduced to a suitable concentrated form [7] and contained indefinitely in this way.

Dilute and disperse. In this other basic concept of waste management, the radioactivity may be reduced to tolerable levels by dilution in nature—in air or water. For example, certain types of laboratory liquid wastes in which the concentration of radioactivity is only a few times greater than drinking water standards may be disposed of in streams, where dilution will drop the concentration far below the maximum permitted. However, the fact that some wastes can be dispersed directly to the environment makes it essential to control these operations carefully so as to assure that the safe capacity of the environment is not exceeded.

Three basic factors determine the methods that must be applied to managing radioactive wastes. These are:

a) The maximum quantity of specific radioisotopes which research and experience indicate man can tolerate, either in his total body, or in various organs. These quantities are translated into the maximum concentrations of various radioisotopes that can be

[7] For example, the total weight of all fission products resulting from operation of a 1,000-megawatt (thermal) power reactor for one year is about 750 pounds. If the elements were to be separated and converted into chemical compounds (chlorides, oxides, or fluorides), then dried and compressed into a density of three grams per cubic centimeter, they would occupy a volume of about five cubic feet. The compounds of the two important long-lived radioisotopes, cesium 137 and strontium 90, would occupy less than one cubic foot. Since the total volume of waste from which the fission products were removed would be about 540,000 gallons, or 73,000 cubic feet (natural uranium process waste), this would represent a volume concentration by a factor of 100,000.

safely allowed in air and water. In setting these levels the Commission takes into consideration, for example, the concentration of radioactivity by various organisms in man's food chain and other important and complex factors.

b) The specific radioactive and chemical nature of the waste under consideration, which may vary from a weak solution of a single short-lived radioisotope to crude fission products from processing reactor fuel elements in solutions containing high concentrates of nonradioactive chemicals.

c) The physical, chemical and biological characteristics of the environment in which the waste will be handled, including specific, quantitative data on the atmosphere, the hydrosphere and the lithosphere relating to dilution or concentration of radioactivity in the environment. Essentially, proper waste management requires identifying and quantitatively describing the wastes and their environment, then establishing performance or operating criteria necessary to assure conformance to standards of safety for the specific wastes involved.

The Commission, and the war-time Manhattan Engineering District, U.S. Army Corps of Engineers, that preceded it as manager of atomic energy facilities, have conducted extensive programs of research to establish the facts of radioactive effects, so that the standards of protection will be based on adequate knowledge. The standards fixed are based on the best available biological and medical experience and knowledge, and on specific research. Understanding still is not complete and new problems continue to arise as atomic energy programs develop and expand; consequently, standards are modified as more and better knowledge is gained.

Using these standards as a guide, each factor affecting waste handling then is evaluated on an individual basis for specific cases.

Performance criteria then are determined for waste dispersal operations for each nuclear installation in line with these two principles: Keep the discharge as low as practicable; check continually on results. The minimum practicable amount of radioactivity that can be dispersed safely into the environment is determined on a case-by-case basis, by quantitative assessment of the capacity of the specific environment to assure protection of public health and safety. Continuing, periodic checking is mandatory to verify that performance criteria are being followed and accepted standards are being met. If changing requirements so dictate, performance criteria must be modified.

Examples of Waste Management

This chapter describes the application of waste management methods, based on these various standards and criteria, at different types of Commission installations: a nuclear powerplant (Shippingport Atomic Power Plant), a production and chemical processing installation, (Hanford), and a national research and development laboratory (Brookhaven); and by different methods, sea and land burial.

Wastes at Shippingport

An example of waste management at a nuclear powerplant is the operation at the Shippingport Atomic Power Station in Pennsylvania. The 400-acre plant site is located in a well-populated area of the western part of the State, on the banks of the Ohio River.

In a normally-operating reactor, disposal of high-level wastes is not involved, since used fuel elements would be shipped to a Commission site for the processing that produces the greatest volume of high-level wastes.

The Shippingport plant uses recirculated pressurized water as coolant. Build-up of radioactivity appears in three ways: in the coolant due to activation of corrosion products; formation of tritium from the lithium hydroxide used to improve the pH (acid-alkali balance) of the water for corrosion control; and from fission products introduced by occasional fuel ruptures. In this plant, the chief source of wastes is discharged coolant. The waste disposal system is so designed that all low-level radioactive wastes will be reduced in concentration and the level in water measured before discharge into the Ohio River, and into air at the point of discharge, will not exceed one-tenth the maximum permissible concentration as recommended in the National Bureau of Standards Handbooks Nos. 61 and 52, which the Commission has adopted as a standard. (A new handbook, No. 69, now is under consideration for adoption by the Commission.)

The Shippingport reactor uses fuel that is zircaloy clad and this cladding prevents release of the fission products from the fuel to the circulating water. However, some fuel elements occasionally may develop holes which would allow fission products to escape to the coolant. The plant and waste disposal facilities have been conservatively designed to allow operation with up to 1 percent failed fuel elements. Discharged reactor coolant water, containing both volatile and nonvolatile radioisotopes, is stored in large underground surge tanks before being released. Normally the storage period is a maximum of 45 days to allow radioactivity to be reduced by natural decay.

The coolant water from the reactor contains trace amounts of radioactive gases, primarily inert xenon 133 and krypton 85. To remove these, all tanks and vessels containing reactor plant effluent are flushed continuously with a recirculating gas stream. The gases from the stripping column also are discharged into the flush gas system and, at regular intervals, gas is bled from the system into drums for storage and decay of the radioactive xenon and krypton. After a sufficient decay period, which may be as long as 60 days, this gas is mixed with the discharge of an air dilution fan and released in a very diluted form to the atmosphere. This final mixture is continuously monitored and an alarm is provided to indicate approach to overtolerance conditions.

The reactor-waste effluent totals about 23,000 gallons a month; it contains about 3μc/ml (3 microcurie per milliliter) of nonvolatile radioactivity and about 10μc/ml of gaseous activity. The treatment process reduces the activity to about 5×10^{-5} μc/ml for the nonvolatile and 1×10^{-8} μc/ml for the volatile activity.

Besides the reactor coolant discharges, the monitoring program at Shippingport continually checks the radioactivity in liquid wastes from various laboratory drains, personnel showers, and laundries. Normally only slightly radioactive, these wastes are collected and sampled in separate tanks. When the level of the activity is low enough, either initially, or after a hold-up period for decay, wastes are discharged at a controlled rate after dilution in the condenser cooling water stream to less than one-tenth the maximum permissible concentration. When it is discharged to the river it is further diluted. Some wastes are processed through an evaporator, the radioactivity either passing off as a dilute gas or being concentrated in the small amount of residue.

An incinerator is used to burn combustible solid radioactive wastes. Fuel gases are scrubbed and filtered before discharge. Noncombustible waste, consisting of resins, residue ash from the incinerator, residue from evaporators, solids from strainers in the pipelines, and contaminated items of plant equipment, are stored on site, or imbedded in concrete and disposed of at sea.

Provisions are made to sample the waste liquid and gaseous streams as they enter the waste disposal system, before and after each waste treatment process, and before discharge from the plant. Sampling facilities also are provided so that diluted waste streams can be monitored after dilution. Any waste stream may be reprocessed if necessary to minimize the possibility of discharging above-standard wastes from the plant.

An off-site monitoring program, begun early in 1956, determined the types and amounts of radioactive materials that occur naturally in the environment. These preoperational data make it possible for continuing studies to evaluate changes due to plant operations. Evaluations are made continually on air, soil, and vegetation in the general area, Ohio River water above and below the site, and well water within 1 mile of the site.

Three stations are maintained for river water analyses, and another is being installed at the water-intake service to the city of Midland, Pa. In general, averages of gross beta activity in Ohio River water samples both before and after reactor operation have ranged from less than 5 micro-microcuries per liter to slightly more than 30 micro-microcuries per liter for composite samples analyzed on a weekly basis. From 25 to 100 percent of the gross beta activity has been due to potassium 40, a naturally occurring radioisotope. Results from the two downstream sampling stations have not varied significantly from upstream results. Fluctuations have shown no correlation with wastes discharged into the river at Shippingport.

Five atmospheric monitoring stations are operating—four fixed and one mobile—to evaluate the presence of radioactive dusts and gases in the air and to measure normal background radiation.

Since the reactor went critical December 2, 1957, environmental radiation surveys have revealed no indication of an increase in area radioactivity levels that could be attributed to operation of the Shippingport plant.

Management of the plant was worked out by the Commission in cooperation with local, State, and national public health agencies. Work is being continued as a cooperative effort by the Pennsylvania State Department of Health and the Duquesne Light Co.

Waste Management at Hanford

The Commission's Hanford plant site, covering about 650 square miles, is located in a saucer-like basin surrounded by hills and mountains up to 3,600 feet above sea level. Within the basin there is a high plateau where much of the plant area is located. It is a semi-arid region which is lightly populated. To date, Hanford has discharged to the environment about 95 percent of all low- and intermediate-level radioactivity so disposed of in the United States through atomic energy operations. Because of this, and the variety of wastes generated at Hanford, its waste management practices and activities were selected for description in this report. The techniques used depend to a large extent on specific characteristics of the Han-

ford environment—geological and meteorological conditions, level of water tables, soil conditions, and other related factors. Accordingly, these techniques could not be applied directly to other environments and installations.



Monitoring in transit. Obsolete equipment, too-heavily contaminated to be repaired economically, is boxed and buried on the 750-square mile Hanford reservation. For disposal crew protection during transit, empty railroad cars are placed between the "hot" material (center right of photo) and the engine, and the radioactivity level at the moving engine is constantly monitored. The box will be snaked off the car at the burial site by a long cable attached to it before the box was filled.

Waste disposal policy at Hanford is designed to limit to the lowest practicable level exposures and radiation dosage to people and to other life forms. In essence, the long term exposure of personnel within the controlled zones is limited to a maximum of 5 rem [8] per year. Outside controlled zones, an annual limit of 0.5 rem per year is considered tolerable.

[8] A "rem" (roentgen equivalent, man) is the dose of any ionizing radiation that will produce the same biological effect as that produced by one roentgen of high voltage X-radiation.

Hanford waste management controls discharge from all sources, taking account of dilution, radioactive decay, and reconcentration of radioisotopes in biological systems, so that no permissible limit is exceeded at any point of exposure, however remote in distance and time from the point of discharge.

Actual radiation exposure to persons in the environs of the Hanford plant is estimated to be between 3 and 15 percent of currently accepted limits for continuous exposure. For exceptional cases, where unusual amounts of local fish and leafy vegetables are eaten, the exposure may reach as much as 40 to 60 percent of appropriate limits. These values include not only radiation from Hanford operations, but also from the worldwide pattern of fallout from weapons tests.

Various Federal and State agencies have contributed to the evaluation of Hanford waste disposal practices. They have reviewed existing research programs, suggested additional avenues for study, and worked cooperatively. This relationship has materially assisted the Commission in discharge of its public responsibility.

Various kinds and quantities of radioactive wastes are evolved from essentially all operations at the Hanford plant, which include fuel preparation, reactor operations and chemical separation.

Fuel preparation. Uranium-metal fuel elements are prepared and jacketed in aluminum containers. Radioactive waste is limited to small quantities of unirradiated uranium which, with other liquids containing nonradioactive chemicals, are released to ponds. The radioactive concentration in pond water averages about 5×10^{-7} μc/cc, which is about 25 percent of the maximum permissible concentration for occupational exposure. The ponds are located near the banks of the Columbia River and percolate slowly through the soil to the river. In comparison with the uranium found naturally in the river,[9] the quantity which seeps from the pond is so small that it can be detected for only about a mile downstream.

Plutonium-producing reactors. The eight reactors used for producing plutonium from uranium are cooled by Columbia River water passed through the reactor tubes. Although the river water is filtered

[9] Uranium is found naturally in Columbia River water at a concentration of about one microgram per liter (about 7×10^{-10} μc/cc). At an annual average flow of about one million gallons per second, about 130 tons of uranium thus go down the river each year. The soil and groundwater throughout the central southern region of Washington contain appreciable amounts of uranium. Concentrations 5 to 15 times that of the Columbia River water have been found in samples taken from water wells at Pasco (about 15 miles southeast of the Hanford reactor area, and on the opposite side of the river); at Benton City (about 12 miles southwest, and on the opposite side of a low hill mass from the reactor area): and in the Yakima River which flows west and south of Hanford, and enters the Columbia River well below it. This uranium is in no way connected with operations of the Hanford plant.



Deep burial. Bulldozers, working from behind mounds of earth, backfill a deep pit into which a box containing highly-contaminated obsolete equipment has been snaked off a railroad car (note skid marks in upper right of photo). Since radiation normally travels in straight lines, these Hanford bulldozer operators are protected by the mounds of earth they push into the "grave." Protective masks prevent inhalation of possibly-contaminated dust.

and purified before entering the reactors, traces of minerals still left in the cooling, or eroded from the process tubes, water are made radioactive by the bombardment of neutrons. Small quantities of fission products also are present from the natural uranium in the water, and from occasional ruptures of fuel elements. Close control of water quality by treatment plants holds down the amount of resulting radioactivity, *i.e.*, removal of impurities which would be activated by neutrons results in less radioactivity in the coolant stream. Some foreign materials inevitably deposit on the surfaces of the process tubes and fuel elements to form a film, which is periodically removed by "purging" with mild abrasives.

Prior to release to the Columbia River, the effluent is retained from one to three hours in large basins or tanks. During this time, radioactive decay reduces the gross radioactivity of the water by 50 to 70 percent. The retention basins are monitored, and effluent which has an unusually high radioactive content because of occasional ruptures of fuel elements and purges is discharged to trenches where it seeps

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into the ground. The basins discharge into the river through large pipes buried in the river bottom, and the effluent is immediately mixed with a large volume of water. By the time the effluent has traveled to the vicinity of Pasco, 35 miles downstream, and the first point of substantial use, further radioactive decay has reduced the gross activity by a total of about 90 percent and well below the permissible limits for safe consumption.

As will be discussed in a later section of the report on Environmental Research, samples are periodically taken to monitor concentrations and effects of isotopes in the river at the discharge points, at points where water is used and where the water enters the sea. The concentrations as measured have been well within the maximum permissible concentrations (MPC) as recommended by the National Committee on Radiation Protection and Measurements. These concentrations are kept low by quality control of the coolant water entering the reactors, and also, by the dilution capacity of the Columbia River, averaging approximately 600,000 gallons per second at Pasco, Wash., and 1,462,000 gallons per second at The Dalles, Oreg. This volume is sufficient to dilute the approximate 2,500 curies a day passing Pasco to well within permissible concentration limits (see Table VI for isotopic concentrations at Pasco).

TABLE VI.—CONCENTRATIONS OF INDIVIDUAL ISOTOPES IN RIVER WATER AT PASCO, KENNEWICK—1957 [a]

	Half-life	*December* [d] *(Units of 10⁻⁸ μc/cc)* [c]
Na–24	15 h	110
Si–31	2. 6 h	0. 22 [b]
P–32	14 d	3. 5
Ca–45	152 d	2. 0
Sc–46	85 d	3. 0
Cr–51(γ)	28 d	1,000
Mn–56	2. 5 h	1. 3 [b]
Fe–59	45 d	0. 3
Cu–64 (42%γ)	13 h	130
Zn–65(γ)	250 d	29
As–76	27 h	240
Sr–89	53 d	2. 0 [b]
Sr–90	28 y	0. 24 [b]
I–131	8 d	1. 5
Ba–140	125 d	2. 4
Np–239	2. 33 d	370
Rare Earths	----------	34
Gross Beta	----------	2,200

[a] As submitted in a United States paper "Radiation Exposure to People in the Environs of a Major Production Atomic Energy Plant" by J. Healy et al. at the United Nations Second International Conference on the Peaceful Uses of Atomic Energy, September 1958, Geneva, Switzerland.

[b] Extrapolated from reactor effluent analyses.

[c] One hundredth of one millionth of one millionth of one curie per cubic centimeter of water.

[d] Period of lowest flow of Columbia River.

Monitoring of the effluent is an important aspect in management of the reactor waste. Radioactive composition of the effluent is obtained first from samples which originate from various parts of each reactor; secondly, as it leaves the retention basins. Concentrations of individual isotopes, or groups of isotopes, are determined routinely in analytical laboratories. A continuous sample of the effluent being discharged to the river is pumped into an aquatic biology laboratory and its toxicity tested with live fish.

A second, minor source of radioactive waste from reactor operations is gases and aerosols. Air used for ventilation picks up contaminated dust from buildings, and gas which leaks from the reactors. Release of these materials through high stacks, after proper filtering, has produced no distinguishable contamination levels outside of the reservation.



Storage tunnel. Highly-radioactive equipment not in use can be loaded on railroad cars and stored in this tunnel at Hanford. In above photo, a waste disposal crew member (right, center) monitors the radiation emanating from the tunnel as the large steel and concrete door is raised. Crew members wear protective masks to guard against inhalation of radioactive dust in the tunnel. On the left is a second tunnel (note emplaced studs to facilitate rail laying) not yet in use.

Solid wastes, such as contaminated paper, boards, worn out tools, construction items, and aluminum spacers used to center the fuel charge, are buried in trenches in the reactor areas. These wastes are isolated from the environment, being well above the water table in an area where rainfall is so low that percolation through the deposits is practically nil. Large pieces of equipment which become unusable through obsolescence or damage and are too highly radioactive to be dismantled into scrap metal, are either buried in very deep pits or stored in large concrete-lined tunnels.

Chemical separations operations. In this process, aluminum jackets of the fuel are removed, and the irradiated fuel elements are dissolved in acid. The plutonium and residual uranium are separated, purified, and processed separately.

The primary stages of the separation processes have created some 52 million gallons of high-level radioactive liquid waste, which is retained in underground storage tanks. Later process steps have created some 3 billion gallons of intermediate-level wastes which have been deposited to the ground under carefully controlled conditions. In addition, almost 30 billion gallons of cooling water, with only minor and incidental amounts of radioactive contamination, have been released to surface ponds.

The location of the separations facilities on an interior plateau takes advantage of the high elevation for the stack release of gases, the deep dry sediments for the downward percolation of liquids to the ground water level some 200 feet below and the 7 to 10 miles distance to the river for underground travel of liquids. During movement through the soil, practically all radioactivity is removed from the waste liquid by ion exchange with the earth.

Although radioactivity in all the wastes described originates principally from fission products, each type of waste—the various gases, vapors, and high, intermediate and low-level liquids—requires a different management method.

While the dissolving of fuel elements is the principal source of *radioactive gases and vapors*, others are released in later processing steps. Radioiodine is the principal material requiring control. Volatilized radioruthenium also has been present.

The quantity of radioiodine discharged is partly controlled by aging the fuel elements before processing. This allows radioactive decay of the short-lived iodine 131. Removal in silver reactors takes out most of the remaining volatilized iodine. Periodically, the filter beds are regenerated, and the liquid waste containing radioiodine is placed in

underground storage tanks. In 1957, facilities were installed which absorb acid-producing vapors and also remove iodine as a back-up for the silver reactors.

Most of the ruthenium which is volatilized is removed in caustic scrubbers. Some of it forms minute particles which are effectively retained in filters.

The ventilation air of the process buildings also is vented to high stacks because it may, from time to time, contain minor releases from process vessels. It is first passed through large filter beds made up of graded layers of sand or mats of glass fiber to remove entrained radioactive particles.

Plutonium purification facilities are equipped with filters which remove radioactive materials from process gases before they are released, and no significant contamination of the atmosphere from these facilities has yet been experienced.

The amount of radioactive material which leaves the stacks is monitored to provide a continuous record of the release.

High-level liquid wastes containing the bulk of the fission products from the irradiated fuel elements are stored as alkaline slurries in underground tanks constructed of reinforced concrete and lined with steel plate. Each tank has a capacity of 500,000 to 1 million gallons, and is placed well below ground to shield personnel from the radiation, and to protect the tanks from weather and other damage.

No environmental hazard exists as long as the tanks maintain their integrity. A small leak would not create a significant hazard, since the tanks are 200 feet above the water table and dry sediments beneath the tanks have a large capacity for retention of liquid waste. A considerable part of the radioactivity becomes associated with a heavy sludge that probably would not move far through the soil. The life of the Hanford tanks is not yet known, but it is estimated to be at least 20 years.

New management techniques have recovered some storage space so that additional tank construction has been postponed. One technique is self-concentration of the liquids accomplished when the heat of radioactive decay causes the liquid in the tanks to boil. The volume of nonboiling wastes might be reduced by separating out undecayed long-lived isotopes and returning these to the tanks in a concentrated form.

An inventory is maintained of the contents of each tank and the liquid level is watched carefully. Dry wells are drilled adjacent to the tanks as an additional means of detecting any leaks that may occur.



Low- and Intermediate-waste disposal. Liquid wastes are allowed to percolate into the dry Hanford soil from gravel-filled trenches, or "cribs," shown under construction. Perforated pipes carry the wastes into the gravel. Ion exchange fixes the radioactivity to the soil as the liquid seeps into the ground. The disposal trenches are surrounded by deep wells which are continuously monitored to detect any underground movement of the radioactivity.

Intermediate level liquid wastes at Hanford include waste streams from decontamination in late steps of the separations process, spent solutions used to absorb or scrub gases, condensed vapors from self-boiling tanks, various other condensates from process equipment, and aged solutions from which longlived isotopes have been scavenged.

These wastes are discharged into the ground by seepage from structures known as "cribs," and from trenches. The cribs are placed underground to minimize radiation levels and surface contamination. Open trenches, protected by fences, are used for isolated batches of waste that would cause complications at other disposal sites. After use for a single disposal, the trenches are refilled to prevent surface contamination.

Favorable geological and hydrological conditions in the area, and the capacity of the soil to absorb isotopes, make it possible to hold the vast majority of the radioactive materials in a thick layer of sediments. Thus, the wastes are essentially "stored" in the ground, and any water percolating through to the water table is purified by time

and the action of the soil. Were the radioactive materials to enter the ground water, additional decay time and retention capacity of the soil would abate the hazard during the relatively slow movement of ground water to the Columbia River where ample dilution would be available.

Behavior in the soil of each major type of waste is evaluated in the laboratory before disposal operations start. After disposal, a network of monitoring wells drilled around the trench or crib area keeps track of isotopes movement. Any process waste stream that would not be adequately retained in the soil is stored in tanks as a high-level waste.

Low-level wastes at Hanford consist, for the most part, of cooling water and utility steam condensates which ordinarily are not radioactive. Since these waters may be contaminated occasionally from process vessels, they are considered low-level wastes.

This waste is discharged to surface ponds or swamps and seeps through the soils to the water table some 200 or more feet below.

Environmental monitoring. Work in this field is described in a later chapter on Environmental Research.

Laboratory Waste Management: Brookhaven

A variety of wastes is generated in research and development operations and programs carried out at the Commission's national laboratories. The systems and methods used to manage waste at these installations differ in detail, but generally are similar. Waste management operations at Brookhaven National Laboratory are described in this report as an example of the operations and functions involved where there is a considerable population density and weather and geological conditions minimize the amount of radioactivity that may be released to the environment.

Brookhaven National Laboratory is located at the geographical center of Long Island with farming and residential areas just beyond the boundaries of the 3,600-acre site, and several villages at distances of 5 to 15 miles. Most of the radioactive waste at Brookhaven is generated directly or indirectly by the large air-cooled research reactor. No large-scale processing of fuel elements is involved and waste disposal does not include large volumes of highly radioactive wastes. Gaseous and some liquid wastes are managed on the site. Other liquids and solid wastes are disposed of at sea.

Gaseous wastes. The major sources of gaseous waste activity are the off-gases from the hot (radioactive) laboratory and the cooling air

from the reactor. The off-gases from the hot laboratory are cleaned by filters and scrubbers and released through a pipe going up the center of the 310-foot stack provided for the reactor cooling air. The major gas problem is radioactive argon 41 in reactor cooling air.

The Brookhaven Research Reactor, until 1958, released approximately 6,600 curies a day of argon 41, generated by the brief exposure of air to neutrons. Since argon 41 is a chemically inert gas that is not metabolized by the body, its hazard is limited to external radiation exposure. Its radioactive half-life is 112 minutes. Thus, although the total activity emitted amounted to 6,600 curies per day, no more than 730 curies was in existence at any one time. This rather considerable amount of activity was diluted in an air flow of 220,000 cubic feet a minute through the 310-foot stack whose base is about 50 feet above the immediate surroundings.

When the reactor first was put into operation in 1950, the standard allowed levels at the edge of the site that, when averaged over a week, would be no more than 1 percent of the limit prescribed for occupational exposure—at that time 50 mr (milliroentgens) a day. Thus, the effect of the reactor was not permitted to exceed 3.5 mr/week, which was about twice the natural gamma ray background level in this area.

With this low limit, it was necessary to provide 2 separate but coordinated means for evaluating and controlling exposure levels: first, a network of 15 monitoring stations; second, a meteorological program for computing the levels from measured values of the pertinent weather conditions.

The 15 monitoring stations were located at distances up to 10 miles in various directions from the center of the Brookhaven site. Each was equipped with an ionization chamber monitor for gamma radiation, several Geiger counters, a moving-tape type of dust monitor and a battery-operated ratemeter. All the data was recorded photographically every 6 minutes. Before start-up of the reactor, a full year of data was obtained with these stations to establish naturally existing background radiation levels.

For meteorological work, a 420-foot high tower was equipped with instrumentation for determining the wind and temperature structure as a function of height and time. In addition, weather forecasts were made. Analytical procedures were developed for forecasting the radiation dosage resulting from the argon 41 on the basis of theory, and experimental determinations.

This intensive monitoring system showed that the 1950 limitations for radioactivity released into the atmosphere from the research reactor were unnecessarily stringent. In 1953, after an exhaustive

study by Brookhaven and Commission personnel, the old 3.5 mr/wk was raised to 10 mr/wk, or 0.06 mr/hr. This was 10 percent of the occupational limits for integrated exposure which, as an average, has the limitation of no more than 100 mr/wk for persons 18 years of age and over.

Between August 1957 and April 1958, the research reactor was reloaded with enriched fuel. This raised the release of radioactive argon discharge by approximately 2.5 times, or to 16,100 curies per day. Also, in March 1958, Brookhaven's new medical research reactor became critical. The argon 41 release from this reactor is about 0.73 curies per hour which, after treatment, is released to the atmosphere from a 150-foot stack located a half-mile southwest of the older research reactor stack.

Monitoring studies to date have shown that the increased argon discharge caused by the research reactor reloading and the new medical research reactor still are well within the limits prescribed in 1953.

Liquid wastes. Most of the more radioactive liquid wastes at Brookhaven are generated at the reactor, hot laboratory, and cyclotron buildings. Lower level wastes are produced in most of the laboratories.

The underlying philosophy is to segregate the wastes at the source. Containers are provided for collection of concentrated waste in all laboratories where the wastes are produced. The reactor-hot laboratory complex is provided with a separate liquid waste system, including tanks, so that release to the general laboratory system can be monitored and controlled. Monitoring arrangements are provided for the general laboratory sewerage system so that the limit for the release of activity will not be exceeded. Where there is a possibility that excess amounts of activity might be released to the sewerage system, local hold-up facilities are provided and an evaporation plant is used to reduce their volume.

In order to dispose of it safely, some low-level radioactive concentrate liquid is used in making concrete which is poured into 55-gallon drums and disposed of at sea.

Low-level laboratory liquid wastes and sanitary wastes are discharged to a sewerage system installed when the site was used for a large Army camp. The effluent passes through an Imhoff tank that removes most of the solids and then is discharged to a large sand filter, collected by an underlying tile field, chlorinated, and discharged to a small stream.

Proportional samples are collected continuously at the point where the effluent is discharged to the filter beds, and prior to its discharge

to the stream. These samples are analyzed daily for gross activity.

Early in the history of the laboratory a limit was established of 3×10^{-6} μc/cc (microcuries per cubic centimeter) for gross activity at the point of discharge to the filter beds, with the further stipulation that the total activity discharged per year should not exceed 1.5 curies. Levels measured at the input to the sand filters have averaged, so far, only about 20 percent of the allowed concentration. A large fraction of the activity released to the filter beds is filtered out or absorbed and does not reach the stream. Tests downstream so far have failed to detect any effect from the laboratory effluent.

The *reactor-hot laboratory complex* originally was provided with several piping systems for collecting different classes of liquid wastes; accountable metal waste containing uranium and other fissionable material; high-activity chemical waste containing no accountable material; contaminated solvent waste containing volatile solvents or hydrochloric acid; low activity chemical waste which does not require shielding; and normally uncontaminated waste which must be monitored for activity before disposal.

These piping systems were brought together at a waste control center provided with tanks to store the wastes until their activity could be determined for discharge either to the tank farm or to the sewerage system. Radioactive wastes collected in containers are dumped into these tanks as appropriate.

The tank farm contains three 100,000-gallon tanks and six 8,000-gallon tanks, and an evaporation plant which reduces the volume by a factor of about 140 is adjacent.

In other sections of Brookhaven, a tank or tanks is provided to which waste effluent is discharged for holdup. Periodically, the contents are analyzed and either discharged to the sewer or transported to the hot laboratory.

Solid wastes. Solid wastes may be produced wherever experiments are being conducted with radioactive materials. Objects activated in the research reactor, including experimental equipment, thermocouples, pile structural materials, graphite, irradiated samples, furnaces, autoclaves, etc., are used in various experiments and then become waste. Cleaning mops, rags, swipes, and other materials used for decontamination become waste. Left-over isotopes and excreta from animals treated with radioactive isotopes must also be disposed of. The liquid slurry from the tank-farm evaporator must be solidified, for example by addition of cement, so that it can be handled as solid waste.

Solid wastes are handled in one of three ways, depending on the amount and type of radioactivity. If levels of radioactivity are low, some can be disposed of on the Brookhaven dump area. Wastes too active for local burial ordinarily will be packaged for sea burial, or if this is not feasible because of the radioactivity level, they are stored in underground, concrete-lined, waterproofed pits for radioactive decay and possible subsequent disposal.

Initially, the laboratory did not permit local burial of any radioactive solid wastes. In 1953, the policy was restudied and now allows local burial each year of material on the following basis: 10 curies of activity with a half-life of less than 100 days, 1 curie with a half-life between 100 days and 5 years, and $\frac{1}{10}$ curie with half-life longer than 5 years. The amounts of plutonium or radium which can be buried on-site are limited to 1 millicurie each. Thus, most of the short-lived isotopes used by biologists and medical personnel can be handled by burial. The 100 millicurie ceiling for long-lived activity permits certain bulky equipment, and containers slightly contaminated with uranium or thorium, to be buried locally.

Waste Disposal by Burial

Except for storage in rigorously maintained tanks, there is no waste management method that withholds radioactive wastes from the environment on an essentially permanent basis. Actually, such rigorous control is not necessary for many radioactive elements since most such materials, through radioactive decay, lose their capacity to harm within a few years, or a decade at most. Land and sea burial are means of disposal intermediate between long-term storage and diluted release to the environment. Where burial involves some release to the environment, the conditions imposed by the Commission insure that the release will be gradual, and either limited to a Government-maintained reservation, or assured of immediate, enormous dilution to levels considered nonharmful. The Commission allows burial only of low-level wastes in the ocean.

Most low-level solid wastes from Commission operations are handled by burial at Commissioned-owned sites. However, because of their location, Brookhaven and the radiation facility at Livermore, Calif., have disposed of laboratory wastes at sea. In line with Government policy of not competing with private industry, wastes from licensee operations have not, up until now, been generally accepted by the Commission for disposal on its reservations. However, a recent change in policy will enable licensed disposal firms to utilize the Commission's land-burial sites.

Sea Disposal

In using burial at sea as one means of disposing of radioactive materials, the Commission has followed a traditional military practice—for example, sea burial of toxic chemicals and other munitions. Such disposal is carried out only under rigidly enforced special conditions. The paramount consideration, in the conditions the Commission enforces and requires of its contractors and licensees, is the protection of public health and safety.

The radioactive wastes disposed of at sea contain quantities of radioactivity normally associated with research and development activities rather than production facilities, such as at Hanford, or chemical reprocessing plants like those at the National Reactor Testing Station in Idaho. For example, in terms of radioactivity concentration, the relatively small quantity of solidified liquid wastes buried at sea at one time is less than a curie and generally in the thousandth or millionth of a curie per gallon range; while the liquid high-level waste resulting from a chemical processing operation at the Idaho facility might have a concentration in the hundreds or thousands of curies per gallon. Thus, there is a factor of difference in concentration on the order of tens or hundreds of millions. Also, the total number of gallons (i.e., total quantity of radioactivity), evolving from the two situations is vastly different. For instance, during 1957 the Commission disposed off both coasts of the United States at designated locations 686 drums (55-gallon) of solidified laboratory waste liquids. (The volume includes concrete and other solidifying agents.) On the other hand, there are more than 65 million gallons of high-level wastes in storage principally at Hanford, Savannah River, and the Idaho Station. The Commission does not propose to dispose of these high-level wastes at sea, even though some oceanographers and other experts have indicated that a "dilute and disperse" waste dispersal approach may be theoretically possible.

Sea burial from Brookhaven. The methods used at Brookhaven National Laboratory in sea burial operations are typical of Commission operations, and the standards required of licensed commercial activities for sea disposal.

Brookhaven uses 55-gallon 18-gauge steel drums as the standard package for sea disposal, after reducing the wastes to solid form. The slurry of low-level wastes from the Brookhaven evaporator is mixed with cement and poured into drums to harden. Glass containers are broken, and bulky metal objects crushed. Acids are neutralized and solidified. No liquids are permitted.

Since radiation levels outside the drum must be held low for handling, concrete shields, varying according to need from 2 to 10 inches, are poured into the drums prior to packaging the material. The waste is placed in a cylindrical cavity and then concrete is poured on top.

Combustibles such as paper, rags, and mops are compressed into bales approximately 1 foot square and 20 inches high. One bale is placed in each drum and concrete poured around it. Each drum is weighed to make sure that it is heavy enough to sink to the prescribed 1,000 fathom (6,000 feet) depth of water. The Commission requires that the containers for sea disposal must have a minimum density of 10 pounds per gallon.

When drums are ready for shipment, they are monitored for radiation and recorded by number, contents, radiation level, and estimated curie content. The drums then are stored on the ground upside down so that rain water cannot seep into them, with the least radioactive drums on the outside to provide extra shielding. Each is color-coded to indicate radiation level, and the area is enclosed by an 8-foot fence kept locked when no one is in attendance.

Since the Navy was disposing of surplus Naval ordnance materials collected at Earle, N.J., by using an LST (Landing Ship, Tanks), the Commission arranged in 1954 with the Navy to pick up full shipload quantities of Brookhaven waste once each year.

When approximately 700 drums are accumulated at Brookhaven, a commercial trucker who can furnish a sufficient number of flat bed trucks at one time (48 drums to a truck) is hired to haul the drums to a wharf at Floyd Bennett Field, Brooklyn. The drums are loaded aboard by Brookhaven personnel and Brookhaven equipment, and the trucks travel to the wharf in convoys with escort cars. Brookhaven men and equipment unload the trucks at the wharf. The ship's crew with radiation monitors on hand at all times, handles the loading of the vessel. The ship's crew is moved from quarters amidships where the drums are stored and each crew member wears a radiation-measuring badge. The whole procedure, from arrival of the trucks at Brookhaven for loading to the actual dumping of the drums at sea, is on a tightly timed schedule so as to minimize the possible exposure time of the personnel engaged in the operation.

The ship sails to a predesignated dumping area approximately 250 miles south-southeast of Brooklyn, and the drums are deposited off the continental shelf in water at least 1,000 fathoms deep. Sailing time out is ordinarily about 24 hours, with 60 minutes required to unload the drums. During the return voyage, the ship is surveyed for radioactive contamination. If decontamination is required, it is done under supervision of Brookhaven experts.

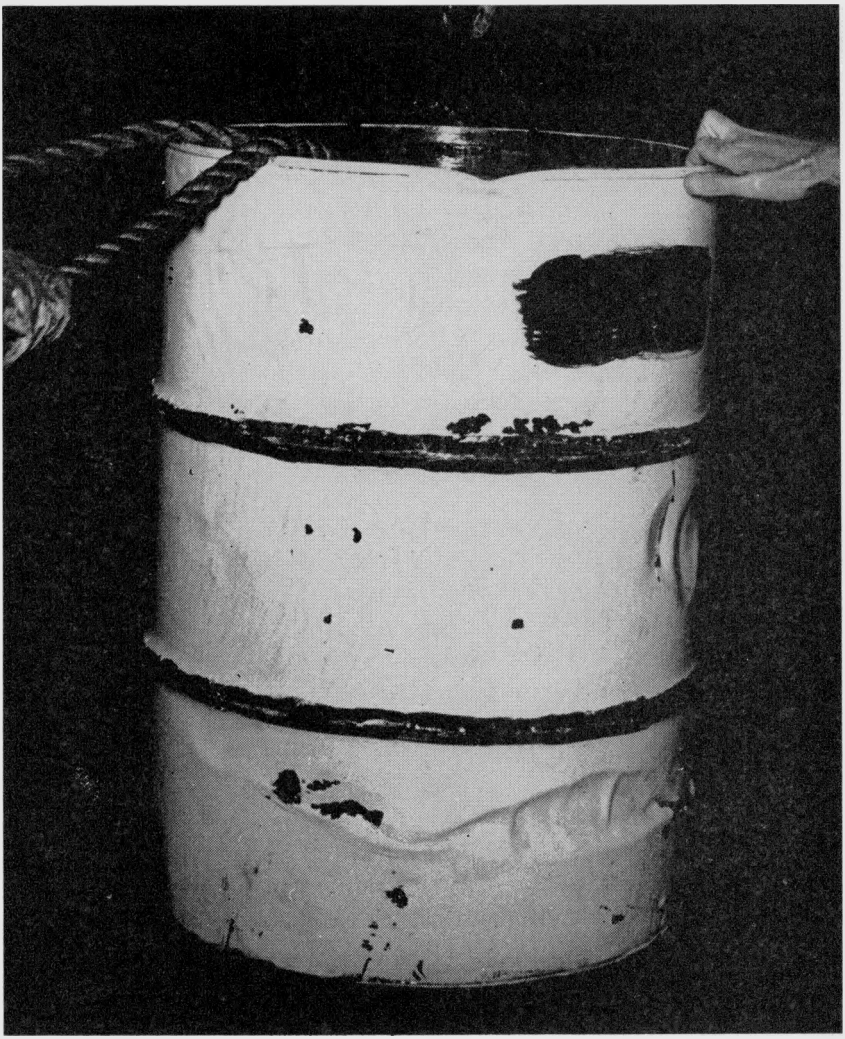
During 5 annual sea burial operations, no overexposures have occurred, and contamination on shipboard has been negligible. Sea burials of radioactive wastes from Brookhaven have taken place as follows:

Year	*No. drums*	*No. curies*
1954	472	233
1955	658	597
1956	638	660
1957	704	700
1958	692	1,100
Total	3,164	3,290

Drum tests. Because of the great water pressures, there is likely to be some drum failure by implosion at ocean depths of 1,000 fathoms, particularly in the case of drums containing combustible wastes which leave voids within the concrete package. However, the amounts of leaching of the contents by sea water that occur are not hazards.

In order to determine the effects of water pressure on the drums and the effects caused when they strike the ocean bottom, the Commission has had tests conducted. Recently the United States Coast and Geodetic Survey found that cement-filled drums maintained their integrity and the contents were not released even though the drums hit the ocean floor at velocities calculated to be up to 17 miles per hour. The tests were conducted near Woods Hole, off the coast of Massachusetts, in depths of 50 to 90 feet of water. Simulated radioactive wastes marked with dyes were used.

Previously, some 180 miles off San Diego, Calif., the Scripps Institute of Oceanography had made a series of depth-presssure tests for the Commission. Drums, containing concrete-encased, low-level radioactive wastes from the Lawrence Radiation Laboratory were lowered to depths ranging from 200 feet to more than 6,000 feet (1,000 fathoms). The tests were run with drums loaded in various manners. Those drums in which the radioactive waste was solidified and surrounded by concrete could withstand the pressure of 6,000 feet with little or no effect. However, those drums where the encased waste material was left in an uncompressed state (i.e., the whole carcasses of test animals, unbroken glassware, unbaled paper, etc.) which created voids within the container, implosion of the drum could occur even at 200-foot depths. As a result, the Commission requires that wastes must be solidified or highly-compressed within their containers for sea disposal so as to minimize the possible release of the wastes through implosion of the container.



Tested 1,000 fathoms deep. Steel drums used for sea disposal of low-level wastes must withstand great water pressure in the ocean depths. The solidified wastes are in the center of the drum, surrounded by several inches of concrete. Photo shows a 55-gallon concrete-filled drum which was lowered to depth of 1,000 fathoms off California coast. The concrete-filled drum maintained its overall integrity, although small voids in the concrete allowed inward bending of sides in two places.

Commission standards and record. The radioactive material involved in Commission sea burial off both the Atlantic and Pacific coasts is of a relatively low or intermediate levels—in the same categories released to land environment where conditions are favorable. The total vol-

ume involved in sea disposal is also relatively low. Since 1946, the Commission has buried at sea, in some 45,000 steel drums or concrete containers, radioactive materials totaling about 22,000 curies at the time of burial—a total of less than 2.5 million gallons. In addition, the reactor structure of the land-based Seawolf prototype reactor which had been built at West Milton, N.Y., also was buried at sea, in one of the regular disposal areas in early 1959. This equipment was estimated at 33,000 curies, all induced activity in stainless steel that would be released to the sea only through corrosion of this material—a release rate estimated at not more than 2 or 3 curies per year.

Experience in other countries has indicated the feasibility and safety of disposing of considerable amounts of radioactivity in liquid form through a pipeline directly to the sea. The Commission and its contractors and licensees do not discharge liquid wastes directly to the sea. Low level wastes are discharged, however, into waterways which may carry the undecayed, unabsorbed portion of the original radioactivity to the sea. Disposal into waterways is done only when the flow of water is ample to dilute the radioactivity to well below maximum permissible levels. This is true, for example, of the Hanford plutonium production reactors which, using Columbia River water as their coolant, discharge a considerable volume of water which has been made somewhat radioactive by passage through the reactors. This discharge is largely diluted immediately by the high flow of the river, and is kept well below permissible levels.

Downstream, where the river enters the sea, analyses of the water indicate that the radioisotope concentration is less than 1 percent of the maximum permissible drinking water concentrations. The total radioactivity entering the ocean at this point per day is about 1,000 curies, made up chiefly of the following isotopes in the approximate amounts indicated: 20 curies of phosphorus 32, 900 curies of chromium 51, 10 curies of zinc 65, and 70 curies of neptunium 239. The reduction from the 2,500 curies a day measured at Pasco to 1,000 at the estuary results chiefly from the decay to stable forms of short-lived radioisotopes and, to some extent, from sedimentation and other effects.

All wastes deposited directly in the sea by the Commission, its contractors, or licensees, is placed at designated deep-water sites in solidified form.

Two major disposal areas have been used by the Commission, both beyond the continental shelf and in 1,000 or more fathoms of water.

Since 1951, the Commission has buried at sea in the Atlantic Ocean radioactive materials totaling about 8,000 curies at time of burial. This was packaged in some 23,000 steel drums.

In the Pacific Ocean, sea burial operations began in 1946. Since then approximately 14,000 curies (at time of disposal) contained in about 21,000 drums and 329 concrete boxes have been disposed in an area approximately 48 nautical miles west of the Golden Gate. Since 1953, about 60 curies contained in about 2,950 drums have been disposed of in an area approximately 53 nautical miles west of Point Vicente, Calif. Both areas are in depths of water of 1,000 or more fathoms. The radioactivity content ranges from about one-half millicurie to 15 curies per drum for the solid wastes—with most around one-half curies or less, and from one-half millicurie to 1.5 curies per drum for the solidified liquid wastes at the time of disposal. The Commission has not disposed of any radioactive waste materials into the Gulf of Mexico.[10]

Details of the Commission's control over licensed sea disposal are given in chapter V, Part Three, of this report, "Licensing, Regulation, and Inspection." Volumes of material disposed of by licensees also are reported there.

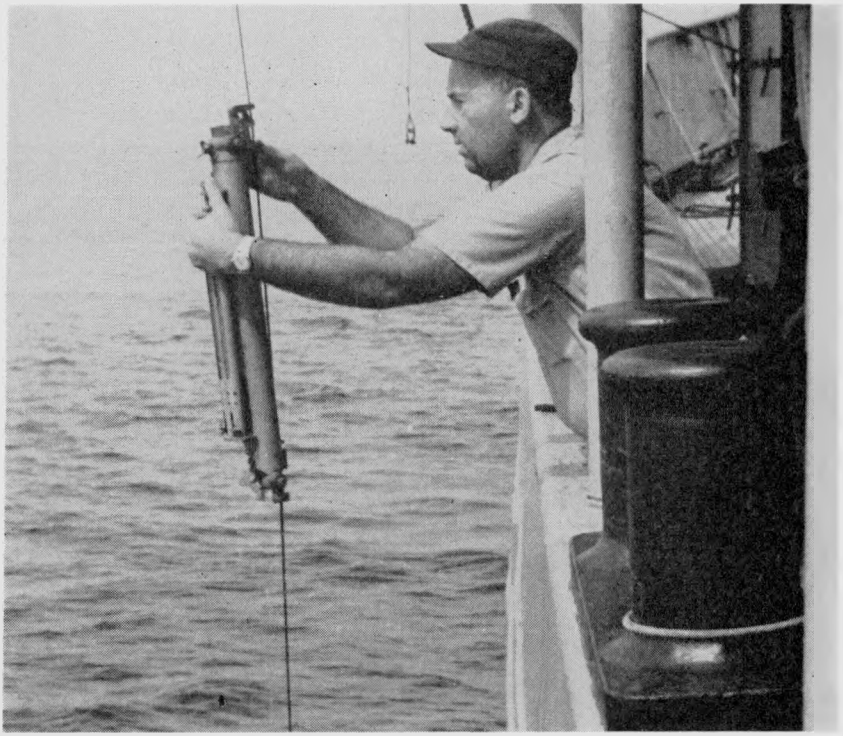
The Commission believes that sea disposal operations are carried out in a manner that is safe and provides adequate protection to the public. This belief is based on field research, the views of experts in the marine sciences and other pertinent fields, and actual operating experience over a period of years.

In-shore site studies. The recent report of marine scientists for National Academy of Sciences-National Research Council, in its Publication 655, "Radioactive Waste Disposal to Atlantic and Gulf Coastal Waters," indicated that, with conservative consideration of the factors involved, it was feasible to dispose safely of solid, packaged wastes at much shallower water locations than now used by the Commission. This was a preliminary study as a part of the Commission's long-range planning program and concerned only the basic feasibility of the in-shore sites. The NAS-NRC committee listed 12 sites—mainly locations where explosives and certain toxic chemical wastes have been dumped—where, with proper precautions, radioactive wastes in low concentrations might be disposed of. The study was sponsored by the Bureau of Commercial Fisheries, Office of Naval Research, and the Commission.

In case of a possible future need for coastal disposal sites in the New England area where there is a heavy concentration of industrial, medical, university, and other users of radioisotopes, the Commission

[10] Figures shown in this section refer only to wastes disposed of by the Commission and its contractors. Amounts buried at sea by Commission licensed disposal firms or other licensees are shown in Chapter V, page 373, of this report, and total approximately 2,535 curies in the Atlantic Ocean, 102 curies in the Pacific Ocean, 10 curies in the Gulf of Mexico.

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Sea disposal site monitoring. Oceanographic studies in connection with sea disposal of low-level radioactive wastes are carried out for the Commission by the U.S. Coast and Geodetic Survey. The work includes taking water and bottom samples for checking against known background radiation data—obtained from areas not used for disposal—to determine possible presence of radioactivity from disposal operations. In above photo, a Nansen bottle is about to be lowered for a water sample at an Atlantic ocean site.

has selected for further investigations four locations listed in the NAS-NRC study. The investigations were begun in September and are being conducted, under contract with the Commission, by the United States Coast and Geodetic Survey, the United States Public Health Service, and scientists from the University of Connecticut. However, use of these sites for waste disposal is not contemplated at the present time by the Commission.

In 1957, the Commission conducted a survey of the currently used Atlantic Ocean disposal area through the Chesapeake Bay Institute of the Johns Hopkins University in cooperation with the U.S. Coast and Geodetic Survey. A series of samples taken from the ocean bottom in and near the disposal site indicated no radioactivity detectable above background levels. A similar survey by the Scripps

Institution of Oceanography of the two Pacific Ocean disposal areas gave comparable results.

Land Burial

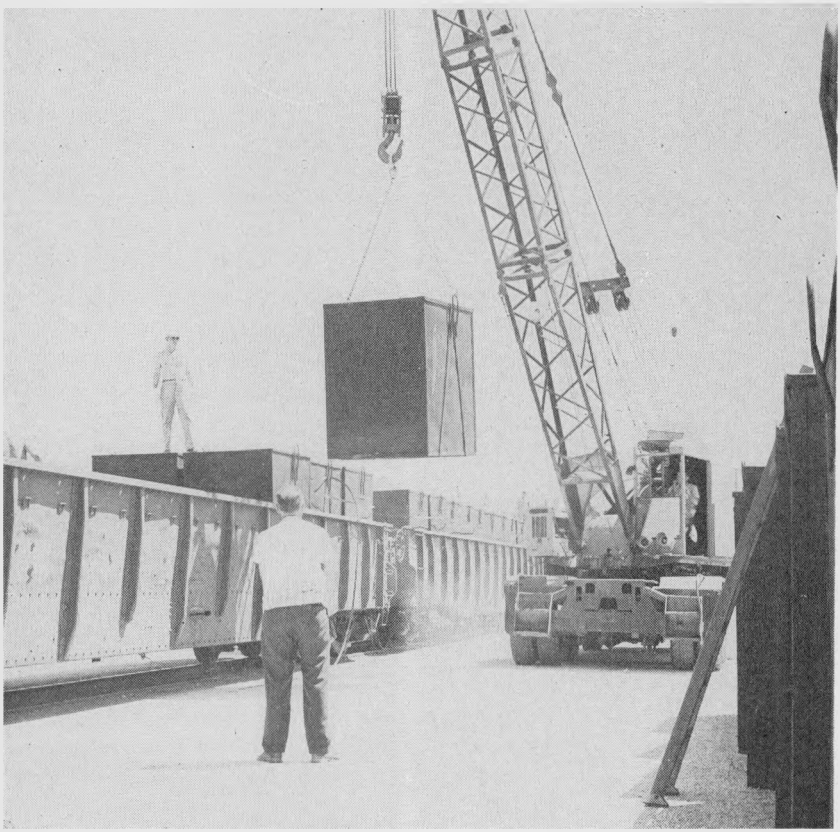
Solid or packaged waste materials currently are buried underground only on major Commission reservations. Burial grounds have been operated at Oak Ridge, Tenn., Hanford, in Washington State, the National Reactor Testing Station in Idaho, Savannah River, S.C., and Los Alamos, N. Mex. The Oak Ridge site is used by a number of Commission facilities and contractors for disposal purposes.

Oak Ridge National Laboratory is located in a relatively isolated section of central Tennessee, near the Clinch River. Aside from the city of Oak Ridge, the surrounding area is only lightly populated. A local shale formation lends itself to waste disposal operations. The Oak Ridge reservation has served as the major disposal site not only for its own wastes, but also for wastes from Argonne National Laboratory, Knolls Atomic Power Laboratory, Mound Laboratory, Battelle Memorial Institute, General Electric Co. in Evendale, Ohio, and other Commission off-site installations east of the Mississippi River. Under special conditions some of the Commission's radioisotope customers (industrial organizations, medical and educational institutions) also send their radioactive wastes to Oak Ridge for burial. Solid radioactive wastes from these sources occupy approximately half the burial ground reservation currently used at Oak Ridge.

The solid wastes usually contain minor quantities of radioactivity, probably about 1 percent of the total disposed of by Oak Ridge National Laboratory.

In collecting contaminated solid wastes, the prime considerations are personnel safety and preventing any spread of contamination. Ordinary galvanized garbage cans are used as collectors inside buildings. They are painted a distinctive yellow color and marked with a radiation symbol; they are leak-proof and fitted with tight covers. They are monitored frequently to assure that radiation levels are safe.

Special leak-proof containers are used to collect larger volume wastes. Personnel are provided with protective clothing to prevent contamination. Where an inhalation hazard exists, personnel wear filter masks. A radiation survey is made before moving materials, and to establish working time to prevent personnel exposure in excess of permissible limits. If necessary, remote handling devices may be used to reduce personnel exposure. All personnel involved in



Safe shipment containers. Low-level waste shipment containers meeting Commission and Interstate Commerce Commission standards are so constructed that the radiation level on the surface is negligible. Note man standing on containers (left of photo) filled with baled low-level paper, glassware, and textile wastes as they are loaded at Argonne National Laboratory for rail shipment to Oak Ridge for burial. Containers are held at laboratory until several carloads can be shipped at one time.

disposal operations wear film badges and dosimeters to measure radiation exposure.

Wastes shipped to Oak Ridge must be described by their shippers in writing, and materials handled by commercial carrier must be packaged and shielded in prescribed ways to meet Commission standards. Wastes shipped in small lots by truck may be dumped directly into the burial pit. Large shipments which arrive by rail are surveyed to determine radiation levels. If, on occasion, containers are damaged, precautions must be taken to prevent the spread of contamination. After completion of burial, men, equipment, and vehicles are



Oak Ridge burial. The Oak Ridge National Laboratory reservation is the Commission's major burial site for low-level, solid radioactive wastes in the eastern United States. Wastes are shipped to Oak Ridge in containers meeting Interstate Commerce Commission regulations (radiation on outside of container is negligible). Each day's accumulation of waste containers is buried by 3 or more feet of earth. Current burial operations at Oak Ridge use about 5 acres of land a year.

checked and decontaminated as necessary. Vehicles cannot be released to a public carrier until satisfactorily decontaminated.

Waste solids at Oak Ridge normally are transported to the burial site by special trucks used only for this purpose. They are distinctively marked, fitted with leak-proof beds, and equipped with lead shielding between the cab and the bed of the truck. Pickup, loading, and discharge of materials are constantly monitored.

Solid radioactive wastes currently are buried in Conasauga shale formations in Melton Valley near the Oak Ridge liquid disposal pits. Alpha contaminated wastes are buried in holes approximatley 15 feet deep and covered by about a foot of earth, plus 8 inches of concrete and an additional 2 or more feet of earth on top of the concrete. The concrete is a precaution against personnel later inadvertently digging into the long-lived wastes.

Waste materials contaminated by beta-gamma activity are buried in trenches approximately 10 feet wide by 15 feet deep, which are dug completely across the burial site. When a portion of the trench is filled, the wastes are covered by 3 or more feet of earth. In special cases where small, extremely active solid waste materials must be disposed of, auger holes approximately 1 foot in diameter and 15 feet deep are drilled. This procedure is primarily to limit the radiation exposure of personnel.

The location of the burial site now in use is such that the ground water flow is toward White Oak Creek and the Clinch River into which low-level liquid wastes have been released almost since the beginning of the project. Records are kept of the type and quantity of materials buried, and their locations. The site is completely fenced to prevent unauthorized entry and marked with radiation signs to warn personnel of the potential hazard.

To date, four burial sites, totaling about 25 acres of land, have been used at Oak Ridge. The earlier burial sites were relatively small and, as each was filled, it was closed. The site used prior to the present area comprised approximately 7 acres, and was filled at an average rate of 1.5 acres a year. The current burial rate runs about 5 acres per year, the increase resulting chiefly from use of the Oak Ridge site by outside agencies—about 25 are using these facilities at the present time.

Study on future site. In case of a future need to dispose of solid radioactive wastes in the western part of the United States, the Commission engaged Stanford Research Institute during 1959 to make a preliminary study of the feasibility from the standpoint of public health and safety of establishing a site for land burial in that region. The study supplied the basis for possible future detailed investigations to determine the desirability and feasibility of land burial at specific sites, and to obtain an estimate of the long-range regional needs for such facilities.

The Stanford study includes a survey of sources and volumes of low-level atomic wastes in California, Arizona, Nevada, Utah, Idaho, Washington, and Oregon. The study did not include a survey of radioactive waste materials from the Commission's Hanford Works at Richland, Wash.; the National Reactor Testing Station near Idaho Falls, Idaho, and the Nevada Test Site at Mercury, Nev., since these wastes are handled on Commission sites.

Major sources of the seven-State region are in the San Francisco and Los Angeles-San Diego areas. It was found that, on an annual basis, the greatest activity—1,100 curies—would come from the San

Francisco area, and the greatest volume—30,000 cubic feet—would come from the Los Angeles area.

Maximum and minimum estimates were made of foreseeable radioactive waste production to 1970. For the period from 1960 to 1970 the annual waste production in the western States was estimated to be between 58,000 and 118,500 cubic feet containing activities between 1,200 and 1,600 curies.

In the site study, 14 areas were listed which appeared to have the isolation, and geological, hydrological, and meteorological characteristics to justify further investigation. The study does not constitute an official selection of a burial ground site or sites. Whether or not a disposal site is to be selected and which, if any of the sites listed by the Stanford survey would be used, is a matter for future consideration and decision by the Commission.

Future land-burial site policy. In December 1959, the Commission established a policy that regional disposal sites for permanent disposal of low-activity packaged wastes from all authorized users shall be established, as needed, on State- or Federal Government-owned land. Placement of the waste materials in Commission-inspected, Government-owned lands, under long-term Government control, will assure adequate protection of the public health and safety throughout the period of any potential hazard. Commission studies are being carried out to identify appropriate areas for one such regional site in the West and another in the Northeast part of the United States. Before establishing the regional sites on land not owned by the Commission, the State concerned would be consulted, and public hearings held if called for. In this interim, Commission sites will be designated to receive and dispose of these wastes.

The Commission does not contemplate that the ownership and control of the sites must necessarily be restricted to the Federal Government. As the atomic energy industry grows and the need for new sites is established, the Commission anticipates that State governments may wish to assume some responsibility in the establishment and control of sites for the benefit of their citizens. Publicly owned disposal installations would be operated by Federal or State government, or by their contractors or licensees under strict Government controls and would be available to all firms engaged in the disposal of radioactive waste materials. Currently quantities of non-Commission low-activity waste material is disposed of at sea by commercial firms operating under Commission license and control. Such activities would be affected by the Commission's land disposal policy only if convenience

and economic factors induce disposal firms to use land burial facilities in preference to sea disposal sites.

On the basis of past experience with land burial of low-level solid or packaged wastes at Oak Ridge, it is estimated that all such wastes generated between now and 1980 in the 16 northeastern States could be safely disposed of in a 200- or 300-acre site. It is expected that the first regional site will be needed in the northeastern part of the country where the sources of radioactive wastes are expected to be the most concentrated. At present there are more than 2,500 licensees in that area.

At the present time, the total quantities of solid or packaged waste materials requiring off-site disposal is estimated to be of the order of 150,000 cubic feet per year, on a nationwide basis. While this amount of radioactive waste can be handled safely at Oak Ridge and the National Reactor Testing Station at this time, it is anticipated that growth of the nuclear industry in the forseeable future will require between 5 and 10 regional burial sites.

III

RESEARCH ON WASTE DISPOSAL

The Commission conducts an extensive, coordinated research and development program in all phases of waste control operations. Individual projects are carried out at all the Commission's national laboratories and its major production sites; through contracts with a number of State and private universities; through working agreements and transfer of Commission funds to special Federal agencies; and by contract with private research organizations.

The general, but basic, objectives of the program can be listed as follows:

First, to develop practical systems for the final disposal, or long-term management, of highly radioactive wastes associated primarily with the chemical reprocessing of irradiated nuclear fuels.

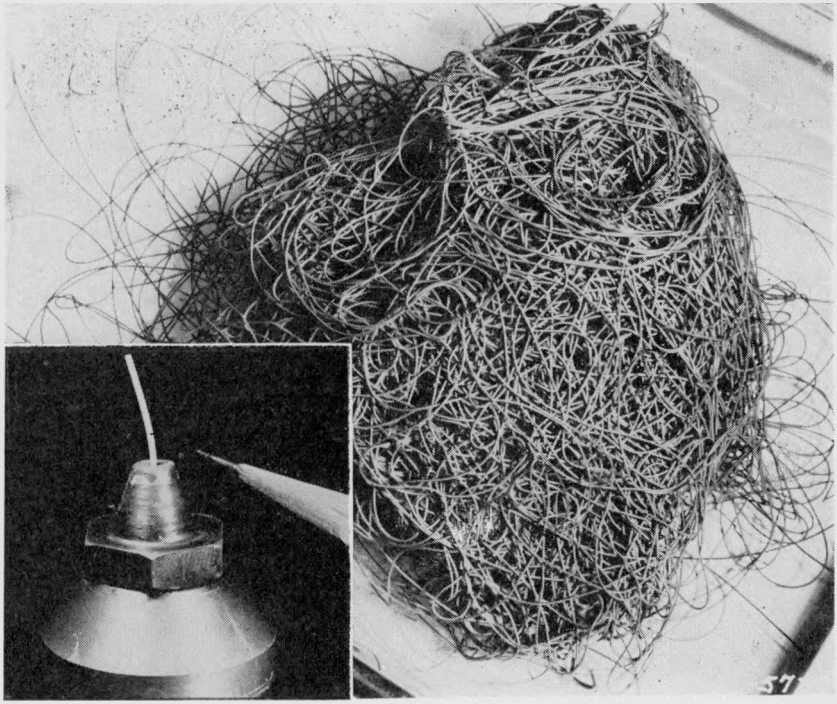
Second, to evaluate quantitatively the dilution or concentration factors in nature in order to determine the degree of treatment required prior to release of low-level wastes to the atmosphere, ground, or waterways.

Third, to obtain increased knowledge of the fundamental phenomena and processes involved in handling and disposal of radioactive wastes so that more efficient and economical systems may be devised.

In addition, the program helps to integrate the nationwide efforts of private and Federal, State and local agencies in dealing with waste disposal and environmental problems of industry with the newer and, in some cases, unique operations of the nuclear energy industry.

Research on High-Level Wastes

In the last few years, increased emphasis has been placed on development activities related to problems of high-level wastes. Systems for final disposal of high-level wastes must be such that they permit continuing control by man for hundreds of years, and also assure that the wastes will be contained essentially at the point of disposal so that man, his environment, and his resources are not adversely affected.



Clay for high-level waste fixation. Research on solidifying high-level liquid wastes has shown that montmorillinite clay may be used as a fixation medium. Photos show extruded clay at Brookhaven National Laboratory. In this thin, spaghetti-like form, it is packed into a column and will filter radioactive atoms from the liquid wastes passed through the column. The clay is then baked for permanent storage. Smaller photo shows clay coming from extruder, and its size in relation to pencil point.

Treatment and Processing

Little work has yet been done outside the laboratory on full-scale final disposal systems as differentiated from processing, treatment, or storage of these wastes. One method of treatment and processing being studied is fixing radioactive material in *chemically inert solid* nonleachable material that may be permanently stored or disposed into specific environments with negligible long-term hazard.

In one method under investigation at Brookhaven, the waste solution is passed through a column containing extruded natural clay and the radioactive ions are adsorbed on the clay minerals by an ion exchange process. In laboratory tests, decontamination factors for simulated waste solution using strontium 90 as a tracer were shown to be about 100 million. Fission products are fixed in the clay mineral by heating the clay to about 1,700° F. After this treatment, experi-



High-level waste facility. A major objective in handling high-level wastes is reducing them to small volume for storage. Photo shows the 60-gallon-an-hour pilot plant Waste Calcination Facility under construction at the National Reactor Testing Station. Liquid wastes, generated by reprocessing of spent fuel elements, will be reduced to solids one-seventh the volume of the original liquids. Filtered, discharge gases will be monitored by a telemetered network of air sampling stations.

ments have shown that sea water would leach very little of the activity from the clay.

Another method for converting liquid wastes to solids is fluid-bed calcination. This process consists of spraying a radioactive waste solution into the side of a heated fluidized bed of inert oxide. The calciner acts to drive off the water and to decompose the contained salts to their oxides. This process has been carried out on a pilot plant scale at Argonne National Laboratory, using radioactive solutions, and on a somewhat larger scale using nonradioactive solutions at the Idaho Chemical Processing Plant, National Reactor Testing

Station. The Commission is installing at the Idaho Station a $4 million 60-gallon-an-hour pilot plant to test this process on a large scale using Redox wastes. Discharge gases from the calciner must be filtered.

It has been found possible to retain essentially all the radioactivity in the calcined oxide with the possible exception of ruthenium. Decontamination factors of 100,000 for ruthenium and 10,000,000 for nonvolatile species have been demonstrated. The plant reduces the volume to one-seventh the original quantity of wastes.

Direct Disposal

While the cost of tank storage of high-level wastes from power reactor fuels probably could be borne by the industry, tank storage does not represent disposal in the ultimate sense. Experience with tank storage is limited to 15 years; containment will be required for hundreds of years. The program for developing other methods of ultimate disposal includes: (*a*) the conversion of liquid wastes to solids, as described in the preceding section, and the development of ultimate storage methods for the produced solids, (*b*) direct disposal of high-level liquid wastes into the earth at great depth, (*c*) removal of specific, especially toxic and long-lived isotopes to reduce the total waste problem.

Research is being conducted on deposited wastes converted to solids in some geological formation, probably salt. Research and development on direct disposal of wastes into deep wells is just getting under way. It is generally agreed that the removal of specific fission products from the wastes would not significantly change the waste disposal picture. Economic return from the waste streams is an important goal for private operators of reactors, but economic removal of key wastes—cesium 137 and strontium 90—would not be the same as the essentially complete removal that would be necessary for health and safety. Commercial chemical processes do not recover all of a given material, and the cost of the process used tends to exceed the benefits derived as the effort is made to push recovery above certain percentages which still would leave dangerous quantities of these radioisotopes in the fission products to be disposed of.

For high-level wastes, ocean disposal has been given some theoretical consideration, but sea burial or release of high-level fission product wastes from chemical reprocessing probably will not be feasible for many years to come, if ever. Specific knowledge of oceanic behavior is inadequate, and attendant engineering problems appear so

complex for high-level wastes, that alternate systems that are easier to control directly are the most likely solution.

In the first comprehensive discussion of underground waste disposal—a National Academy of Science conference on "The Disposal of Radioactive Wastes in Land," Princeton University, September 1955—two approaches to underground storage were discussed: storage in deep porous beds and sedimentary rocks by means of deep wells, and storage in underground openings, either natural or artificial, at comparatively shallow depths. Concerning the second method, storage in surface excavations such as quarries, underground caverns and shallow mines was considered unreliable because such openings are rarely watertight. The possibility of storage in deep mines below the shallow fresh water table then was studied, and openings in salt domes or salt beds, or space in abandoned salt mines, were the most promising.

Rock salt has considerable compressive strength. At normal temperatures its movement is controlled by plastic flow and deformation occurrs only slowly when salt is under pressure below the yield point. These unique characteristics give salt remarkable geological features. Excavations in salt are practically always dry. Because of its plasticity any fractures in salt close rapidly. Large spaces may be mined out; even at depths of 1,000 feet two-thirds of the salt area may be removed without perceptible deformation of the pillars left in the caverns as ceiling supports.

The location of salt deposits is widespread in the United States. Deposits of rock salt underlie 400,000 square miles of the United States and represent some of the few naturally occurring dry environments in the eastern part of the country. The volume of high activity wastes that will probably be produced in the year 2000 is computed to be less than 10 percent of the salt space now being mined out annually.

Extensive laboratory experiments on the behavior of salt in relation to nuclear wastes led to the initiation, in mid-1958, of a series of tests in portions of a Carey Salt Co. mine near Hutchinson, Kans. These preliminary tests, expected to take about 2 years, are being conducted with nonradioactive equivalents of fission product wastes which are heated to simulate the temperatures normally generated by radioactive decay. Primarily, the tests will concern: the structural integrity of the cavity; the migration of nuclides from the cavity; the migration of the cavity itself due to condensation of water on the surfaces which causes the salt to go into solution and flow back into the waste cavity; temperature gradients, both inside and outside the cavity; and production of gases.

One potential major advantage in the storage of solid wastes in salt is that they are not required to be nonleachable since no water will come into contact with them other than the vapor droplets possibly formed within the cavity itself by the waste's decay heat. Secondary advantages anticipated are that the solid-form wastes may be easier and cheaper to cool than liquid wastes, and this type of storage would make these waste materials available for the future if an economic use were ever found for them.

The petroleum industry has developed an extensive technology of injecting fluids into deep wells, and the American Petroleum Institute was requested to appoint a small committee to consider the feasibility of disposing of radioactive liquids in this way. The following major problems are associated with the development of a system for disposing of radioactive wastes in abandoned deep oil wells: a suitable disposal reservoir must be clearly defined and must be capable of confining radioactive wastes solutions for indefinite periods; the heat generated must be safely dissipated; the disposal reservoir must be protected against damage such as fracturing, premature plugging or other causes; the failure of equipment as a result of corrosion or other causes must be prevented; an economical disposal plant must be designed and safe operating procedures must be developed.

Research on Low-Level Wastes

The early phase of the research and development program on waste problems was concerned primarily with handling and disposal of large-volume, low-level liquid effluents, gaseous and particulate wastes, and assessment of the effect of relatively low levels of radioactive materials discharged to the environment through public sewage treatment and water supply facilities. Work also was done on waste processing and treatment systems for various types of wastes. This activity was carried out in a coordinated program at the national laboratories and by contract with various universities and industrial laboratories and by other Government agencies.

Examples of accomplishments in the program include:

a) Determination of limitations and feasibility of using biologic sewage treatment processes for low-level wastes.

b) Determination of the efficiency of standard water treatment methods in removing radioactivity.

c) Development and commercial production of high efficiency air filters and publication of a handbook on aerosols and a handbook on air cleaning.

d) Development of specific waste treatment systems including evaporators, precipitation plants and incinerators.

Extensive meteorologic, geologic and hydrologic programs were conducted with the U.S. Weather Bureau, Department of Commerce, the U.S. Public Health Service and the U.S. Geological Survey, Department of the Interior, to define and assess important environmental factors involved in the location, design, construction and operation of nuclear installations. Accomplishments of this work include:

a) Detailed meteorologic, geologic and hydrologic reports on a number of Commission operating areas.

b) A quantitative evaluation of dilution factors in the Mohawk River in New York which enabled the elimination of treatment of low-level wastes at Knolls Atomic Power Laboratory and their safe discharge directly to the river.

c) Publication of a compendium of important meteorologic information as a report entitled "Meteorology and Atomic Energy." [11] This document has been translated and published in several foreign languages. In addition, numerous detailed technical reports of work in this field were published.

Low-Level Wastes in Surface Streams

The behavior and fate of low-level wastes dispersed in streams and rivers are of specific interest. When liquid radioactive wastes are released in rivers and lakes various natural processes operate to disperse them and to remove them wholly, or in part, from the flowing water. Collectively these processes are called stream self-purification. In conjunction with the physical dispersion and dilution of the waste stream, important chemical and physical changes may be brought about by hosts of aquatic plants and animals, by other chemical compounds in the stream, by sunlight, and by the hydraulic agitation and mixing of the stream. (Chapter IV, Part Three, Environmental Research of this report describes research on the effects on the ecology of the environment—the vegetable and animal life of the region—of continuing releases of radioactive wastes.) The mechanisms that tend to purify the water include chemical precipitation, agglomeration of particles, deposition by gravity, adsorption on the streambed and biological uptake by aquatic organisms. In addition to these effects, the stream provides time for radioactive decay and ultimate transportation of remaining materials to the ocean.

[11] "Meteorology and Atomic Energy," AECU—3066, July 1955, U.S. Weather Bureau, Washington, D.C.

The research program in this area includes the close interrelationships between artificial and natural purification and reconciliation use of a stream for waste disposal with other important stream uses.

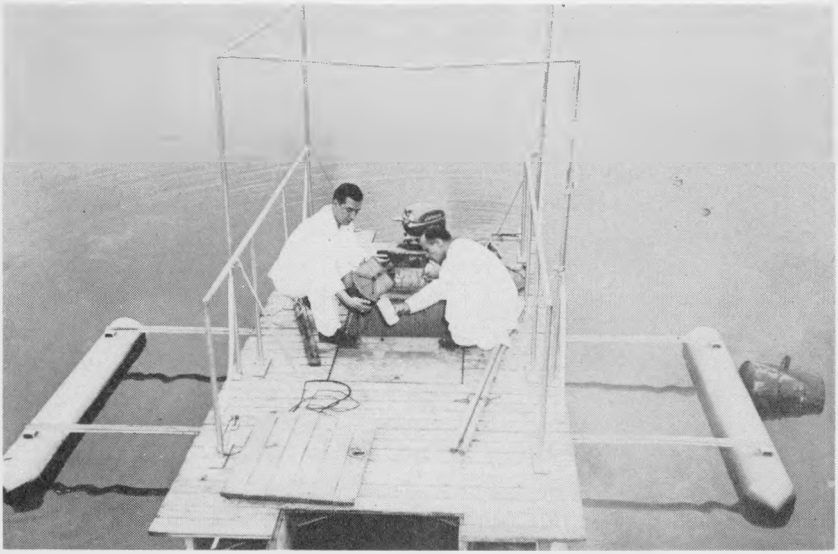
In a series of investigations carried on since 1951 at Harvard University under contract with the Commission, the feasibility of disposal of low-level liquid radioactive wastes in streams has been assessed. Most of the experiments have been on Cochichewick Brook, a small privately owned and controlled stream near Lawrence, Mass.; other streams and reservoirs have been used in special tests. This work has been done in cooperation with the Sanitary Engineering Division of the Massachusetts State Department of Public Health.

The standard test procedure has been to inject various radioisotopes into the stream at biweekly or monthly intervals, and to trace the progress of the pollutant 1.5 miles downstream past seven sampling stations to the junction of the Brook with the Merrimack River.

The results indicate a wide range in the degree of self-purification. In some runs (tests) with radiophosphorus, less than 5 percent of the initial amount was found to pass the terminal downstream station. However, with rubidium, often no reduction occurred. The efficacy of the stream for self-purification has been found to vary considerably with the volume of flow, temperature, season of the year, presence or absence of ice cover, density of algae in the stream, amount of carrier added with the dose, and wind direction and magnitude. Correlation coefficients between the degree of self-purification and such environmental factors have been calculated, but for some isotopes it is difficult to predict accurately the result of a given run. Collateral tests on artificial streams and basins in the laboratory show that with a small streamflow, because more time is required for transportation of the pollutant, biochemical and chemical activity may effectively reduce high concentrations. During high water, the relatively large dilution may be offset by the shorter flow-times available for self-purification and decay.

Hydraulic mixing and dispersion processes induced by currents, winds, and temperature gradients materially affect the capacity of streams for handling pollution. An understanding of the mechanism of lateral, longitudinal, and vertical mixing of wastes in waterways has been assisted by the Harvard studies and by similar Commission-sponsored investigations at Northwestern University, Johns Hopkins University, and other research centers.

A series of large-scale tracer tests in the Mohawk River below the sewer outfall of the Knolls Atomic Power Laboratory (KAPL), carried out as a joint project with the United States Geological Survey, the KAPL Health Physics Division, the New York State



River monitoring. Low-level wastes disposed of into streams and rivers are monitored continuously in the interests of public health and safety. In photo, samples of water, biota, fish, and bottom material of the Mohawk River are being obtained for analysis and to assure that there has been no adverse effect from the low-level liquid wastes discharged into the river by Knolls Atomic Power Laboratory.

Department of Public Health, and the Harvard group, assessed the health hazards associated with accidental spillage of radiocontaminants, and the amounts of certain low-level wastes that might be discharged safely to the river. An agreement based on these tests was reached between the laboratory and the New York State Health Department as to permissible levels of activity discharge and details of monitoring and streams surveys.

Considerable research and development has been done at Hanford, Oak Ridge, and Savannah River in connection with the discharge of low-level radioactive wastes to the Columbia, Clinch, and Savannah Rivers respectively. Typical results of this work, as they affect the environment, are reported in a later chapter.

Research and development work at Hanford has produced information on the expected time, place, and concentration of reactor effluent isotopes in Columbia River water and in plants and animals to provide assurance that effluent disposal practices there are well within safe limits.

The Hanford studies have shown that the limiting factor of the toxicity of wastes to the Columbia River fishlife is not so much radioactivity but dichromate, a common industrial chemical used to

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inhibit corrosion. The studies have shown that if the level of dichromate found in the river were doubled, it would have an effect upon the fish. However, in terms of radioactive phosphorus, for instance, the amount could be at least 10 times greater than the current level, and possibly 50 times greater, without damage to the fishlife. Thus, while atomic energy has brought about a new and unique kind of waste, its effect may be less hazardous in some cases than more conventional industrial wastes.

Several surveys have been made to map the distribution of Hanford reactor cooling water in the Columbia River, and to determine the travel time to points of water use under various hydrographical and operational conditions. The methods used to obtain the required information include sounding to determine bottom contours, temperature readings, and float studies to determine the speed of the current temperature readings. Visible dye application has been made at times for definition of the effluent plume, and counting of radioactivity to determine the distribution pattern.

The need to identify and measure individual isotopes has resulted in development of analytical methods capable of measuring extremely small quantities of the isotopes. Development work in instrumental analysis still is being carried forward. One objective is to perfect an automatic waste stream analyzing monitor which could detect, measure, and record the concentrations of individual isotopes of special interest. Such an instrument would provide continuous monitoring which could be interpreted readily in terms of permissible limits and could be used to correlate isotope formation with variations in plant operation.

Disposal in Soil

Low-level wastes may be discharged to the environment by percolating them into the earth at or near the surface. Such liquids then work their way slowly into ground water, leaving all or part of their radioactivity held either chemically or physically on the soil. Considerable use has been made of this method of disposal at Hanford and at Oak Ridge.

This method of disposal is very dependent upon the geology and hydrology of the particular site, and research and development work on soil disposal is ordinarily applicable only to the specific location for which it is conducted. The depth to the water table varies from 200 to 600 feet at Hanford and Idaho and to 20 feet at Oak Ridge and Savannah River. The overburden soil varies markedly in composition and in permeability. One of the most important characteristics of

soil is its capacity for ion exchange, which varies at the Commission sites from 5 to 300 grams of exchangeable sodium and calcium per cubic foot of soil. Even the smallest capacity, however, is immense compared with the quantity of radioactive ions likely to be discharged into the ground.

In support of ground disposal operations, extensive research and development efforts in geology, hydrology, minerology, soil chemistry and fluid dynamics have been undertaken by Oak Ridge National Laboratory and Hanford for the Commission, by the U.S. Geological Survey, and the University of North Carolina and Columbia. Although fundamental studies are required to develop general principles, the variability of the natural environment makes it essential to carry out field investigations at specific locations under consideration.

Sea Disposal

Research and development related to disposal of radioactive wastes in the oceans deals separately with tidal estuaries, coastal waters, and the open or deep sea. Since only solid, packaged low-level wastes are buried at sea, major research interest currently centers on estuarial and coastal regions of the sea, although close, in-shore disposal is not currently contemplated by the Commission. Such research is conducted as a preliminary to long-range planning in connection with nuclear-powered vessels.

The fate of radioactive materials deposited in sea waters depends upon five principal factors:

a) The physical and chemical form in which the material occurs at time of deposit, together with any relatively rapid changes in the physical and chemical character of the material which occur on contact with sea water. Subsequent dispersion by physical processes and re-concentration by aquatic life and bottom materials will be greatly affected by the physical and chemical form in which the wastes occur in sea water.

b) Initial mechanical dilution of the wastes by the water, which will depend upon the manner of deposit since a liquid waste will be diluted more rapidly if introduced into the water as a strong jet, than as a gently flowing stream on the surface. Rapid dilution is important in reducing the difference in density between the deposited liquids and the surrounding waters, and assists subsequent turbulent diffusion.

c) The movement of waste material away from the source region, and simultaneous turbulent diffusion, which lead to reduced concentrations of the radioactive components in the water.

d) Uptake of the activity by suspended silt and bottom sediments, which removes some radioactive materials from the water, and restricts further dispersion. In deep water removal of this kind would be favorable since the bottom sediments would be unlikely to return to man's environment. In shallow coastal areas which are the habitat of bottom-living shellfish and bottom-feeding commercial fish, concentration of radioactivity on the bottom may be unfavorable since both may concentrate the radioactivity.

e) Concentration of activity by various aquatic life, including shellfish and commercial fish important as source of food. Some important fission products and corrosion products are concentrated by marine organisms by factors of 100 to 10,000 over the concentrations of these isotopes in the water.

Commission-sponsored research now in progress is attacking projects related to these five key factors, as follows:

a) Basic studies of the mechanism of diffusion in restricted waterways and in coastal waters. The process of turbulent mixing is one of the less understood physical phenomena in the field of oceanography. In the present study, data obtained from introduction of tracer material into hydraulic models of estuaries, as well as directly into actual estuaries and coastal regions, are employed in formulation and in testing hypotheses and equations describing the mixing process.

b) Specific evaluation of New York Harbor in regard to the dispersion and movement of any radioactive materials which might be purposefully or accidentally introduced there. An intensive field program, jointly sponsored by the Commission and the Maritime Administration, is designed to obtain data on movements and distribution of physical and chemical properties of harbor waters. With these data, investigators will attempt to predict the distribution of waste radioactivity under various assumed conditions. The work is being performed by the U.S. Coast and Geodetic Survey, the Chesapeake Bay Institute of Johns Hopkins University, and the Commission's Computing and Applied Mathematics Center, New York University.

c) The classification of harbors and coastal waters according to major factors influencing the dispersion and movement of contaminants. This study is expected to provide a basis for extrapolating the results of detailed investigations, such as the one being conducted in New York Harbor, to harbors and coastal areas for which only limited data are available.

d) Geochemical studies involving the physical and chemical state in which the various components of the radioactive wastes would occur in sea water, and the processes of uptake of these components by suspended silt and by bottom sediment.

e) Concentration of certain components of the radioactive wastes by marine life. Present emphasis by the Chesapeake Bay Institute, conducting this work, is on the uptake by marine phytoplankton, the first stage of the food chain. Other laboratories, notably the Fish and Wildlife Service Laboratory at Beaufort, N.C., have been concerned with the uptake of radioactive isotopes by fish.

In addition, field investigations in cooperation with the U.S. Coast and Geodetic Survey, the U.S. Public Health Service, The Committee on Oceanography of the National Academy of Sciences—National Research Council and the University of Connecticut, are being carried out in Atlantic and Pacific Ocean areas as reported earlier.

Gaseous Wastes

In connection with dispersal of gaseous and particulate wastes to the atmosphere, the Commission carries out research and development programs in two areas—air cleaning and meteorology. Air and gas cleaning is primarily concerned with controlling the release of wastes; the meteorology work is concerned with the behavior and fate of the material in the atmosphere.

The *meteorological program* has been carried out by the U.S. Weather Bureau at several Commission sites, Argonne and Brookhaven National Laboratories, and Hanford. The capacity of the atmosphere to disperse radioactivity or any other pollutant varies widely. It is affected by lakes and mountains, daylight and darkness, winter and summer, and the flow of air and its diffusive capacity must be quantitatively measured and then interpreted in terms applicable to the operation of specific nuclear plants. Studies of atmospheric diffusion are built upon early investigations, particularly in England, on understanding the dispersion of chemical smokes and agents, and industrial air pollution.

Results of research and development to the present time have shown how to measure wind and temperature gradients in a manner suitable for diffusion studies, associated with atomic energy. Automatic weather networks have been developed to permit remote measurements at numerous locations; these are automatically transmitted to central collecting points and in many instances summarized and analyzed by high speed computers, necessary because of the volume of measurements and 85,000 observations collected.

From these wind and temperature gradient data the diffusion coefficients appropriate to the various locations can be determined and

an assessment made of variations with seasons, time of day and, to a degree, with large scale weather variations.

The object of the meteorological research and development program is to provide estimates of expected airborne concentrations, deposition, and translocation of industrial wastes—estimates sufficiently precise to govern design of plants and their control during operation. The primary purpose is to provide the knowledge necessary to assure safe operation of industrial facilities insofar as atmosphere disposal of wastes is concerned.

Air and gas cleaning for nuclear energy processes differs from general cleaning problems in two major respects: the contaminated gas is highly toxic, and the cleaning device becomes severely contaminated. Because of the high toxicity of radioactive gases and particulate matter (in solid or liquid forms), a higher degree of cleaning is necessary than for most nonradioactive materials.

The Commission's research and development in this area includes fundamental studies of the nature and behavior of aerosols (this work is being done primarily at the air cleaning laboratory of Harvard University and the University of Illinois), the development of new or improved air cleaning devices, evaluation of air cleaning systems and methods, development of test and evaluation procedures and methods, and consultation and training.

Current investigations center around several major studies: the first to develop an inexpensive method for the removal of radioiodine. An inexpensive low flow resistant silver-plated copper gauze has been developed. This gauze material with exposed copper surface is an excellent media for fixing iodine as silver iodide. It can be incorporated into existing systems without adding any appreciable loads to fans or other air movers.

Another current problem is the development of a small, inexpensive incineration device for solid combustible wastes at hospitals and laboratories. Development of a suitable gas cleaning system is a key problem. The wastes do not burn completely, and tar-like combustion products would plug the kinds of filters now in use. A filter made from inexpensive byproduct blast furnace slag, which will operate at filtration temperatures close to 1100°F, appears promising. This filter will collect the discharge from an incinerator with efficiency exceeding 99 percent.

New filtration devices, which will operate with lower resistance to air flow, and with high efficiency at lower capital costs also are under development. A simple electrostatic fluidized bed filter for cleaning supply air to laboratories has been designed at Harvard University. The filter produces an electrostatic charge by fluidization of poly-

styrene granules. While it appears useful for this purpose, radioactive effluents with high loadings could leak off the mechanically created charge. It does, however, provide an inexpensive way to reduce atmospheric dust loadings by as much as 99 percent. This has proved to be the major source of loading which causes shortened life of filters used in most Commission installations.

Economical methods for large-volume collection and containment of radioactive noble (chemically inert) gases such as krypton 85 and xenon 133 are necessary for economical and safe nuclear power operations. Present methods of removing gases are economical only if very small volumes or low flow rates are involved. In cleaning high temperature gases contaminated with fine particulates, it is necessary to provide filters which will function above 1,000° F. To date, such filters are only experimental and need further development and study.

IV

ENVIRONMENTAL RESEARCH

Complete evaluation of the hazards involved in handling, treatment, and disposal of radioactive wastes can be based only on detailed knowledge of environmental, biological, and operational variables affecting the handling of the wastes, and upon accurate isotopic analysis to assure that maximum permissible limits established by the Commission, are not exceeded.

Individual projects, integrated with the broad program, are carried out at the Commission's major laboratories and production sites, through contracts with State or private universities, and research organizations, and through agreements with other Government agencies.[12]

In addition to research and development directly related to handling radioactive wastes, the Commission carries out through its biological and medical programs many studies designed to increase understanding of the long-term effects of radiation on man and his biological environment.

"Safe limits" of exposure for a multitude of different radioactive products and compounds must be determined in order to cope successfully with the byproducts of advancing nuclear science and technology.

In this chapter, the Commission describes examples of the various methods used to assure continual monitoring of radioactivity released to the environment of research, to evaluate the efficacy of disposal methods, and typical ecological programs aimed at determination of the total impact of radioactivity on man's environment, and the evolution of living organisms in this environment.

Environmental Monitoring

Methods of monitoring are dependent upon the types and amounts of radioactive waste material released to the environment. Whenever solid, gaseous, or liquid wastes are placed in the environment, monitoring checks must be made to assure that the low-level of radioactivity

[12] See Appendix 12 for a complete list of research contracts.

remains well within the permissible limits so as not to endanger public health and safety.

Solid Wastes

For the most part solid wastes are buried under controlled conditions on land or disposed of in the sea. The United States Coast and Geodetic Survey, cooperating with the Commission, has periodically sampled the water and bottom mud of the ocean waste disposal locations. This monitoring has shown that no radioactive hazard has been created.

Burial grounds are fenced on land to limit access to the areas which are dedicated plots that may not be used for other purposes for very long periods of time.

Monitoring wells are maintained on the periphery of the area plots and periodic analyses are made of water and soil samples to determine the extent to which wastes may have moved away from the burial area.

Such studies are described in more detail in a later section on waste pit operations at Oak Ridge National Laboratory.

Gaseous and Other Airborne Wastes

Gaseous and other airborne wastes are monitored through use of high efficiency filters, and through continuing study of diffusion of gases from effluent stacks.

At many installations, continual measurements are made on the periphery of the operation. One such system of special interest is in operation at Idaho National Reactor Testing Station which utilizes a telemetry system for continuous monitoring of radiation levels over some 1,700 square miles of southeastern Idaho.

Operated by the Commission's Idaho Operations Office, this electronic data-gathering and recording network provides a round-the-clock environmental evaluation, and permits early warning of any unusual amounts of radiation in the area.

The telemetering system consists of 11 radiation monitoring stations, 24 radio-controlled air sampling stations, two weather data stations, and a control center. The control center receives automatic mechanical reports at predetermined intervals from the monitoring stations. The 24 sampling stations can be activated from the control center or other points by telephone when additional radiation monitoring is needed in any area.

Each radiation monitoring station constantly samples the atmosphere by a combination filter and carbon cartridge which indicates whether the radiation level is above or below a predetermined background level. The apparatus stores this information and when periodically interrogated by the control center—if necessary as often as every 15 minutes—the readings are telemetered in terms of "high" or "normal" to a teleprinter at the main station.

When radioactive releases are made, either planned or accidental, continual remote monitoring makes it possible to scan large areas within minutes. By combining weather information and the monitoring station data, it is possible to send monitoring teams promptly, calculate air concentrations and release trajectory, and evaluate exposure. Information collected also assists the ecology group in their biological uptake studies.

Liquid Low-Level Radioactive Wastes

Low-level liquid radioactive wastes can be disposed of directly after suitable treatment or with natural dilution in rivers, lakes and streams.

Rivers. Hanford makes continuous studies on the hydrology of the Columbia River with particular attention to flow velocity, temperature, and channeling effects.

Lakes and streams. At Oak Ridge and Brookhaven National Laboratory, disposal is made into lakes or streams. Such methods make it essential to have rapid, continuing analysis of the kinds of activity. Special instrumentation to detect the radioisotopes of concern (gamma ray spectrometry, beta ray proportional counters and scintillation counters) make maximum sensitivity and speed possible. Analyses such as these together with studies of the absorbing quality of the stream bottoms and diluting properties of the waterways assure that any releases are kept well within maximum permissible limits.

Current research programs conducted at major Commission installations on environmental contamination include the following:

Argonne National Laboratory conducts a variety of projects dealing with the long-range effects of internally deposited fission products such as strontium 90, radium 226, plutonium 239, polonium 210, carbon 14, etc. Particular emphasis is placed on carcinogenesis and life-shortening studies directed toward establishing radiation standards. Statistics obtained from human populations subjected to environmental radiation, either from natural, occupational, or medical sources, are being utilized to establish radiation standards. Meteor-

ological studies, including micrometeorological research with respect to diffusion of gases and particulates in the lower layers of the atmosphere, are also being conducted.

Brookhaven National Laboratory investigates the physical and theoretical aspects of atmospheric turbulence close to the ground with emphasis on the dispersion and deposition of particulates and gases.

University of California at Los Angeles studies the differential availability in biological cycling of mixed fission products of the several biologically significant nuclides.

Hanford studies accumulation and transfer of radioisotopes by ecological systems, and conducts health physics and earth sciences investigations designed to evaluate and control potential radiological hazards in the Hanford plant area.

Health and Safety Laboratory N.Y. carries out health and monitoring studies, including methods and procedures of implementing environmental health surveys and other research.

Knolls Atomic Power Laboratory does health physics developmental studies.

Oak Ridge National Laboratory conducts ecological research on the long-range effects of radioactive contamination of the environment with emphasis on radiation accumulation and effects in the White Oak Lake area.

University of Tennessee—Agricultural Research Laboratory performs studies in large animals of fission product metabolism and the toxicity of gamma rays and fission neutrons arising from test site operations, and in particular with the pathology and physiology of radiation damage. A portion of the program is devoted to soil-plant relationships as it is pertinent to the fate of fission products in the food chain.

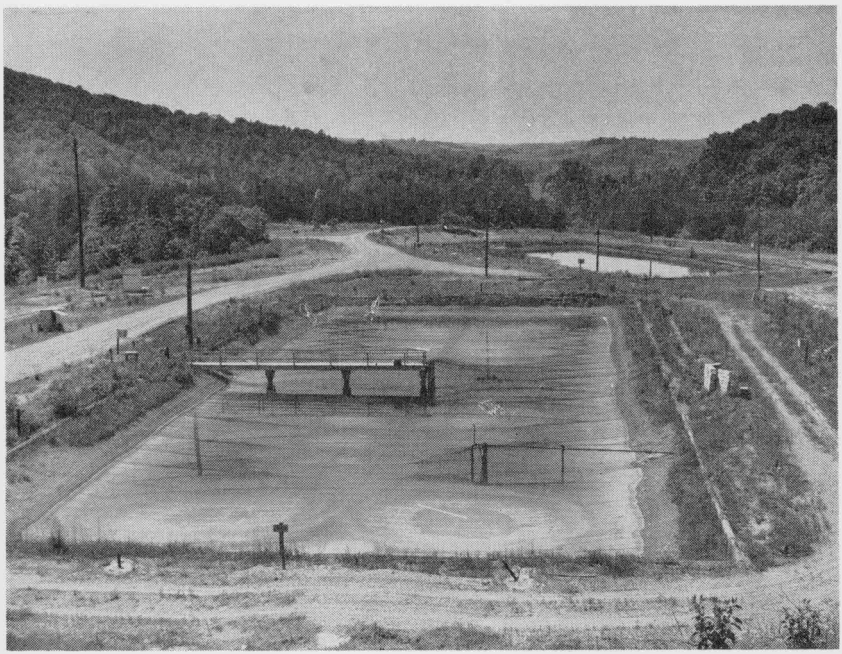
University of Washington did field studies of radiation biology at or near the Eniwetok Proving Ground in the Marshall Islands.

Eniwetok Marine Biological Laboratory conducted biological research associated with the testing program at Eniwetok and with fundamental investigations in nontesting periods.

The programs conducted at Oak Ridge National Laboratory and Hanford Atomic Products Operation, selected as examples, comprise monitoring, evaluation of waste disposal methods, and ecological research.

Oak Ridge National Laboratory

Evaluation of waste disposal. The Health Physics Division of the Oak Ridge National Laboratory is responsible for evaluating the



Intermediate-level waste ponds. As an experiment, intermediate-level liquid wastes are being placed in pits dug in a local shale formation at Oak Ridge. Photo shows two of the three pits in use. Each pit holds 1 million gallons and is covered by a mesh screen to keep wildlife from coming in contact with the liquid. Observation wells and waterway sampling stations are used to monitor for any underground movement of the radionuclides away from the pits.

potential hazards of present methods of disposal of low- and intermediate-level liquid radioactive wastes from the plants and laboratory area, and to establish criteria consistent with Commission standards for permissible dispersion of waste constituents from seepage pits. The project includes definitive studies of geologic and hydrologic factors in the waste pit area, a chemical and radiochemical budget obtained by composite sampling and analysis of the wastes, detailed study of the volume of waste input and of rainfall to the pits and of losses by evaporation and seepage, and estimates of the dispersion based on radiologging and sampling of test wells and analysis of surface drainage below the waste pit area. The results are examined in the light of Oak Ridge National Laboratory operations, gaging measurements and sampling data on White Oak Creek and Clinch River, and accepted values for the maximum permissible concentrations in the Clinch River.

Oak Ridge is concerned mainly with *soil disposal* of intermediate-level liquid and solid wastes and the discharge, after treatment, of

low-activity-waste water through White Oak Creek to the Clinch River. Most fission products exist as cations in aqueous wastes and soil materials are known to remove cations from solution in contact with them. Studies of soil disposal help in taking advantage of the sorptive capacity of soils in disposal practice, and also in evaluating the potential hazards of soil contamination.

The use of soil presents a variety of methods for waste disposal, extending from outright release to a geologic formation to the use of a membrane to contain prepared soil that will act as a filter-sorbent bed. The safety and operating limits of all soil disposal schemes must be determined.

The safety of soil-disposal practices at Oak Ridge is evaluated ultimately in terms of their effect on the uncontrolled environment, particularly the Clinch River. White Oak Creek is the drainage channel for any waste constituents released from soil-disposal facilities, as well as for low-level wastes discharged directly to the creek. The dilution capacity of the river is used to reduce to acceptable levels the concentration of radioactive materials in the effluent from White Oak Dam.

Current studies in the laboratory and in the field include:

a) The development of equipment and techniques for routine monitoring of waste disposal pits and solid waste burial grounds. This includes a compact well-logging unit capable of detecting and recording low concentrations of gamma-emitting radionuclides, and a portable well pump and sampling device for intermittent sampling of monitoring wells.

b) An investigation of the occurrence of air-borne contamination from operation of the waste pits and determination of the type, amount, and distribution of specific radionuclides involved.

c) Continuation of the liquid, chemical, and radiochemical inventory on the liquid-waste-pit system as an indication of the potential of this system for contamination of the environment.

d) Cooperative studies and special investigations to identify the several sources and assess their contributions of waste constituents to White Oak Creek, and to evaluate the discharges through White Oak Dam to the river in relation to flow and other conditions.

e) Formulation of procedures and criteria for monitoring the present Oak Ridge burial ground and the new burial sites when they are used, and assistance in the evaluation of waste movement in and from the solid waste burial facilities.

Monitoring activities include quantitative and qualitative assessment of radioactive materials released to waste disposal systems. Examples of activities and results obtained during the past year follow.

Liquid, chemical and radiochemical inventory of releases to the waste-pit system, and of routing of wastes through the system, were maintained. Collection and analysis of samples from observation wells in the waste-pit area were made periodically to define ground water conditions in soil disposal areas. To define the water table on a year-round basis, weekly determinations of ground-water elevations in wells in the new solid waste burial areas have been made and tabulated since the areas were laid out and the observation wells installed.

The volume of surface drainage, including surface seeps, from the waste-pit area to the White Oak Creek Drainage has been measured and recorded at two weir-gaging installations below the pit area. The discharges at these weirs have been sampled weekly and analyzed for chemical and radioactive contaminants. The results are interpreted in relation to the dilution available in the Clinch River; and, by comparison with data from other studies, in relation to the total releases through White Oak Dam to the river.

Ecological research. The ecology program at Oak Ridge National Laboratory provides the fundamental information on the natural environments necessary for realistic assessment of the long-term impact of radioactive contamination. It encompasses the two related objectives of determining the fates of radionuclides as well as effects as follows:

a) Quantitative information on the movement and rates of biological and chemical cycling of strontium 90 and cesium 137,[13] and other fission products in a variety of forest and fresh water habitats.
b) Sufficient characterization of the biological populations, their chemical and physical environment, as well as quantitative information on the processes operating therein so as to provide a valid basis for evaluating the effect of radioactivity as an environmental factor.

Training and experience in radiation ecology research is being given to college and university faculty members and graduate students.

The Oak Ridge reservation contains contrasting forest types, soils, and parent geological materials, and has a moderate continental climate. Portions of the area have been contaminated with mixed fission products. This combination of uncontaminated and contami-

[13] Strontium 90 and cesium 137 are not ordinarily released to the environment by the Commission as radioactive wastes, but are atmosphere contaminants as a result of world-wide atomic detonations. However, during the war-time and early post-war operations at Oak Ridge, some areas became contaminated with these two radionuclides. Because of their long half-lives they still are in existence, in low-level concentrations, in some portions of the Oak Ridge reservation.

nated habitats makes this area unusually suitable for a comprehensive program, and data obtained will have broad application to economic and safe nuclear activities. The program consists of four related projects.

White Oak Lake bed is a unique 35-acre site which is being utilized as a gigantic tracer experiment with strontium 90, cesium 137, and other fission products. Studies of movement, rates of transfer, and soil-plant-animal-soil cycling of strontium 90, cesium 137, and cobalt 60 are underway. Data are being obtained on the accumulation of these radioisotopes in native vegetation and agricultural plants in relation to soil conditions and local climate. Related laboratory studies include investigations on (*a*) the ability of different plant species to extract strontium 90 and cesium 137 from pure clay types of the kind found on the lake bed; (*b*) factors controlling uptake of strontium 90 and cesium 137 from contaminated soils; and (*c*) factors that determine concentration of radioisotopes in plant-feeding insects.

Field and laboratory studies have been conducted on the more abundant species of *insects* to investigate the extent to which radionuclides are accumulated. Strontium 90, cesium 137, ruthenium 106, and cobalt 60 have been detected in the insects with a greater uptake of strontium 90 and cesium 137 than of the other radionuclides (up to 2×10^{-4} microcurie per gram dry wt). In general, the concentrations of strontium 90 and cesium 137 in these insects are directly related to that in the plants on which they feed. Concentrations of cesium 137 in the insects are almost as high as in the plants; strontium 90 concentrations are nearly an order of magnitude lower. Laboratory studies on certain of the grasshopper species of White Oak Lake bed disclosed that these insects eliminate strontium much more than cesium, and seemingly absorb less strontium than cesium. For example, in the species *Melanoplus differentialis* biological half-lives were approximately 8 hours for strontium 90 and 2 days for cesium 137. As a result, strontium 90 and cesium 137 concentrations in insects are at similar levels, although the plants contain more strontium 90 than cesium 137.

There has been a significant loss of strontium 90 from the first 6 inches of surface *soil* of White Oak Lake bed (radioactive waste disposal area at the Oak Ridge National Laboratory) during the first 3 years after being drained. The data for 1956 to 1958 suggest two possibilities: (*a*) the loss of strontium 90 for the whole bed is exponential with a half-life of 1.25 years; (*b*) the two parts of the bed (upper and lower) are losing strontium 90 at different rates. In either case it is possible that the rate of loss may decrease later so that the strontium 90 could remain above fallout levels for many years.

The total strontium 90 burden in *vegetation* on the 40 acres, using the highest values for accumulation per unit area (about 1 percent), would be 150 millicuries. If it is assumed that equal quantities are contained in the accumulation of undecayed litter during two years (1956 and 1957) then a maximum of 500 millicuries are bound in these compartments of the biological system. As more strontium 90 (and calcium) is leached out of the surface soil, the possibility remains that the vegetation might translocate a relatively greater proportion of this fission product than it has during the past 3 years.

Other soil-plant studies show a major difference between corn grown on the lake bed and the native vegetation. Lake bed grown corn accumulated more cesium 137 than strontium 90 whereas the opposite was true for the native plants. Native plants accumulated more strontium 90 in all parts than did corn. Within the corn plant, the grain showed the greatest discrimination against strontium 90.

Small-*mammal* populations which are exposed to chronic low-level radiation during most of their life span in the lake bed are being studied. Ten acres of the White Oak Lake bed, where the average radiation dose rate is 0.4 r/day, and a 10-acre uncontaminated site are being compared with improved field techniques during the entire year. Related laboratory work will consist of body burden determinations, pathological examinations, and experiments to test for the development of radioresistant or radiosensitive strains in the exposed mammal populations.

Fundamental knowledge on the biological and chemical processes operating in *forest* systems is needed. Characterization of the species, chemical composition, and present contamination of the forest types and the animal populations are necessary to an understanding of these processes. Large-scale field experiments in which trees, in selected forests growing on contrasting soil types, will be tagged with radioisotopes (strontium, cesium, calcium, rubidium) are part of the study of forest. The subsequent movement of elements through the ecological cycle will be evaluated. Laboratory and field experiments include (*a*) studies of the role of mites and other arthropods in the turnover of nutrients and radioisotopes in the soil, (*b*) studies of the role of bacteria in the natural decay processes, and (*c*) long-term observation in areas that can be assured permanent protection, of seed, seedlings, and larger trees exposed to internal or external radiation at Oak Ridge National Laboratory or taken there from elsewhere.

The cycle of movement of radioisotopes and other elements in contaminated forests includes: uptake and translocation; dispersal by fallen litter or by animals; and incorporation into soils by litter decay.

Different isotopes injected into trees in mixtures do not move at

the same rates. Potassium 42 in solution moved to the top of a dogwood tree in a few hours. Strontium 85 and calcium 45 in the same solution moved more slowly, perhaps because of greater ion exchange with nonradioactive ions along their pathway.

Most leaves from a contaminated tree fall in the quadrants to the lee of the dominant SW winds and secondary NE winds; 75 percent fell within 10 meters of the tree; and only a small fraction of a percent blew farther than 30 meters from the source. Rates of decay of leaves placed in net bags on the forest floor vary considerably with climate (Oak Ridge Reservation and two altitudes in the Great Smoky Mountains), with the kind of forest (conifer and deciduous at each altitude), and with species of leaves. Tagged leaves from injected trees like those mentioned above also are being used to start tracer experiments for estimating rates of isotope movement into the soil and soil animals.

Clinch River studies include evaluation of the hazards and the long-term effects of stream contamination by fission products, not only because of a lack of fundamental knowledge of stream processes, but also because the Clinch River still receives low-level radioactive wastes. Fish contamination, food chain studies, and rates of mineral transfer in aquatic systems are major phases of this project.

Hanford Program

The program at Hanford comprises studies related to potential biological hazards attendant upon production of atomic energy, and those which are anticipated as a result of the expanding use of atomic energy, as a result of operation of reactors and chemical processing plants for used fuels.

In addition to the numerous measurements made on the radioactive wastes prior to, or at the time of, release to the environment, Hanford conducts an extensive and continual program of monitoring to evaluate the radiation exposure in the environs of the reservation and adjoining area. Table VI gives the breakdown of the average annual principal samples involved in this environmental and field survey program.

Monitoring methods. Studies are made to establish the relative radiological importance of individual isotopes or groups of isotopes appearing in low-level effluent streams from the Hanford plant. A companion objective is to evaluate existing monitoring equipment in use on waste streams for effectiveness in warning and measurement of significant quantities of the radioactive materials being measured. New design or improvement of existing equipment is undertaken.

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TABLE VII—ANNUAL ENVIRONS MEASUREMENTS

Total analyses made		75,000
Samples taken:		
Gaseous waste samples	10,000	
Liquid waste samples	17,000	
Vegetation and ground samples	11,000	
Biological monitoring samples:		
Birds	500	
Rabbits	700	
Aquatic organisms	1,200	
Total samples taken		40,400
Field measurements, vegetation and ground		17,000
Total test wells dug since 1943		600
		(120,000 ft.)

Data relating to fission product isotopes in reactor effluent and the Columbia River are analyzed to determine the significance of these isotopes as contributors to the fraction of maximum permissible concentrations at the point of use.

Other investigations involve chemical problems associated with disposal of wastes to the environment, and include determination of the chemical and radiochemical content, mode of formation, and distribution patterns of wastes. Recently, progress has been made on understanding the mechanism of formation of reactor effluent water radioisotopes. The parent materials for these radioisotopes are present in process water primarily from contaminants not removed in the water treatment process. By means of isotope ratio measurements it has been shown that a small fraction of the parent material resides in the reactor film from 10 hours to 20 days. Studies also were completed of the effectiveness of removal of these materials by purging operations.

A promising technique for removing a large fraction of the reactor effluent water radioisotopes on a bed of aluminum turnings also was developed.

Investigations of food contamination by radioisotopes from Columbia River water also are conducted.

Waste disposal evaluation. The bulk of the Hanford research on waste disposal is directly related to current problems, but many of the results, techniques, and concepts are applicable in programs elsewhere.

Specific studies at Hanford are aimed at improving knowledge of hazards, and the techniques that need to be applied for adequate control. Earth sciences studies of soil physics and soil chemistry and the hydrologic features of the Hanford area are necessary to de-

termine protective measures needed in the disposal of liquid plant wastes. Studies of analytical techniques permit increased efficiency in measuring the radioactive materials in their various physical forms and to applying this knowledge to protection practices. An important aspect of this problem is development of techniques that allow operation at lower costs while improving the collection of information.

Techniques and data developed in this program find application in plant operations in waste disposal, and radiation protection.

Work on analytical bioassay, and counting methods provides low level chemical and radiochemical methods for the determination of radioisotopes in waste streams, materials of the environs, and biological fluids. These methods are used in special studies and by analytical laboratories to obtain information relative to the contamination of life forms and the environs. The data provide the bases for radiological protection and the scope includes all chemicals and radioisotopes produced by the Hanford plant.

Guides must be established for the practice of disposal of radioactive liquids to the *soil.* Laboratory and field studies are conducted on the effects of Hanford's routine disposal operations. Specific wastes were studied by passing them through soil columns and measuring breakthrough curves. Factors affecting breakthrough include temperature, flow rate, soil column geometry, soil packing density, and the nature of the accompanying ion. Special problems associated with the ground disposal of wastes from new processes such as those for chemical reprocessing of power fuels also are under study.

Basic studies of the *geology and hydrology* of the Hanford area are needed for determination of their influence on disposal activities. Complete, detailed knowledge of the regional geology is fundamental for predicting the capabilities of the area for waste disposal, for predicting waste behavior and the movement of the ground waters, and for guiding exploratory and monitoring activities. The composition and structure of the formations beneath disposal sites profoundly influence the downward vs. lateral movement of the wastes and define the path the wastes and ground waters will travel. This defines the sediments that will be contacted, the effectiveness of removal of radioisotopes of concern, and the permanency of fixation. Such investigations are performed by standard and special geologic techniques including field mapping.

Clarification of the regional geologic and hydrologic situations disclosed that ground water mounds were so located as to provide maximum travel time, distances, and suitable materials in the path of movement of contaminants to the Columbia River.

Significant advances have been made in *soil chemistry studies* to define specific minerals which remove radioisotopes from solution. The principal chemical process involved in reactions of specific waste constituents with soil minerals is that of ion exchange on the clay minerals of the soil; another significant reaction is that of mineral replacement. Results of these studies are of importance in the solution of local waste disposal problems in specifying the optimum chemical composition of wastes disposed to the ground. Radiostrontium and other isotopes have been removed from solution by the calcite-phosphate reaction. Natural zeolites, such as clinoptilolite, are being studied for their ability to remove radiocesium from solutions. Studies also are under way on the behavior of cerium, zirconium, and niobium in the soil.

Soil physics studies are concerned with the hydraulics of water movement at the surface and beneath the surface of the ground. Included in such studies are fundamental determinations of the mathematical models describing saturated and unsaturated flow and the influence of system variables on these models. The hydraulic characteristics of the Columbia River are of concern in evaluating the influence of reactor effluent on aquatic life in the river and on downstream installations. The rate and direction of ground water movement beneath disposal sites influence the disposal policy since this information establishes the rate of appearance of contaminants at points of public availability. The research includes the development and testing of special techniques, equipment, and instrumentation for ground water experimentation.

Laboratory research is conducted in various sized models and columns of porous sand and soil to obtain basic data concerning the hydraulics of water movement. Field data are obtained to permit the evaluation of specific aquifer characteristics in critical areas in the vicinity of actual disposal sites.

Micromeritics and related studies are for the purpose of developing techiques and instrumentation to delineate the characteristics and behavior of radioactive particles generated in reactor operations and plutonium separation facilities. It also embraces the application of these data to development of optimum particle samplers and automatic radioactivity and particle size analyzers.

This research is required to permit a realistic assessment of the radiological consequences of particles in the environment, and to provide data for the development of monitoring methods. Since the radiation significance of particulates is a function of particle numbers, size, chemical nature, and content of radioactive material, valid measurements of these quantities must be made. Factors affecting

the movement of particulates through porous media such as soils are of great interest in waste disposal of liquids containing suspended material. The scope of the work embraces all these areas with particular emphasis on particle sampling methods and automatic analysis and recording of particles carried in gaseous effluents.

Ecological research. The environmental sciences research program at Hanford provides information on the effect of radioisotope contamination upon the natural populations of organisms living on the Hanford reservation. Fields of study include (*a*) atmospheric transport, diffusion, deposition, and erosion, (*b*) accumulation and transfer of radioisotopes by ecology systems, and (*c*) effects of radioactive material upon ecological systems.

The atmospheric transport, diffusion, deposition, and erosion studies provide the needed link in information covering movement between the emission of radioactive materials and deposition at some site. These studies provide models of transport mechanisms which assist in assessing the problems with new plants or in evaluating the hazards of disposal from existing plants. In addition, these results help direct monitoring following off-standard emissions, and preplanning for emergencies, and also assist in evaluating the potential consequences of hypothetical reactor accidents.

The studies are designed to provide information on the ultimate fate of released radioactive materials and the levels which could seriously damage the biological chains upon which man is dependent. They provide realistic estimates of maximum permissible concentrations in streams, lakes, and the atmosphere. These values in turn will permit better assessment of the dose to man and the actual limitations required upon disposal of wastes to the environment.

The studies consist of determination of: (*a*) routes, rates, and quantities of special radioisotopes transferred through different aquatic and terrestrial ecosystems, (*b*) influence of biological, physical, and chemical environmental factors upon the accumulation and transfer of radioelements, in ecological systems, (*c*) biological half-life of specific isotopes in biological communities under different environmental conditions, (*d*) potentialities of retarding or accelerating movement of radioactive contaminants by manipulation of ecological factors.

Population dynamics of wildlife exposed to radioactive waste at Hanford are being studied. The flora of the Hanford reservation also are being studied for better definition and to establish long-term study plots of natural plant communities.

Accumulation of cesium 137 was compared for plants growing under aquatic, semi-aquatic, and terrestrial conditions and experiments attempted to define better the effects of environmental factors upon the accumulation of cesium 137 by organisms in an aquatic system. Zinc 65 was introduced into aquatic communities to study its accumulation and transfer within the ecology. There was a rapid accumulation of the isotope by plants and animals during the first day followed by a gradual uptake that continued beyond 3 weeks.

Effluent from Hanford reactors may affect aquatic life through high temperature, chemical toxicity or radioactive materials. Studies with fish have been continued to define more closely the significance of each of these features.

Increased temperatures in the Columbia River could affect the survival of eggs of salmon by upsetting the normal rate of development during early embryological stages. Temperature is also important indirectly as it may contribute to the incidence of disease among Columbia River fish and influence the uptake and deposition of radioactive materials.

Radioactivity levels in plants depend primarily upon concentrations of isotopes in water with the highest values occurring during the fall and winter- low-flow periods. Most of the aquatic plants and animals which inhabit the Columbia River downstream from the Hanford reactors contain minor amounts of radioactive isotopes. One-half mile below the downstream reactor as many as 20 different radioisotopes have been observed in plankton and attached algae, whereas certain species of fish may contain only 5. Such differences in radioisotopic composition are attributed to ecological and physiological factors.

Phosphorus 32 and zinc 65 are the most highly concentrated isotopes in common organisms. The patterns of geological distributions of radioactive contaminants in aquatic organisms also varied among species of organisms. This is a result of ecological factors and biological habits. Trace amounts of phosphorus 32, zinc 65 and chromium 51 are common in organisms collected at the mouth of the river.

Since phosphorus 32 is the dominant isotope present in Columbia River fish, it was the first isotope selected for toxicity studies in trout. Fish were fed 0.6μc per gram of body weight per day survived for nearly three months in the laboratory. Radiation damage which resulted involved the gastrointestinal tract, kidney, spleen and liver and caused a reduction in both erythrocytes and leukocytes. In fish which received 0.06μc phosphorus 32 per gram each day, no definite pathological alterations were observed. However, growth was suppressed beginning at about 17 weeks when the cumulative dose to the bone was

on the order of 6,000 rads. The concentration of phosphorus 32 in these fish was about 100 times that reached in Columbia River fish of similar size.

Information is needed on the principal *metabolic routes* of uptake, the site of deposition, the turnover rates, and the mechanisms of elimination of radioisotopes in fresh water and other aquatic organisms.

Several patterns of basic metabolism already have been determined for phosphorus 32 and work now is under way on strontium 90 in trout. Work with cesium 137 and zinc 65 is planned.

Studies on the *toxicity of radioelements to aquatic organisms* are conducted to determine concentrations of deposited radioisotopes which are the threshold for radiation damage in fish and possibly other aquatic animals, and to determine the primary sites and mechanisms of damage.

Knowledge of the maximum permissible concentrations of radioisotopes in fish and other important aquatic forms provides one basis for the establishment of reasonable limits on the disposal of radioactive liquid wastes. The limiting factor on the quantity of particular isotopes released to streams may in some cases be the permissible concentration allowable in drinking water, in other cases the concentration of the isotope collected in edible parts of fish, and in still other cases, the body burden which can be tolerated by the fish or other aquatic organisms. Very little information now is available on this last area.

At Hanford, past emphasis has been on the effects of phosphorus 32. Work now has shifted to strontium 90 and cesium 137 to establish a comparison between isotopes which are deposited in bone and soft tissues. It also is hoped to establish the relationship between somatic damage and effect on offspring. Ultimately, permissible body burdens should be established for other radioelements which concentrate heavily in fish, such as zinc, cobalt, and iron.

Efforts are being made to determine the biological parameters required for evaluation of the potential hazards from absorption and metabolism of radioisotopes produced by neutron activation discharged to the Columbia River in reactor cooling water.

A direct measure of the relative hazard of shorter lived radioisotopes in the reactor effluent was obtained by feeding concentrated reactor effluent to rats, followed by measurement of the amounts of the various radioisotopes deposited in organs and tissues. The distribution of phosphorus 32 in the rat was studied by using autoradiography with results indicating that radiation delivered to the ovary may be of critical consideration in the establishment of permissible

concentrations. Other studies will include reevaluation of the hazard from internally deposited radioisotopes of iron, and other activation product radioisotopes.

Biological effects of iodine 131 are studied since radioiodine is one of the principal constituents of concern in gaseous effluent from chemical separations plants. It may contaminate vegetation which may be eaten by grazing animals or man, or may be transferred in the milk of cattle grazing on contaminated forage.

A study at Hanford is designed to establish a realistic basis for chronic exposure limits of iodine 131 in sheep and swine for purposes of applying the findings in sheep to other animals.

Shippingport Atomic Power Station

The Shippingport Atomic Power Station of the Commission, operated by the Duquesne Light Co. and sited on the Ohio River some 40 miles below Pittsburgh, affords a unique opportunity for radioecological research. Its design, construction and operation were extremely conservative in all aspects related to radiation safety with a view toward possible relaxation of the stringent safety standards, if warranted by operational experience.

The Sanitary Water Board of Pennsylvania granted an industrial waste permit to the Duquesne Light Co. for the discharge of its liquid wastes to the Ohio River provided: (*a*) the effluent of the plant is not more than 10 percent of the maximum permissible concentration of fission products of unknown constitution; (*b*) except for tritium, the average daily discharge for 1 year does not exceed 1,590 microcuries; and (*c*) tritium average over 1 year does not exceed 10 curies per day.

These requirements are well within Commission values for maximum permissible concentrations. However, information still is needed on what the long-range effects of these discharges will have on the Ohio River, the biota in the Ohio River, and on man in relation to his utilization of the Ohio River as a source of drinking water, fish, industrial water, and recreation. To get answers to these questions, a research program to carry forward studies begun in 1958 [14] now is being conducted as a cooperative undertaking between the Graduate School of Public Health, Sanitary Engineering Section, University of Pittsburgh, and the Department of Biological Sciences, Division of Natural Sciences, University of Pittsburgh.

The ecological group will investigate the complex ecosystems of the

[14] A preoperational site monitoring program begun in 1956 was discontinued September 1957.

upper Ohio River from the standpoint of detailed census and composition of the community; primary productivity (photosynthetic ability); and the changes occurring in both of these over a period of several years. From this, there should emerge an ecological base line for drainage systems of the region, and the biological samples necessary for investigation of levels of radioactive materials. A preliminary ecological survey of the 400-acre reactor site at Shippingport also will be conducted and later developed into a study similar to the one under way on the ecosystem of the Ohio River.

Ohio River studies. Exploration of an ecosystem as complex as the Ohio River calls for considerable effort. During the first year of the study project, stations were established at suitable intervals on the Ohio River from the jointure of the Monongahela and the Allegheny to the Ohio State line, a distance of approximately 40 miles. The entire distance consists of a series of impoundments formed by navigation dams and locks. The dams will serve as natural check points for investigation of the primary productivity of the river system. These investigations will require detailed chemical, physical, biological, and radiological examination of the water entering and leaving a particular portion of the stream. In addition, a number of stations will be established within the impoundments. Finally, sampling also will be accomplished by traveling the river by boat for the entire 40 miles. These samples will permit assessment of variations in biological, chemical, or physical characteristics that may occur from time to time.

Results of investigations conducted to date indicate that there has been no constant elevation in radioactivity concentrations in the Ohio River. This was during the initial period of operation of the plant and when it was operating at reduced power or shut down completely, and when during the summer and winter of 1958 and the spring of 1959, the river had high water flows, however.

Plant site studies. The Shippingport site also is being subjected to intensive study. Permanent stations are being established according to terrain and vegetative cover. At these stations, the environment and dynamics of biological components are being determined quantitatively to provide an ecological base line for the area. Base line data are of major importance biologically and ecologically, and of prime necessity in determining what effect, if any, atomic wastes, liquid, solid, and gaseous, have on these systems from the standpoint of acute and chronic effects.

Waste characteristics are being studied from the standpoint of radioactivity, radiochemistry, volume of discharge, frequency of discharge, and fate of gases and liquids discharged to the environment.

V

LICENSING, REGULATION, AND INSPECTION

Title 10 CFR, Part 20, "Standards for Protection Against Radiation," is the basic Commission regulation dealing with radiation protection and applies to all Commission licensees. Among other stipulations for health and safety, it prescribes standards specifying the maximum radiation doses which individuals may be allowed to receive, maximum permissible radiation levels in public or unrestricted areas, maximum concentration values for discharge of radioactivity into air and water, and methods for disposal of insignificant quantities of low-level radioactive wastes. The standards are based on the recommendations of recognized technical authorities, such as the National Committee on Radiation Protection and Measurement, and the Commission's experience in its own operations.

Waste Disposal Regulation

Because of varied and complex technical problems which arise in disposal of radioactive wastes, the Commission's regulations do not attempt to give detailed standards for this type of operation. Instead, they establish permissible concentrations of radioactivity in effluents to public or unrestricted areas, and permit the disposal on a routine basis of only extremely low quantities of radioactive waste by release into sanitary sewer systems or by burial at sea or in soil. The concentrations permissible in effluents to unrestricted areas under Commission regulations are extremely low. Persons in those areas could continually breathe the air and drink the water containing the prescribed concentrations of radioactive materials without exceeding the permissible radiation dose during a lifetime. The limit on concentrations is placed on the effluent as it leaves the licensee's control and enters an unrestricted area in view of the fact that the licensee has no control over the ultimate fate of the radioactivity after it leaves his premises.

Except in cases where prior authorization of the Commission is granted the licensee is not allowed to take advantage of the additional dilution of the effluent available in streams and in air in an unre-

stricted area in determining the permissible concentration. The regulation provides that the Commission will consider proposals for other methods of disposal of higher levels of wastes on an individual case basis. This would permit taking advantage of such dilution factors on the basis of prior evaluation of the safety of such a method and specific approval from the Commission. These provisions of the regulation for nonroutine cases are intended to provide for safe releases of various low-level wastes that cannot be economically processed or treated, and under conditions where environmental dilution is safely available. They do not provide a means for disposing of significant quantities of waste that can be economically processed or treated prior to disposal.

In applying to the Commission for approval of procedures other than those generally authorized in the regulations, the applicant must describe the quantities and kinds of radioactive material involved, and the proposed manner and conditions of disposal. He must further provide a detailed analysis and evaluation of the nature of the pertinent environment, including topographical, geological, meteorological, and hydrological characteristics; usages of ground and surface waters in the general area; the nature and location of other potentially affected facilities; and procedures to be observed to minimize the risk of unexpected or hazardous exposures. The Commission may approve a proposed procedure where the particular circumstances provide adequate safeguards to public health and safety.

The Commission's regulatory program not only establishes health and safety standards but also is designed to provide assurance that the standards will be complied with. This is accomplished through licensing procedures to determine the adequacy of proposed health and safety measures prior to any operations and through inspections to determine compliance with regulations and licensing conditions.

Licensing Procedures

Each applicant for a licensed operation involving radioactivity must provide information as to his equipment and facilities available, training and experience of personnel, safety procedures and a detailed hazard analysis of the proposed operation including waste disposal. The analysis must demonstrate that the proposed activity will not present undue risk to public health and safety, either from accidental release of radioactive materials or release from routine operations or from disposal of radioactive waste.

The information and technical data submitted by the applicant is reviewed by the Commission and, if a power or testing reactor is in-

volved, also by the Commission's Advisory Committee on Reactor Safeguards. Conferences may be held with the applicant to resolve difficult questions. Particular attention is given to the question of radioactive effluents which will be discharged to unrestricted areas.

Incineration

Waste treatment by incineration under controlled conditions requires specific Commission approval and is limited to combustible solids such as paper, linens, and small animal carcasses contaminated with small amounts of radioactive materials. This treatment, used primarily by research laboratories and hospitals, reduces the bulk of the waste which must be collected and disposed of in an authorized manner.

Land Burial

The Commission has issued no licenses for commercial disposal of radioactive waste by land burial. Since no private firm has demonstrated that it can guarantee long-term maintenance and control of a burial site, which may be necessary for hundreds of years to protect the health and safety of the public. All land burial is currently done on Commission-owned sites and in some instances industrial, medical, or educational users of radioactive materials may use these facilities for disposal purposes. As mentioned in the preceding chapter, the Commission has now adopted a policy that regional land-burial sites will be located on land owned either by the Federal Government or a State government and will be maintained under close Commission supervision.

Sea Burial

An applicant for a license to dispose of radioactive waste in the ocean must submit a detailed description of the quantities and kinds of radioactive material and the proposed manner and condition of disposal. The applicant also must include detailed information on container and packaging specifications, processing facilities, transportation facilities, instrumentation for measurement of radiation levels and contamination, radiation safety procedures to be followed in collecting, storing, packaging, and transporting the material; emergency procedures; site location of disposal, including depth of water at proposed location and records of disposal which are to be maintained.

A prelicensing visit is made to an applicant for a sea disposal license by technical representatives of the Commission to review all aspects of the proposed program, and to assure that it can be conducted in accordance with Federal regulations and licensing conditions. A firsthand evaluation is made of the site for packaging and storage of radioactive waste—the size of the site, nature of surrounding area, possible effects of fire or flood. In addition, the applicant's radiation protection procedures, proposed equipment and facilities, method of packaging, container specifications, radiation instrumentation, method and place of final disposal, transportation, and storage are reviewed. Any deficiencies are pointed out to the applicant.

The Commission's criteria for licensing sea disposal of low-level radioactive waste is based upon the best technical and scientific data available. The basic guide is the recommendations of the National Committee on Radiation Protection and Measurement as published in National Bureau of Standards Handbook 58, "Disposal of Radioactive Wastes in the Ocean." These criteria are designed to assure packaging adequate for safe handling and to assure sinking of the packages in the ocean. The packages must be able to withstand handling operations during loading and unloading operations and have a minimum of 10 pounds per gallon displacement volume to assure sinking—the same applied in Commission-supervised sea disposal. Packages must be properly labeled. If materials are shipped by common carrier, conformance with Interstate Commerce Commission and Coast Guard regulations is required.[15] It is not required that packages for sea disposal be constructed so as to maintain their complete structural integrity at a depth of 1,000 fathoms of water, although the package must be so prepared as to prevent material from floating to the surface.

Because of the widespread interest in ocean disposal of radioactive materials and to keep interested persons fully informed, the Commission publishes in the *Federal Register* notices of receipt of applications for, proposed issuances and issuances of, licenses authorizing radioactive waste disposal services resulting in sea disposal. When a license application is received a notice of receipt of application is published in the *Federal Register.*

At the time the Commission completes its evaluation of the application and determines that the proposed activities meet the requirements for a license, a notice of proposed issuance of the license, the proposed

[15] Coast Guard and ICC regulations limit the amount of radioactive material in a container and the radiation level from a container; require both an inside and outside container, require durable leak-type inside container, prescribe the specific types of outside containers that may be used (i.e., steel drum, wooden box), require specific types of labels for such containers, and prescribe limits for radioactive contamination on containers. Intrastate transportation by the licensee is governed by a condition of the license which establishes requirements similar to those of the Interstate Commerce Commission.

license, and a statement of safety considerations are published in the *Federal Register*. A public announcement is also issued by the Commission and is distributed to news media and an extensive list of organizations and individuals. Fifteen days are allowed for persons having an interest in the matter to intervene and request a hearing. If there are no interventions, the license is issued as proposed. If an interested party intervenes, as provided in the Commission's "Rules of Practice," or the applicant requests, or if there is sufficient public interest demonstrated, the matter is set down for a public hearing. The Commission's hearing examiner presides at such hearings and determines from the evidence adduced whether or not, and under what conditions, the proposed license should be issued. The hearing examiner's decision is subject to review by the Commissioners either on their own motion, or if exceptions to his decision are filed by any party to the hearing.

In addition, copies of license applications, *Federal Register* notices and licenses involving sea disposal are placed on file in the Commission's Public Document Room, 1717 H Street NW., Washington, D.C. Copies of the notices and licenses are sent to the Governor and other interested authorities in each State where the applicant will operate.

Special conditions are placed on all sea disposal licenses. These include specification of a sea disposal location, notification to the Commission before each sea disposal is made, and a time limit for storing radioactive waste. Based on the training and experience of the individuals handling the wastes and the equipment and facilities available, certain licensees are not permitted to open containers of waste received from customers but may only package these containers for sea disposal by encasing them in sufficient concrete to obtain the proper weight for sinking.

Methods of Disposal

At the present time, the primary source of radioactive waste from licensee operations is from radioisotope materials being used in medicine, research, and industry. This waste has a low level of radioactivity, is bulky and quite heterogeneous in nature. It consists chiefly of solid trash contaminated with radioisotopes, such as blotting paper, rags used for cleaning, broken beakers, test tubes, bottles and other glassware used to contain radioactive material, animal carcasses used for biological experiments, and other types of contaminated laboratory equipment. The levels of radioactivity in each container of waste are usually in the microcurie to millicurie range. For the foreseeable future, all high-level waste resulting from processing of used fuel

elements from licensed reactors will be returned to the Commission for processing and handling.

In practice, the most common methods and procedures used by licensees, other than disposal by sewer and burial in soil as provided for in the regulations, are return of radioactive waste to Commission installations, and disposal at sea.

Return of waste to Commission installations. Since the beginning of the Commission's isotope distribution program in 1946, the Oak Ridge National Laboratory has provided a waste disposal service for radioisotope licensees. The waste must be packaged in accordance with ICC regulations and requirements of the Oak Ridge National Laboratory. The packaged waste is shipped by rail or truck to the Oak Ridge National Laboratory for ground burial.

This provides a means of disposing of solid waste materials for licensees who are within economical shipping distance. One license has been granted to a private concern to collect waste from other Commission licensees and ship it to Oak Ridge National Laboratory for final disposal.

Disposal at sea. Eight organizations are licensed by the Commission to dispose at sea the waste generated in their own laboratories (see Appendix A). Six of these organizations have disposed in the Atlantic Ocean a total quantity of approximately 31 curies of activity.[16] Two licensees in this category have disposed of approximately 101 curies of activity in the Pacific Ocean.

In addition, a few licensed users of byproduct materials disposed of waste at sea prior to 1958 but have discontinued the practice. In this group, six organizations disposed of a total of approximately 4 curies into the Atlantic, two organizations a total of less than 1 curie into the Pacific and two organizations a total of approximately 10 curies into the Gulf of Mexico.

At present nine commercial firms have been licensed by the Commission to collect, package, store, and dispose at sea, in at least 1,000 fathoms, solid or packaged low-level radioactive waste generated by Commission licensees and contractors using radioisotopes in medicine, industry, agriculture, research, and training. (See Appendix B.) Five firms are licensed to dispose of waste in the Pacific Ocean, three to dispose of waste in the Atlantic, and one firm to dispose in

[16] Figures shown in this section show amount disposed of by Commission-licensed commercial disposal firms and other licensees. They do not show the amounts disposed of by the Commission or its contractors as a result of Commission operations; such figures (8,000 curies in Atlantic Ocean, 14,000 in Pacific Ocean) are shown in chapter II. page 327, of this report.

both the Atlantic and Pacific Oceans. To date these licensees have disposed of about one-half curie in the Pacific and 2,500 curies in the Atlantic. In total, Commission licensees have disposed of approximately 2,535 curies of radioactive material in the Atlantic Ocean, 102 curies in the Pacific Ocean, and 10 curies in the Gulf of Mexico.

How Precautions Work

In all licensed waste disposal operations the written operating and emergency procedures are the key to a safe operation. They clearly spell out the actions that must be taken to satisfy the requirements of the Commission's regulations and license conditions.

In complying with the regulations, waste disposal licensees must limit radiation exposure to prescribed levels, require workers to wear personnel monitoring dosimeters to measure radiation exposure, limit radiation levels in unrestricted areas to specified amounts, post signs at areas where radiation or radioactivity exist in excess of certain amounts, and label containers of waste to indicate the presence of radioactive material. They also must instruct personnel in the hazards of excessive exposure, and the steps necessary to control such exposures. Radiation surveys must be conducted to control exposure and in order to post radiation caution signs in the proper locations.

Incidents, or accidents such as breaking open of a waste container, must be reported to the Commission within a specified period of time depending upon the seriousness of the incident. Records of radiation exposure of personnel, radiation surveys conducted, and receipt and disposal of waste must be kept.

Typically, the waste material either is received from customers by common carrier or is collected by truck by the disposal firm. In either case the waste must have been packaged in containers meeting the specifications of the ICC for radioactive materials, and the transportation of the waste must be in accordance with the ICC requirements. Upon receipt of the material, the licensee's personnel are required to survey each waste container to assure that the radiation levels and the degree of contamination do not exceed prescribed limits. The licensee must obtain from the customer an inventory showing the type and amount of radioactive material in each container.

The waste then is stored at the licensee's facility and packaged for sea disposal. Storage of the waste containers must be in an area secure from unauthorized entry and posted to indicate the presence of radioactive material. The unrestricted area around the storage site must be surveyed to assure that the levels of radiation are within the limits of the Commission's regulations.



Shipment of wastes. Debris from Commission laboratories having only very low levels of radioactivity can be shipped to Oak Ridge for burial with a minimum of shielding. To meet the Commission's and Interstate Commerce Commission's standards for radiation levels at specific distances from boxcars, Knolls Atomic Power Laboratory personnel took advantage of distance and shielding by sandwiching the wastes with more radiation between boxes of baled, only slightly-contaminated refuse, in loading this car. The radiation on the outside surface of the car is negligible.

Most of the commercial sea disposal licensees, depending on the training and experience of the individuals handling the wastes and the facilities and equipment they have available, are not permitted to open the containers of waste received from customers. These containers are packaged for sea disposal by encasing them in concrete within a 55-gallon drum or by surrounding them with a sufficient layer of reinforced concrete to obtain the required density—10 pounds per gallon to assure sinking in the ocean. The persons involved in the packaging of the waste must wear personnel monitoring dosimeters to measure radiation exposure and perform surveys of radiation levels to assure that the levels do not exceed the radiation dose limits of the regulations.

Those licensees who are authorized to open the containers of waste received from customers and repackage it for sea disposal must have personnel with sufficient training and experience in handling radioactive materials and proper facilities and equipment for packaging the waste. In repackaging the waste, steps must be taken to control contamination of personnel and equipment. Radiation surveys must

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be conducted to determine the effectiveness of the control procedures. Also, depending on the method of repackaging used, certain protective clothing such as coveralls, gloves, and respirators may be necessary for personnel involved in the operation.

When the packaging is complete, the package must be durably labeled with the name of the firm preparing the package, amount of radioactivity contained, date of packaging, and most hazardous radioisotope contained. This is usually done by means of a metal tag welded to the steel drum, or by inscribing the information in the concrete. The package also must be labeled with the conventional three-bladed radiation caution symbol in color and the words "Caution—Radioactive Material."

After the packaging operations, the containers are stored at the licensee's facility until a sufficient number has accumulated to warrant a trip to sea. The Commission license limits the storage period for any container of waste to 21 months, and the amount of radioactive material the licensee may have in his possession at any one time. The quantity allowed is based on the licensee's facilities and equipment and the amount of business the licensee expects.

When the licensee is ready to dispose of the waste at sea, he must notify the Commission at least 20 days in advance of disposal and give the number of containers of waste to be disposed of and the type and amount of radioactive material involved. This notification allows the Commission to send an inspector along to check disposal operations.

Since it is necessary for most waste disposal licensees to hire ocean-going equipment to transport the waste to a disposal location, the licensee must send personnel with the waste to be responsible for radiation safety during the trip and to assure the waste is disposed of at the required location. The waste must be stored aboard ship in an area not frequented by personnel and the area must be posted to indicate the presence of radioactive material. Radiation surveys must be conducted to establish time and distance limitations in regard to the waste storage area. In addition to keeping records of the receipt of waste material, the licensee must also maintain records of the number of containers disposed of, the type and amount of radioactivity, and the date and location of disposal. Records of personnel monitoring and radiation surveys must also be kept.

Inspection and Compliance

Commercial waste disposal licensees are inspected by the Commission to determine compliance with regulations and the conditions of

their licenses. The inspection representative interviews top management and the person responsible for radiation protection as well as those who actually carry out the operations. He reviews with the licensee the administrative controls for radiation safety, the training and experience of those responsible for conducting the operations, and the written and emergency procedures being followed. He examines the licensee's records dealing with radiation exposure, surveys, and the receipt and disposal of the waste. The facilities for packaging and storing the waste and the waste containers are observed to determine that the requirements of the regulations and license are being met. If feasible, the inspection representative actually observes the waste-packaging operations. In addition to observing actual sea disposal when feasible, the inspector gathers information from Port and United States authorities that regulate vessels carrying the cargoes.

If inspection discloses evidence of noncompliance, appropriate action is taken promptly by the Commission to assure that deficiencies are corrected. If necessary, the Commission may issue an order under its "Rules of Practice" requiring a licensee to take appropriate corrective action. The Commission also has authority to take procedural action to revoke, suspend or modify any license where such action is necessary to assure protection of the health and safety of the public.

Review of Policies and Standards

The radioactive wastes generated in licensee operations to date have been of low level and small total volume. The policies and standards established by the Commission for disposal of radioactive waste by Commission licensees provide, in accordance with present knowledge, a substantial margin of safety to the public.

As the Nation's atomic energy program expands, the trend will be toward increasing quantities of low-level radioactive waste. The disposal of large volumes of radioactive waste presents complex problems. It will be necessary to continue to support research work in such areas as sea disposal, land burial, and other types of release of radioactivity to the environment.

The policies and standards of the Commission in the field of radioactive waste disposal are under continuous review and are subject to change with the development of new knowledge.

APPENDIX A

Organizations Licensed To Dispose of Their Own Waste at Sea

1. The National Institutes of Health (NIH), of the U.S. Public Health Service, Bethesda, Md., was issued a license in May 1959 authorizing disposal in the Atlantic Ocean at a location within a 5-mile radius of 36°56′ north latitude. 74°23′ west longitude at a minimum depth of 1,000 fathoms. This site is approximately 105 miles from Cape Henry, Va. The licensee also receives for disposal properly packaged waste from the Naval Research Laboratory, the National Bureau of Standards, and other Government agencies in the Washington area. The waste is transported to sea by the U.S. Coast Guard accompanied by NIH personnel. To date NIH has disposed of about 30 curies of byproduct material.
2. The U.S. Naval Radiological Defense Laboratory, San Francisco, Calif., was issued a license in May 1959 authorizing disposal of radioactive waste in the Pacific Ocean at a location within a 5-mile radius of 37°41′ north latitude and 123°25′ west longitude at a minimum depth of 1,000 fathoms or at other areas when approved by the Commission. The location designated is one which has been used by the Commission for disposal of packaged radioactive waste. To date this licensee has disposed of about 100 curies of its own waste.
3. Atlantic Refining Co., Philadelphia, Pa., is authorized to dispose of radioactive wastes in the Atlantic Ocean. The site used is about 180 miles from shore and located at 32°30′ north latitude and 75°45′ west longitude where the minimum depth is 1,000 fathoms. To date this licensee has disposed of about 650 millicuries of byproduct material.
4. Socony Mobil Oil Co., Paulsboro, N.J., is authorized to dispose of radioactive wastes in the Atlantic Ocean within an area bounded by 31°10′ and 32°54′ north latitudes and 72°20′ and 85°17′ west longitudes at a minimum depth of 1,000 fathoms. To date this licensee has disposed of about 1.6 millicuries of byproduct material.
5. California Research Laboratory, Richmond, Calif., is authorized to dispose of radioactive wastes in the Pacific Ocean at 30°43′ north latitude and 139°06′ west longitude where the minimum depth is 1,000 fathoms. To date this licensee had disposed of about 1 curie of byproduct material.
6. U.S. Naval Medical Research Laboratory, New London, Conn., is authorized to dispose of radioactive waste in the Atlantic Ocean at a minimum depth of 1,000 fathoms. To date this licensee has not disposed of byproduct material in the ocean.
7. In addition, the U.S. Fish and Wildlife Service, Beaufort, N.C., and the University of Georgia, Sapelo Island, Ga., are authorized to dispose of very low-level radioactive waste in liquid or readily dispersable solid form directly into the Atlantic Ocean without packaging. The type and quantity of the waste and the immediate dilution involved are such that this waste could be disposed of by sanitary sewer or burial under the provisions of 10 CFR 20, "Standards for Protection Against Radiation." The site used by the Fish and Wildlife Service is about 8 miles off the North Carolina coast at 34°32′ north latitude and 76°40′ west longitude. To date about 500 millicuries of by-

product material have been disposed of at this site. The disposal site used by the University of Georgia is about 3 miles off the Georgia coast. To date about 2.3 millicuries of byproduct material have been disposed of.

8. In addition to the above described licensed waste disposal operations, a few licensed users of byproduct materials disposed of wastes at sea prior to 1958 but are not doing so now. In this group, six organizations dumped a total of approximately 4 curies into the Atlantic, two organizations dumped a total of less than 1 curie into the Pacific and two organizations dumped a total of approximately 10 curies into the Gulf of Mexico. All of the disposals in the Gulf of Mexico and most of those in the Atlantic and Pacific Oceans were at depths of greater than 1,000 fathoms.

APPENDIX B

Firms Providing Commercial Waste Disposal Service

1. American Mail Line, Ltd., 740 Stuart Building, Seattle 1, Wash., was issued a license in August 1958 to dispose of radioactive waste in the Pacific Ocean. The licensee is authorized to receive waste already packaged for sea disposal only from the Boeing Airplane Co., Seattle, Wash. The licensee acts only as a carrier of the waste from Seattle to the disposal location and is authorized to dispose of this packaged waste in the Pacific Ocean at locations at least 150 miles from the continental shelf at a minimum depth of 1,000 fathoms during regular voyages of their ships. To date, this licensee has made one sea disposal consisting of 540 millicuries of byproduct material and 15 pounds of source material at 51°31′ north latitude and 139°00′ west longitude.
2. Coastwise Marine Disposal Corp., 5216 South Van Ness, Los Angeles, Calif., was issued a license in June 1959 authorizing the disposal of radioactive wastes in the Pacific Ocean. The licensee's facilities are located at 2100 West 15th Street, Long Beach, Calif. Containers of waste received from customers may be opened in connection with preparing the waste for sea disposal. The licensee requested permission to dispose of packaged waste in the Pacific Ocean at a location recommended by the State of California and has been so authorized by the Commission. The waste material must be disposed of within a 5-mile radius circle, the center of which is 32°00′ north latitude and 121°31′ west longitude where the ocean depth is 2,000 fathoms. There are five disposal sites in the Pacific Ocean recommended by the State of California which have a minimum depth of 2,000 fathoms and are at least 60 miles from any sea mount. To date, this licensee has not disposed of any licensed radioactive material in the Pacific Ocean.
3. Isotopes Specialties Co., 170 West Providencia, Burbank, Calif., was issued a license in August 1958 authorizing the disposal of radioactive wastes in the Pacific Ocean. Containers of waste received from customers may be opened in connection with preparing the wastes for sea disposal. The licensee requested permission to dispose of wastes in the Pacific Ocean at the locations recommended by the State of California and has been so authorized by the Commission. To date, this licensee has not disposed of any licensed radioactive material in the Pacific Ocean.
4. Nuclear Engineering Co., Inc., 2600 North Main Street, Walnut Creek, Calif., was issued a license in October 1958 authorizing the disposal of radioactive wastes in the Atlantic and Pacific Oceans. The firm's facilities are located in Cowell, Calif., and Kearney, N.J. The licensee is authorized to open containers of waste received from customers in connection with preparing the wastes for sea disposal. The disposal site in the Atlantic Ocean is within a 3-mile radius of 38°50′ north latitude and 72°00′ west longitude or an area bounded by north latitudes 39°00′ and 38°50′ and west longitudes 72°00′ and 72°16′ where the depth is at least 1,000 fathoms. These disposal sites are in the same location as those used by the Commission for sea disposal. In the Pacific Ocean, the licensee requested permission to dispose of wastes at the locations recommended by the State of California and has been so

authorized by the Commission. To date, this licensee has not disposed of any licensed radioactive material in either the Atlantic or Pacific Oceans.

5. Ocean Transport Co., No. 1 Drumm Street, San Francisco, Calif., was issued a license in October 1959 authorizing the disposal of packaged radioactive waste in the Pacific Ocean. The licensee is authorized to only receive waste which is already packaged for sea disposal in a manner authorized by the Commission. The disposal locations authorized are at 37°40′ north latitude, 124°50′ west longitude and 37°41′ north latitude 123°25′ west longitude. The sites are beyond the continental shelf where the ocean depth is at least 1,000 fathoms and are about 110 and 50 miles from the coast respectively. This licensee has not made any disposals.
6. California Salvage Co., 709 North Pacific Ave., San Pedro, Calif., was issued a license in September 1959, authorizing the disposal of packaged radioactive waste in the Pacific Ocean. Containers of waste received from customers may not be opened but only further packaged for sea disposal. The disposal site authorized is at 32°00′ north latitude 121°30′ west longitude. The site is beyond the continental shelf and the depth is at more than 1,000 fathoms. This licensee has not made any disposals.
7. Crossroads Marine Disposal Corp., 26 T. Wharf, Boston, Mass., has been authorized since 1952 to dispose of low-level radioactive waste at an inshore disposal area in the Atlantic Ocean 12 to 15 miles from the coast at 42°25.5′ north latitude and 70°35′ west longitude. The depth at this location is about 50 fathoms. The disposal location is designated as an explosive and toxic chemical dump-area by the U.S. Army Corps of Engineers and therefore one not used for commercial or recreational activities. This license has been amended, effective August 15, 1959 requiring disposal in the Atlantic Ocean at a minimum depth of 1,000 fathoms within an area bounded by 41°38′ and 41°28′ north latitude and 65°28′ and 65°45′ west longitude or within a 5-mile radius circle the center of which is at 38°30′ north latitude and 72°00′ west longitude. This latter area is used by the Commission for disposal of packaged radioactive waste. Containers of waste received from customers may not be opened but only further packaged for sea disposal. To date, this licensee has disposed of about 2,440 curies of byproduct and source material.
8. New England Tank Cleaning Co., 135 First Street, Cambridge, Mass., was issued a license in September 1958 authorizing the disposal of radioactive wastes in the Atlantic Ocean. The licensee's facilities are located at Great Brewster Island, Boston, Mass., and the National Dock Yard, Boston, Mass. Containers of waste received from customers may not be opened but only further packaged for sea disposal. The disposal site is in the Atlantic Ocean within the area bounded by 41°38′ and 41°28′ north latitude and 65°28′ and 65°45′ west longitude where the minimum depth is 1,000 fathoms. To date, this licensee has not disposed of any licensed radioactive material in the Atlantic Ocean.
9. The Walker Trucking Co., 1283 to 1285 East Street, New Britain, Conn., was issued a license in March 1959 authorizing the disposal of radioactive wastes in the Atlantic Ocean. The licensee's facilities are located on Brownstone Ave., in Portland, Conn. Containers of waste received from customers may not be opened but only further packaged for sea disposal. The disposal site is in the Atlantic Ocean within a 3-mile radius of 38°50′ north latitude and 72°00′ west longitude at a minimum depth of 1,000 fathoms. This disposal site is in the same location as that used by the Commission for disposal of packaged radioactive waste. To date, this licensee has not

disposed of any licensed radioactive material in the Atlantic Ocean. The licensee has requested an amendment to his license to use an additional site for packaging and temporary storage in New Britain. A hearing is being held on this application for amendment.

10. There are three license applications for disposal of radioactive wastes pending. An application has been received from U.S. Nuclear Corp., Burbank, Calif., to dispose in the Pacific Ocean, and from the Military Sea Transportation Service, Washington, D.C., to dispose of packaged radioactive waste from government operations in both the Atlantic and Pacific Oceans. An application from the Industrial Waste Disposal Corp., Houston, Tex., to dispose of packaged radioactive waste in the Gulf of Mexico at 1,000 fathoms is also pending final determination.

APPENDIX 1

Organization and Principal Staff of U.S. Atomic Energy Commission

Atomic Energy Commission	John A. McCone, *Chairman* John F. Floberg John S. Graham John H. Williams *Vacancy*
General Manager	Alvin R. Luedecke
Special Assistant to General Manager (Congressional).	Richard X. Donovan
Deputy General Manager	Robert E. Hollingsworth
Assistant General Manager	Harry S. Traynor
Assistant General Manager for Administration.	Dwight A. Ink
Assistant General Manager for International Activities.	John A. Hall
Assistant General Manager for Manufacturing.	E. J. Bloch
Assistant General Manager for Regulation and Safety.	William F. Finan
Assistant General Manager for Research and Industrial Development.	A. Tammaro
Controller	Don S. Burrows
General Counsel	Loren K. Olson
Secretary to the Commission	W. B. McCool
Director, Office of Contract Policy	John R. Moore
Director, Office of Headquarters Services.	Edward H. Glade
Director, Office of Health and Safety	Nathan H. Woodruff
Director, Office of Industrial Relations.	Oscar S. Smith
Director, Office of Isotopes Development.	Paul C. Aebersold
Director, Office of Operations Analysis and Forecasting.	Paul C. Fine
Director, Office of Personnel	Arthur L. Tackman

Director, Office of Plans	JOHN L. MCGRUDER
Director, Office of Special Projects	EDWARD R. GARDNER
Director, Division of Biology and Medicine.	CHARLES L. DUNHAM, M.D.
Director, Division of Classification	C. L. MARSHALL.
Director, Division of Construction and Supply.	JOHN A. DERRY.
Director, Division of Information Services.	MORSE SALISBURY.
Director, Division of Inspection	CURTIS A. NELSON.
Director, Division of Intelligence	C. H. REICHARDT.
Director, Division of International Affairs.	ALGIE A. WELLS.
Director, Division of Licensing and Regulation.	HAROLD L. PRICE.
Director, Division of Military Application.	BRIG. GEN. ALFRED D. STARBIRD.
Director, Division of Nuclear Materials Management.	D. F. MUSSER.
Director, Division of Production	GEORGE F. QUINN.
Director, Division of Raw Materials	JESSE C. JOHNSON.
Director, Division of Reactor Development.	FRANK K. PITTMAN.
Director, Division of Research	PAUL W. MCDANIEL, *Acting.*
Director, Division of Security	JOHN A. WATERS, JR.

MANAGERS OF OPERATIONS OFFICES AND AREAS

Albuquerque (N. Mex.) Operations Office.	KENNER F. HERTFORD.
Burlington (Iowa) Area	E. W. GILES.
Dayton (Miamisburg, Ohio) Area.	WILLIS B. CREAMER.
Kansas City (Mo.) Area	WALTER C. YOUNGS, JR.
Los Alamos (N. Mex.) Area	PAUL A. WILSON.
San Antonio (Tex.) Area	H. JACK BLACKWELL.
Pinellas (Fla.) Area	HENRY A. NOWAK.
Rocky Flats (Colo.) Area	SETH R. WOODRUFF, JR.
Sandia (N. Mex.) Area	CHARLES C. CAMPBELL.
South Albuquerque (N. Mex.) Area.	WALTER W. STAGG.
Chicago (Ill.) Operations Office	KENNETH A. DUNBAR.
Canoga Park (Calif.) Area	JOEL V. LEVY

Grand Junction (Colo.) Operations Office.	ALLAN E. JONES.
Hanford (Wash.) Operations Office__	J. E. TRAVIS.
Idaho (Idaho Falls) Operations Office.	ALLAN C. JOHNSON.
Lockland (Ohio) Aircraft Reactors Operations Office.	HARRY H. GORMAN.
Hartford (Conn.) Area_____	CLIFFORD E. MCCOLLEY.
New York (N.Y.) Operations Office__	JOSEPH C. CLARKE.
Brookhaven (Long Island, N.Y.) Area.	E. L. VAN HORN.
Princeton (N.J.) Area_____	ENZI DE RENZIS.
Oak Ridge (Tenn.) Operations Office.	S. R. SAPIRIE.
Fernald (Cincinnati, Ohio) Area.	CLARENCE L. KARL.
New Brunswick (N.J.) Area____	C. J. RODDEN.
Paducah (Ky.) Area_____	KENNEDY C. BROOKS.
Portsmouth (Ohio) Area_____	ROBERT H. MCCULLOH.
Puerto Rico (Mayaguez) Area__	JOHN I. THOMAS.
St. Louis (Mo.) Area_____	FRED H. BELCHER.
Pittsburgh (Pa.) Naval Reactors Operations Office.	LAWTON D. GEIGER.
San Francisco (Calif.) Operations Office.	ELLISON C. SHUTE.
Savannah River (Aiken, S.C.) Operations Office.	ROBERT C. BLAIR.
Schenectady (N.Y.) Naval Reactors, Operations Office.	STANLEY W. NITZMAN.

APPENDIX 2

MEMBERSHIP OF COMMITTEES

STATUTORY COMMITTEES AND BOARD

Joint Committee on Atomic Energy—Eighty-sixth Congress

This committee was established by the Atomic Energy Act of 1946, and continued under the Atomic Energy Act of 1954, to make "continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy." The committee is kept fully and currently informed with respect to the Commission's activities. Legislation relating primarily to the Commission or to atomic energy matters is referred to the committee. The committee's membership is composed of 9 Members of the Senate and 9 Members of the House of Representatives.

Senator CLINTON P. ANDERSON (New Mexico), *Chairman.*
Representative CARL T. DURHAM (North Carolina), *Vice Chairman.*
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 HENRY C. DWORSHAK (Idaho).
Senator GEORGE D. AIKEN (Vermont).
Senator WALLACE F. BENNETT (Utah).
Representative CHET HOLIFIELD (California).
Representative MELVIN PRICE (Illinois).
Representative WAYNE N. ASPINALL (Colorado).
Representative ALBERT THOMAS (Texas).
Representative JAMES E. VAN ZANDT (Pennsylvania).
Representative CRAIG HOSMER (California).
Representative WILLIAM H. BATES (Massachusetts).
Representative JACK WESTLAND (Washington).
JAMES T. RAMEY, *Executive Director.*

Military Liaison Committee

Under section 27 of the Atomic Energy Act of 1954, "there is hereby established a Military Liaison Committee consisting of—*a.* a Chairman, who shall be the head thereof and who shall be appointed by the President, by and with the advice and consent of the Senate, who shall serve at the pleasure of the President, and who shall receive compensation at the rate prescribed for an Assistant Secretary of Defense; and *b.* a representative or representatives from

each of the Departments of the Army, Navy, and Air Force, in equal numbers as determined by the Secretary of Defense, to be assigned from each Department by the Secretary thereof, and who will serve without additional compensation. The Chairman of the Committee may designate one of the members of the Committee as Acting Chairman to act during his absence. The Commission shall advise and consult with the Department of Defense, through the Committee, on all atomic energy matters which the Department of Defense deems to relate to military applications of atomic weapons or atomic energy including the development, manufacture, use, and storage of atomic weapons, the allocation of special nuclear material for military research, and the control of information relating to the manufacture or utilization of atomic weapons; and shall keep the Department of Defense, through the Committee, fully and currently informed of all such matters before the Commission. The Department of Defense, through the Committee, shall keep the Commission fully and currently informed on all matters within the Department of Defense which the Commission deems to relate to the development or application of atomic energy. The Department of Defense, through the Committee, shall have the authority to make written recommendations to the Commission from time to time on matters relating to military applications of atomic energy as the Department of Defense may deem appropriate. If the Department of Defense at any time concludes that any request, action, proposed action, or failure to act on the part of the Commission is adverse to the responsibilities of the Department of Defense, the Secretary of Defense shall refer the matter to the President whose decision shall be final."

Hon. HERBERT B. LOPER, *Chairman.*
Maj. Gen. WILLIAM W. DICK, Jr., United States Army.
Maj. Gen. CHARLES H. ANDERSON, United States Air Force.
Rear Adm. WILLIAM E. ELLIS, United States Navy.
Brig. Gen. PAUL T. PREUSS, United States Air Force.
Brig. Gen. JOHN T. SNODGRASS, United States Army.
Capt. JOHN N. SHAFFER, United States Navy.

General Advisory Committee

This committee was established by the Atomic Energy Act of 1946 (Sec. 2(b)), and is continued by Section 26 of the Atomic Energy Act of 1954. The nine civilian members are appointed by the President to advise the Commission on scientific and technical matters relating to materials, production, and research and development. Under the Atomic Energy Act, the committee shall meet at least four times in every calendar year.

Dr. WARREN C. JOHNSON, *chairman;* vice president, University of Chicago, Chicago, Ill.
Dr. JESSE W. BEAMS, chairman, physics department, University of Virginia, Charlottesville, Va.
Dr. MANSON BENEDICT, professor of nuclear engineering, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. JAMES W. MCRAE, vice president, American Telephone & Telegraph Co., New York, N.Y.
EGER V. MURPHREE, president, Esso Research & Engineering Co., Linden, N.J.
Dr. KENNETH S. PITZER, dean, college of chemistry, University of California, Berkeley, Calif.

Dr. J. C. WARNER, president, Carnegie Institute of Technology, Pittsburgh, Pa.

Dr. ROBERT E. WILSON, Retired (former chairman of the Board, Standard Oil Co., Indiana).

Dr. EUGENE P. WIGNER, Palmer Physical Laboratory, Princeton University, Princeton, N.J.

Dr. ROBERT A. CHARPIE, *secretary;* Oak Ridge National Laboratory, Oak Ridge, Tenn.

Patent Compensation Board

This board was established in April 1949 pursuant to Section 11 of the Atomic Energy Act of 1946, and is the Board designated under Section 157a of the Atomic Energy Act of 1954. Section 157 provides that upon application for just compensation or awards or for the determination of a reasonable royalty fee certain proceedings shall be held before such a board.

CASPER W. OOMS, chairman; firm of Casper W. Ooms, Chicago, Ill.

JOHN V. L. HOGAN, consulting engineer, Hogan Laboratories, Inc., New York, N.Y.

LAWRENCE E. KINGSLAND, Kingsland, Rogers & Ezell, St. Louis, Mo.

Advisory Committee on Reactor Safeguards

The committee reviews safety studies and facility license applications referred to it and makes reports thereon, advises the Commission with regard to the hazards of proposed or existing reactor facilities and the adequacy of proposed reactor safety standards, and performs such other duties as the Commission may request. The committee's reports on applications for facility licenses become a part of the record of the application and available to the public, except for security material. Members are appointed by the Commission for a term of 4 years each, and one member is designated by the committee as its chairman. This statutory committee replaced the former Advisory Committee on Reactor Safeguards in 1957.

Dr. LESLIE SILVERMAN, chairman; professor of engineering in environmental hygiene, director of radiological hygiene program, Harvard University, School of Public Health, Boston, Mass.

Dr. C. ROGERS MCCULLOUGH, vice chairman; project specialist, research and engineering division, Monsanto Chemical Co., Washington, D.C.

Dr. HARVEY BROOKS, dean of engineering and applied physics, Harvard University, Cambridge, Mass.

Dr. WILLARD P. CONNER, Jr., technical assistant to director of research center, research department, Hercules Powder Co., Wilmington, Del.

Dr. R. L. DOAN, manager, atomic energy division, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. WILLIAM K. ERGEN, principal physicist, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. FRANKLIN A. GIFFORD, Jr., meteorologist in charge of the Oak Ridge Office, U.S. Weather Bureau, Oak Ridge, Tenn.

Dr. HENRY W. NEWSON, professor of physics, Duke University, Durham, N.C.

K. R. OSBORN, manager of industrial development, general chemical division, Allied Chemical Corp., New York, N.Y.

D. A. ROGERS, manager of project analysis, Central Research Laboratory, Allied Chemical & Dye Corp., Morristown, N.J.

REUEL C. STRATTON, assistant director, department of research, the Travelers Insurance Cos. of Hartford, Conn.

Dr. ABEL WOLMAN, head, department of sanitary engineering and water resources, The Johns Hopkins University, Baltimore, Md.

Dr. CHARLES R. WILLIAMS, assistant vice president, Liberty Mutual Insurance Co., Boston, Mass.

Dr. DICK DUFFEY, technical secretary; professor of nuclear engineering, University of Maryland, College Park, Md.

J. B. GRAHAM, executive secretary; U.S. Atomic Energy Commission, Washington, D.C.

Dr. THEOS J. THOMPSON, director, MIT nuclear reactor, Massachusetts Institute of Technology, Cambridge, Mass.

ATOMIC ENERGY LABOR MANAGEMENT RELATIONS PANEL

The members of this panel were selected by the President to assist in arriving at peaceful adjustments of labor-management disputes which would imperil the Government's atomic energy program when the normal process of collective bargaining and mediation have been fully utilized without constructive results. The panel operates under procedures designed to accomplish this purpose. It reports annually to the President on its activities.

CYRUS S. CHING, chairman; industrial relations consultant and former Director of the Federal Mediation and Conciliation Service, Washington, D.C.

Rev. LEO C. BROWN, S. J., professor of economics and director of the Institute of Social Order, St. Louis University, St. Louis, Mo.

Vice Adm. O. S. COLCLOUGH, USN, Retired, dean of faculties, the George Washington University, Washington, D.C.

ROBBEN W. FLEMING, professor of law, University of Illinois, Urbana, Ill.

GEORGE FRANKENTHALER, attorney, firm of Frankenthaler and Kohn, New York, N.Y.

CHARLES O. GREGORY, professor of law, University of Virginia, Charlottesville, Va.

RUSSELL A. SMITH, professor of law and secretary of University of Michigan Law School, Ann Arbor, Mich.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Advisory Committee for Biology and Medicine

The Advisory Committee for 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. JOHN C. BUGHER, acting chairman; consultant on nuclear energy affairs, Rockefeller Foundation, New York, N.Y.

Dr. H. BENTLEY GLASS, professor of biology, Johns Hopkins University, Baltimore, Md.

Dr. JAMES G. HORSFALL, director, Connecticut Agricultural Experiment Station, New Haven, Conn.

Dr. ROBERT F. LOEB, instructor, department of medicine, Columbia University, New York, N.Y.

Dr. LEONIDAS D. MARINELLI, associate director, division of radiological physics, Argonne National Laboratory, Lemont, Ill.

Dr. HARLAND G. WOOD, department of biochemistry, school of medicine, Western Reserve University, Cleveland, Ohio.

Dr. HENRY I. KOHN, scientific secretary; clinical professor of experimental radiology, radiological laboratory, school of medicine, University of California Medical Center, San Francisco, Calif.

Advisory Committee on Industrial Information

The committee, formed in 1949, advises and assists in the planning and execution of the Atomic Energy Commission's industrial information program.

E. E. THUM, chairman; editor-in-chief, *Metal Progress*, American Society for Metals, Cleveland, Ohio.

S. A. TUCKER, vice chairman; publications business manager, American Society of Mechanical Engineers, New York, N.Y.

BERNARD M. FRY, deputy head, Office of Science Information Service, National Science Foundation, Washington, D.C.

Dr. ALLEN G. GRAY, editor, *Metal Progress*, American Society for Metals, Cleveland, Ohio.

EUGENE J. HARDY, National Association of Manufacturers, Washington, D.C.

KEITH HENNEY, consulting editor, *Nucleonics and Electronics*, McGraw-Hill Publishing Co., Inc.; American Institute of Radio Engineers, New York, N.Y.

NORMAN H. JACOBSON, *Electric Light and Power*, Haywood Publishing Co., Chicago, Ill.

ANDREW W. KRAMER, editor, *Atomics*, The Technical Publishing Co., Barrington, Ill.

JOHN W. LANDIS, assistant manager, atomic energy division, The Babcock & Wilcox Co., representing American Nuclear Society, Chicago, Ill.

FREDERIC A. PAWLEY, research secretary, American Institute of Architects, Washington, D.C.

KARL T. SCHWARTZWALDER, director of research, A–C spark plug division, General Motors Corp., representing The American Ceramic Society, Inc., Columbus, Ohio.

GEORGE F. SULLIVAN, editor, *The Iron Age*, Chilton Publication, Inc., Philadelphia, Pa.

OLIVER H. TOWNSEND, Office of Atomic Development, State of New York, New York, N.Y.

MELVIN S. DAY, secretary; assistant director for technical service, division of information services, U.S. Atomic Energy Commission, Washington, D.C.

EDWARD J. BRUNENKANT, assistant secretary; technical information service, division of information services, U.S. Atomic Energy Commisson, Washington, D.C.

Advisory Committee on Isotope and Radiation Development

This committee was established by the Commission in July 1958 to advise on means of encouraging widescale industrial use of radioisotopes and nuclear radiation.

Dr. PAUL C. AEBERSOLD, chairman; director, office of isotopes development, U.S. Atomic Energy Commission, Washington, D.C.

Dr. JAMES F. BLACK, products research division, Esso Research and Engineering Co., Linden, N.J.

SAMUEL E. EATON, Arthur D. Little, Inc. Cambridge, Mass.

Dr. HENRY J. GOMBERG, assistant director, Memorial-Phoenix Project, University of Michigan, Ann Arbor, Mich.

Dr. THORFIN R. HOGNESS, director, Chicago Midway Laboratories, University of Chicago, Chicago, Ill.

Dr. WILLIAM H. JOHNSTON, president, William H. Johnston Laboratories, Inc, Lafayette, Ind.

JOHN L. KURANZ, vice president, Nuclear-Chicago Corp., Chicago, Ill.

JOHN J. MCMAHON, manager, industrial atomic energy department, National Industrial Conference Board, Inc., New York, N.Y.

HOMER S. MYERS, vice president for marketing, Tracerlab, Inc., Waltham, Mass.

Dr. HAROLD R. NELSON, manager, physics department, Battelle Memorial Institute, Columbus, Ohio.

Dr. LEONARD REIFFEL, manager, physics research department, Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill.

Dr. BERNARD S. SCHWEIGERT, director, research and education, American Meat Institute Foundation, Chicago, Ill.

Dr. ALEXANDER SOMMERVILLE, research laboratories division, General Motors Corp., Detroit, Mich.

Dr. LAURISTON S. TAYLOR, chief, atomic and radiation physics division, National Bureau of Standards, Washington, D.C.

EDWIN A. WIGGIN, manager, technical services, Atomic Industrial Forum, Inc., New York, N.Y.

Dr. LLOYD R. ZUMWALT, General Atomics Division, General Dynamics Corp., San Diego, Calif.

Advisory Committee on Medical Uses of Isotopes

This Committee was established in 1958 and replaces the Subcommittee on Human Applications of the Advisory Committee on Isotope Distribution. The committee will advise the Commission on policies and standards for the regulation and licensing of medical uses of radioisotopes in humans.

Dr. WALLACE D. ARMSTRONG, professor, University of Minnesota Medical School, Minneapolis, Minn.

Dr. REYNOLDS F. BROWN, department of radiology, University of California Medical School, San Francisco, Calif.

Dr. DONALD S. CHILDS, Jr., section of therapeutic radiology, Mayo Clinic, Rochester, Minn.

Dr. JOHN A. D. COOPER, assistant dean, Northwestern University Medical School, Chicago, Ill.

Dr. GEORGE V. LEROY, associate dean, Division of Biological Sciences, University of Chicago, Chicago, Ill.

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

Dr. RULON W. RAWSON, Memorial Hospital, New York, N.Y.

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Plowshare Advisory Committee

The Plowshare Advisory Committee was established in September 1959. The committee's function is to advise the Commission and the General Manager on selecting and carrying out particular Plowshare Projects; developing and making available various applications of Plowshare; and determining the general orientation and policies of the Plowshare program.

Dr. SPOFFORD G. ENGLISH, chairman; special assistant to the General Manager, U.S. Atomic Energy Commission, Washington, D.C.

Dr. PHILIP H. ABELSON, director, geophysical laboratory, Carnegie Institution, Washington, D.C.

WILLARD BASCOM, technical director, The AMSOC Committee, National Academy of Sciences, Washington, D.C.

Lt. Gen. JAMES H. DOOLITTLE, Space Technology Laboratories, Inc., Los Angeles, Calif.

Dr. LOUIS H. HEMPELMANN, school of medicine and dentistry, University of Rochester, Rochester, N.Y.

Dr. W. RANDOLPH LOVELACE, II, Lovelace Clinic, Albuquerque, N. Mex.

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

Dr. PHILIP C. RUTLEDGE, partner, Moran, Proctor, Mueser & Rutledge, New York, N.Y.

Dr. PAUL B. SEARS, chairman, conservation program, Yale University, New Haven, Conn.

Dr. ROBERT E. WILSON, Retired (former chairman of the board, Standard Oil Co., Indiana).

Dr. ABEL WOLMAN, professor, sanitary engineering, The Johns Hopkins University, Baltimore, Md.

Advisory Committee on Reactor Physics

This committee is appointed to consider the status of the development of reactor physics information required for the development of reactor concepts and the design and construction of reactors. Nuclear physics data and reactor physics studies required for the design and development of reactors are reviewed and evaluated. The committee's recommendations and advice are used in planning the research and development work in the field of reactor physics.

Dr. ROBERT A. CHARPIE, chairman; assistant director, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. IRA F. ZARTMAN, vice chairman: division of reactor development, U.S. Atomic Energy Commission, Washington, D.C.

Dr. E. RICHARD COHEN, research adviser, Atomics International, North American Aviation, Inc., Canoga Park, Calif.

DESLONDE DEBOISBLANC, director, reactor physics and engineering, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. GERHARD DESSAUER, director, physics section, E. I. du Pont de Nemours & Co., Inc. Aiken, S.C.

Dr. MILTON EDLUND, manager, physics and mathematics department, Babcock & Wilcox Co., Lynchburg, Va.

Dr. PAUL F. GAST, manager, physics and instrument research and development, General Electric Co., Richland, Wash.

Dr. IRVING KAPLAN, professor of nuclear engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. HERBERT J. C. KOUTS, experimental reactor physics group leader, Brookhaven National Laboratory, Upton, Long Island, N.Y.

Dr. SIDNEY KRASIK, manager, central physics and mathematics department, Westinghouse Electric Corp., Pittsburgh, Pa.

Dr. THEODORE MERKLE, associate director, Pluto Project, "R" division, Lawrence Radiation Laboratory, Livermore, Calif.

Dr. JOHN W. MORFITT, manager, nuclear development laboratory, General Electric Co., Cincinnati, Ohio.

Dr. HUGH PAXTON, group leader, N2, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. THOMA M. SNYDER, manager, physics—APED, General Electric Co., Pleasanton, Calif.

Dr. BERNARD I. SPINRAD, director, reactor engineering division, Argonne National Laboratory, Lemont, Ill.

Dr. PAUL F. ZWEIFEL, professor of nuclear engineering, University of Michigan, Ann Arbor, Mich.

Dr. ALVIN RADKOWSKY, secretary; division of reactor development, U.S. Atomic Energy Commission, Washington D.C.

Advisory Committee for Standard Reference Materials and Methods of Measurement

The committee was originally established by the Commission in March 1956 as the Committee for Uranium Isotopic Standards. The Commission approved its reconstitution in January 1958 under its present title to reflect the broadened scope of its activities. The committee reviews, evaluates and recommends means for providing standard reference materials (i. e., certified chemical and isotopic standards for uranium, plutonium, etc.) and approved methods of measurement for materials of special importance to atomic energy activities.

DONALD F. MUSSER, chairman; director, division of nuclear materials management, U.S. Atomic Energy Commission, Washington, D.C.

Dr. SAMUEL C. T. MCDOWELL, chief, chemistry and physics branch, division of nuclear materials management, U.S. Atomic Energy Commission, Washington, D.C.

Dr. CHARLES F. METZ, group leader, analytical chemistry group, chemistry and metallurgical research division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. HORACE W. NORTON III, professor of statistical design and analysis, University of Illinois, Urbana, Ill.

Dr. EDWIN F. ORLEMANN, professor of chemistry and chemical engineering, University of California, Berkeley, Calif.

Dr. LEONARD P. PEPKOWITZ, vice president, Nuclear Materials and Equipment Corp., Apollo, Pa.

C. J. RODDEN, area manager, New Brunswick Area Office, Atomic Energy Commission, New Brunswick, N.J.

CHARLES M. STEVENS, Argonne National Laboratory, Lemont, Ill.

C. D. W. THORNTON, vice president, ITT Laboratories, International Telephone & Telegraph Corp., Fort Wayne, Ind.

Dr. EDWARD WICHERS, associate director, National Bureau of Standards, Department of Commerce, 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. ROY L. CLEERE, executive director, Colorado State Department of Public Health, Denver, Colo.

CURTISS M. EVERTS, Jr., State sanitary engineer, 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.

KARL M. MASON, director, bureau of environmental health, Department of Health, Harrisburg, Pa.

B. A. POOLE, director, bureau of environmental sanitation, State Board of Health, Indianapolis, Ind.

DONALD P. ROBERTS, chief, industrial hygiene section, Tennessee Department of Health, Nashville, Tenn.

Committee of Senior Reviewers

The Committee of Senior Reviewers studies the major technical activities of the Atomic Energy Commission program and advises the Commission on classification and declassification matters, making recommendations with respect to the rules and guides for the control of scientific and technical information. The committee consists of six members appointed for a term of 5 years on a rotating basis.

Dr. ALVIN C. GRAVES, chairman; J division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. JOHN P. HOWE, chief research department, Atomics International, North American Aviation, Inc., Canoga Park, Calif.

Dr. FRANK C. HOYT, Institute for Defense Analyses, The Pentagon, Washington, D.C.

Dr. WARREN C. JOHNSON, vice president, University of Chicago, Chicago, Ill.

Dr. WINSTON M. MANNING, director, chemistry division, Argonne National Laboratory, Lemont, Ill.

Dr. J. REGINALD RICHARDSON, professor of physics, University of California at Los Angeles, Calif.

Metallurgy and Materials Advisory Panel

This panel was established in October 1955 to advise on the Commission's research program on metallurgy, solid state physics, and ceramics.

Dr. HARVEY BROOKS, dean, division of engineering and applied physics, Harvard University, Cambridge, Mass.

Dr. MORRIS COHEN, department of metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. MAXWELL GENSAMER, department of metallurgy, Columbia University, New York, N.Y.

Dr. JOHN P. HOWE, chief, research department, Atomics International, a division of North American Aviation, Inc., Downey, Calif.

Dr. ALBERT R. KAUFMANN, vice president, Nuclear Metals, Inc., Cambridge, Mass.

Dr. FREDERICK SEITZ, head, department of physics, University of Illinois, Urbana, Ill.

Dr. JOHN C. SLATER, department of physics, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. DONALD K. STEVENS, division of research, U.S. Atomic Energy Commission, Washington, D.C.

Nuclear Cross Sections Advisory Group

This group is appointed on a yearly basis to make a continuing review of the Commission's program of nuclear cross-section measurements, and to evaluate the needs for cross-section information in the various activities of the Commission. The following members were appointed to serve from July 1959 to July 1960.

Dr. JOSEPH L. FOWLER, chairman; Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. GEORGE L. ROGOSA, vice chairman; division of research, U.S. Atomic Energy Commission, Washington, D.C.

Dr. JACOB BENVENISTE, Lawrence Radiation Laboratory, Livermore, Calif.

Dr. LOWELL M. BOLLINGER, Argonne National Laboratory, Lemont, Ill.

Dr. TOM W. BONNER, department of physics, Rice Institute, Houston, Tex.

Dr. LAWRENCE CRANBERG, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. BENJAMIN C. DIVEN, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. JOHN E. EVANS, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. REX G. FLUHARTY, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. HERBERT GOLDSTEIN, Nuclear Development Corp. of America, White Plains, N.Y.

Dr. DONALD J. HUGHES, Brookhaven National Laboratory, Upton, Long Island, N.Y.

Dr. BOWEN R. LEONARD, General Electric Co., Richland, Wash.

Dr. HENRY W. NEWSON, department of physics, Duke University, Durham, N.C.

Dr. JACK M. PETERSON, Lawrence Radiation Laboratory, Livermore, Calif.

Dr. L. JAMES RAINWATER, department of physics, Columbia University, New York, N.Y.

Dr. VANCE L. SAILOR, Brookhaven National Laboratory, Upton, Long Island, N.Y.

Dr. ALAN B. SMITH, Argonne National Laboratory, Lemont, Ill.

Dr. JOHN A. HARVEY, secretary; Oak Ridge National Laboratory, Oak Ridge, Tenn.

Patent Advisory Panel

This panel was appointed in January 1947. It makes informal reports and recommendations to the Commission and its staff on various questions of policy and procedure relating to patents and inventions.

JOHN A. DIENNER, Brown, Jackson, Boettcher & Dienner, Chicago, Ill.
CASPER W. OOMS, firm of Casper W. Ooms, Chicago, Ill.
Vacancy.

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, special consultant, National Science Foundation, Washington, D.C.
JOHN J. WILSON, firm of Whiteford, Hart, Carmody & Wilson, Washington, D.C.

Stack Gas Problem Working Group

The appointment of this group was authorized in May 1948 to advise the Atomic Energy Commission and its contractors on problems in the treatment and control of gaseous effluents. The group meets formally at irregular intervals but renders continuing assistance in the field of air cleaning through specific research and development work directly by individual members and by individual consulting advice to the various Commission installations.

Dr. PHILIP DRINKER, professor of industrial hygiene, Harvard University School of Public Health, Boston, Mass.
Dr. LYLE I. GILBERTSON, director, research and engineering department, Air Reduction Co., Inc., Murray Hill, N.J.
A. E. GORMAN, consultant, U.S. Atomic Energy Commission, Washington, D.C.
Dr. H. FRASER JOHNSTONE, professor of chemical engineering, University of Illinois, Urbana, Ill.
Dr. CHARLES E. LAPPLE, Stanford Research Institute, Menlo Park, Calif.
Dr. J. A. LIEBERMAN, division of reactor development, U.S. Atomic Energy Commission, Washington, D.C.
Dr. WILLIAM P. YANT, director of research and development, Mine Safety Appliance Co., Pittsburgh, Pa.
Dr. ABEL WOLMAN, head, department of sanitary engineering and water resources, The Johns Hopkins University, Baltimore, Md.

APPENDIX 3

Major Research and Development Installations of the U.S. Atomic Energy Commission

Ames Laboratory (Iowa State College, contractor), Ames, Iowa

Director	Dr. Frank H. Spedding
Associate Director	Dr. H. A. Wilhelm
Assistant to Director	Dr. Adolf F. Voigt
Assistant to Director	Morton S. Smutz

Argonne Cancer Research Hospital (University of Chicago, contractor), Chicago, Ill.

The participating institutions associated with Argonne National Laboratory (listed immediately below) are also affiliated with the Argonne Cancer Research Hospital.

Director	Dr. Leon O. Jacobson
Associate Director	Dr. Robert J. Hasterlik

Argonne National Laboratory (University of Chicago, contractor), Lemont, Ill.

Director	Dr. Norman Hilberry
Deputy Director	Dr. Louis A. Turner
Associate Director for Education	Dr. Frank E. Myers
Associate Director for High Energy Physics	Dr. Roger H. Hildebrand
Assistant Director	Dr. James R. Gilbreath
Business Manager	John H. McKinley
Manager, Technical Services	John T. Bobbitt

The participating institutions are:

- Battelle Memorial Institute
- Carnegie Institute of Technology
- Case Institute of Technology
- Illinois Institute of Technology
- Indiana University
- Iowa State College of Agriculture & Mechanic Arts
- Kansas State College
- Loyola University (Chicago, Ill.)
- Marquette University
- Mayo Foundation
- Michigan College of Mining and Technology
- Michigan State University of Agriculture & Applied Science
- Northwestern University
- Ohio State University
- Oklahoma State University of Agriculture and Applied Science
- Purdue University
- St. Louis University
- State University of Iowa
- 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 Wisconsin
- Washington University (St. Louis, Mo.)
- Wayne University
- Western Reserve University

Bettis Atomic Power Laboratory (Westinghouse Electric Corp., contractor), Pittsburgh, Pa.

General Manager	PHILLIP N. ROSS
Manager, PWR Project	W. H. HAMILTON
Manager, Surface Ship Project	JOHN T. STIEFEL
Manager, Submarine Project	DOUGLAS C. SPENCER
Manager, Naval Reactor Facility (NRTS), Idaho.	JOHN M. YADON

Brookhaven National Laboratory (Associated Universities, Inc., contractor), Upton, Long Island, N.Y.

Chairman, Board of Trustees	Dr. CARL C. CHAMBERS
President, AUI	LLOYD V. BERKNER
Vice President, AUI and Laboratory Director.	Dr. LELAND J. HAWORTH
Deputy Laboratory Director	Dr. GERALD F. TAPE
Associate Director	WILLIAM H. FIELDS
Assistant Director	Dr. ROBERT A. PATTERSON
Assistant Director	R. CHRISTIAN ANDERSON
Assistant to Director	SAMUEL M. TUCKER
Assistant Director	Dr. CHARLES E. FALK

The participating institutions are:

Columbia University	Princeton University
Cornell University	University of Pennsylvania
Harvard University	University of Rochester
The Johns Hopkins University	Yale University
Massachusetts Institute of Technology	

Knolls Atomic Power Laboratory (General Electric Co., contractor), Schnectady, N.Y.

General Manager and Manager, Natural Circulation Reactor (NCR).	B. H. CALDWELL, JR.
Manager, D1G Project	K. A. KESSELRING
Manager, S3G Project	J. D. SELBY

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

Vice President and General Manager (Monsanto Chemical Co.).	H. K. NASON
Plant Manager	EDWARD C. MCCARTHY

Oak Ridge Institute of Nuclear Studies (contractor), Oak Ridge, Tenn.

President of Institute	Dr. PAUL M. GROSS
Executive Director of Institute	Dr. WILLIAM G. POLLARD
Chairman of Council	Dr. R. T. LAGEMANN
Vice Chairman of Council	Dr. W. V. PARKER

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
Fisk 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
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
Vanderbilt University
Virginia Polytechnic Institute
West Virginia University

Oak Ridge National Laboratory (Union Carbide Nuclear Co., Division of Union Carbide Corp., contractor) Oak Ridge, Tenn.

Director	Dr. A. M. WEINBERG
Deputy Director	Dr. J. A. SWARTHOUT
Assistant Director	Dr. G. E. BOYD
Assistant Director	Dr. R. A. CHARPIE
Assistant Director	Dr. R. W. JOHNSON
Assistant Director	Dr. W. H. JORDAN
Assistant Director	M. E. RAMSEY
Assistant Director	Dr. C. E. WINTERS

Raw Materials Development Laboratory (National Lead Co., contractor), Winchester, Mass.

Technical Director and Manager	CHARLES K. MCARTHUR

Sandia Laboratory (Sandia Corp., contractor), Sandia Base, Albuquerque, N. Mex.

President	JULIUS P. MOLNAR
Vice President and General Manager	S. P. SCHWARTZ

University of California at Los Angeles, Atomic Energy Project (University of California, contractor), Los Angeles, Calif.

Director	Dr. JOSEPH F. ROSS
Project Manager	H. B. THOMPSON

University of California, Medical Center, Radiological Laboratory (University of California, contractor), San Francisco, Calif.

Director	Dr. ROBERT S. STONE

University of California E. O. Lawrence Radiation Laboratory (University of California, contractor), Berkeley, Calif.

Director	Dr. EDWIN M. MCMILLAN
Associate Director	Dr. LUIS W. ALVAREZ
Associate Director	Dr. DONALD COOKSEY
Associate Director	Dr. ISADORE PERLMAN
Associate Director	Dr. GLENN T. SEABORG
Associate Director and Director, Livermore Laboratory.	Dr. EDWARD TELLER
Associate Director	Dr. ROBERT L. THORNTON
Associate Director and Director, Donner Laboratory of Medical Physics.	Dr. J. H. LAWRENCE
Business Manager and Managing Engineer	WALLACE B. REYNOLDS

University of Rochester Atomic Energy Project (University of Rochester, contractor), Rochester, N.Y.

Director	Dr. HENRY A. BLAIR
Business Manager	C. S. THOMPSON

National Reactor Testing Station (NRTS) Idaho Falls, Idaho (Three Contractors)

Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho

Project Manager	Dr. R. L. DOAN
Assistant Manager, Operations	J. P. LYON
Assistant Manager, Technical	J. R. HUFFMAN
Assistant Manager, Administration	L. L. LEEDY

Combustion Engineering, Inc., Nuclear Division, Windsor, Conn.

Project Manager	W. B. ALLRED
Site Administrator	E. W. WOOLLACOTT

Aerojet General Corp. and Aerojet General Nucleonics, San Ramon, Calif.

Project Manager	G. B. CARLTON
Assistant Manager	D. C. KING
Site Administrator	C. NEDROW

Nevada Test Site, Las Vegas, Nev.

Eniwetok Proving Ground, Marshall Islands

APPENDIX 4

Radioactive Isotopes Distribution Data and Development Contracts

RADIOISOTOPE DISTRIBUTION BY OAK RIDGE NATIONAL LABORATORY

(Includes Project Transfers, Subsidy Payments, etc.)

Radioisotopes	Aug. 2, 1946–Dec. 31, 1958		Jan. 1, 1959–Nov. 30, 1959		Total to Nov. 30, 1959	
	Activity (Curies)	Shipments	Activity (Curies)	Shipments	Activity (Curies)	Shipments
Carbon 14	69	[1] 2,861	15	255	84	3,116
Cesium 137	17,202	1,028	42,906	188	60,108	1,276
Cobalt 60	509,748	1,877	127,427	146	637,175	2,023
Hydrogen 3	51,998	781	39,421	206	91,419	987
Iodine 131	5,941	41,297	593	2,510	6,534	43,807
Iridium 192	22,196	613	8,216	135	30,412	748
Krypton 85	3,529	168	3,066	122	6,595	280
Phosphorus 32	1,493	24,308	153	1,998	1,646	26,306
Promethium 147	703	263	487	66	1,190	329
Strontium 90 [2]	439	626	116	115	555	741
All others	1,222	44,773	303	6,297	1,525	51,070
Total	614,540	118,655	222,703	12,028	837,243	130,683

[1] Previously (in 25th Semiannual Report) this number included 304 shipments of plaque containing small amounts of carbon 14. These are now included in "All others" item.
[2] Strontium 89 now included in "All others" item.

RADIOISOTOPE SALES FROM OAK RIDGE NATIONAL LABORATORY

Type of Sales	Aug. 2, 1946–Dec. 31, 1958	Jan. 1, 1959–Nov. 30, 1959	Total to Nov. 30, 1959
Domestic	$10,101,218	$1,268,125	$11,369,343
Foreign	1,114,585	264,528	1,379,113
Total commercial sales	11,215,803	1,532,653	12,748,456
Project transfers	1,569,122	165,038	1,734,160
Medical subsidy [1]	2,967,658	233,695	3,201,353
Technical Cooperation Program			
Local sales to Carbide	634,778	72,367	707,145
Civilian defense			
Subtotal	5,171,558	471,100	5,642,658
Total	16,387,361	2,003,753	18,391,114

[1] This represents the cost of the Radioisotope Support Program for research in cancer for the period 1946–1955, since that time these costs are for the 80 percent discount for all approved biomedical research programs including agricultural research.

LOCATION AND TYPE OF NEW LICENSEES

Dec. 1, 1958–Nov. 30, 1959

States	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska				4			4
Alabama	7	1	3	10			21
Arizona	6		1	6			13
Arkansas	2	1	2	1			6
California	66	6	48	31		5	156
Colorado	4	1	9	15		1	30
Connecticut	6	1	8	7			22
Delaware			1	4			5
District of Columbia	2			14	1		17
Florida	20		6	8		1	35
Georgia	7	1		7	1		16
Hawaii	3		1	2			6
Idaho	1		1	1			3
Illinois	16	1	21	22		1	61
Indiana	4	2	7	13		2	28
Iowa	13	2	1	8			24
Kansas	5		1	12		2	20
Kentucky	7	1	3	11			22
Louisiana	9		5	6			20
Maine	3			5			8
Maryland	7	1	4	8		1	21
Massachusetts	19	4	19	10	1		53
Michigan	17	1	20	25		3	66
Minnesota	8	3	5	69			85
Mississippi	2	1	3	7			13
Missouri	11	1	8	28		1	49
Montana	3	1					4
Nebraska	5		1	22			28
Nevada				4			4
New Hampshire	8		1	6			15
New Jersey	12		16	11			39
New Mexico	2		3	1		2	8
New York	45	5	31	27	2	2	112
North Carolina	8	1		29			38
North Dakota	1		1	5			7
Ohio	32	2	19	33	1		87
Oklahoma	11		3	7			21
Oregon	6	1	1	11	1		20
Panama	1						1
Pennsylvania	34	2	29	85		1	151
Puerto Rico	1		1				2
Rhode Island	1		2	5			8
South Carolina	3			2			5
South Dakota	3		1	7			11
Tennessee	4	2	2	17			25
Texas	33	4	25	12		1	75
Utah	2		3	11			16
Vermont	5			2			7
Virginia	9	1	6	11	1		28
Washington	11	1	4	12			28
West Virginia	4		3	11			18
Wisconsin	12		4	17			33
Wyoming		1		12		1	14
Total	501	49	333	694	8	24	1,609

LOCATION AND TYPE OF ALL LICENSEES

Feb. 10, 1956–Nov. 30, 1959

States	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska	2	1	0	2	0	0	5
Alabama	37	4	22	22	0	0	85
Arizona	11	3	5	6	0	0	25
Arkansas	22	2	8	3	0	0	35
California	233	15	204	52	3	9	516
Colorado	30	6	22	27	0	5	90
Connecticut	29	6	40	21	2	1	99
Delaware	3	1	11	7	0	0	22
District of Columbia	22	3	1	35	1	1	63
Florida	66	6	13	15	0	2	102
Georgia	30	5	11	13	1	0	60
Hawaii	13	1	2	4	2	0	22
Idaho	4	1	1	1	0	0	7
Illinois	113	16	109	42	4	4	288
Indiana	40	7	38	15	0	3	103
Iowa	36	7	9	28	0	1	81
Kansas	24	2	9	17	0	2	54
Kentucky	25	4	11	12	0	1	53
Louisiana	33	3	28	9	0	3	76
Maine	7	2	11	8	1	1	30
Maryland	24	5	21	16	0	2	68
Massachusetts	67	26	91	16	5	2	207
Michigan	86	9	57	50	3	5	210
Minnesota	41	7	21	141	0	1	211
Mississippi	10	1	7	7	0	0	25
Missouri	64	9	28	36	1	4	142
Montana	11	2	2	1	0	0	16
Nebraska	17	1	3	22	0	1	44
Nevada	4	1	1	5	0	0	11
New Hampshire	13	3	4	11	1	0	32
New Jersey	69	4	114	23	2	2	214
New Mexico	15	2	9	4	0	2	32
New York	292	26	161	61	8	9	557
North Carolina	46	7	9	37	0	1	100
North Dakota	8	2	1	6	0	0	17
Ohio	126	12	82	46	4	2	272
Oklahoma	34	1	32	11	2	1	81
Oregon	22	4	6	14	1	0	47
Panama	1	0	0	0	0	0	1
Pennsylvania	126	17	151	116	2	1	413
Puerto Rico	8	2	1	3	0	0	14
Rhode Island	9	2	12	8	0	0	31
South Carolina	10	2	4	3	0	0	19
South Dakota	14	1	1	15	0	0	31
Tennessee	35	8	21	24	0	2	90
Texas	145	11	107	29	3	4	299
Utah	9	3	6	15	0	1	34
Vermont	7	1	0	3	0	0	11
Virginia	39	7	28	22	1	3	100
Washington	34	5	18	19	0	1	77
West Virginia	22	1	13	14	0	0	50
Wisconsin	59	3	32	19	4	1	118
Wyoming	8	2	2	14	0	1	27
Total	2,255	282	1,600	1,150	51	79	5,417

SHIPMENTS OF RADIOACTIVE ISOTOPES TO FOREIGN COUNTRIES

Country	Dec. 1, 1958–Nov. 30, 1959	Total Jan. 1, 1947 to Nov. 30, 1959	Country	Dec. 1, 1958–Nov. 30, 1959	Total Jan. 1, 1947 to Nov. 30, 1959
Argentina	24	171	Lebanon	2	31
Australia	82	240	Mexico	103	567
Austria	6	14	Monaco	50	51
Belgian Congo	4	11	Netherlands	49	243
Belgium	66	335	Netherlands, West Indies	5	6
Bermuda	2	20	New Zealand	6	25
Brazil	212	1,025	Nicaragua	10	28
Burma	0	6	Norway	41	147
Canada	829	3,555	Pakistan	12	23
Chile	27	228	Panama, Republic of	24	30
China, Republic of	36	83	Paraguay	7	7
Colombia	26	109	Peru	48	219
Costa Rica	6	15	Philippines	77	246
Cuba	133	865	Poland	1	2
Denmark	89	411	Portugal	17	42
Dominican Republic	6	35	Russia	0	1
Ecuador	20	53	Saudia Arabia	1	2
Egypt	7	24	Scotland	5	7
El Salvador	2	6	South-West Africa	6	11
Finland	15	53	Spain	6	38
France	98	345	Sweden	267	784
Germany, Federal Republic of	125	351	Switzerland	23	149
Ghana	0	1	Syria	0	2
Greece	19	39	Thailand	16	41
Greenland	2	2	Trieste	0	4
Guatemala	21	70	Turkey	0	9
Honduras	0	4	Union of South Africa	15	64
Iceland	0	5	United Kingdom	97	427
India	25	105	Uruguay	0	13
Indonesia	0	6	Venezuela	139	670
Iran	0	8	West Indies Federation—British	5	20
Israel	22	101	Yugoslavia	2	21
Italy	55	158	Others[1]	489	489
Japan	251	1,120			
Korea	8	9	Total	3,741	14,002

[1] Previously reported, i.e., Hawaii, Puerto Rico, etc.

Kind of Isotope	Dec. 1, 1958–Nov. 30, 1959	Total Jan. 1, 1947 to Nov. 30, 1959	Kind of Isotope	Dec. 1, 1958–Nov. 30, 1959	Total Jan. 1, 1947 to Nov. 30, 1959
Iodine 131	1,429	5,412	Calcium 45	32	240
Phosphorus 32	142	1,430	Sulfur 35	3	191
Cobalt 60	220	1,013	Other	1,562	3,971
Carbon 14	95	714			
Iron 55, 59	225	744	Total	3,741	14,002
Strontium 89, 90	33	287			

Research and Development Contracts

RADIOISOTOPES AND INDUSTRIAL RADIATION DEVELOPMENT

Aerojet-General Nucleonics. Radioactive, Independent Transducer-Receiver Systems.

Air Reduction Co., Inc. Fission Product Applications.

Alloyd Research Corp. Design and Construction of an Oxygen Measuring Device for Laboratory and Industrial Use.

Armour Research Foundation. Isotopic Sources of Secondary Radiation.

Armour Research Foundation. An Improved Nuclear Density Gauge.

Armour Research Foundation. Design Study of Cs^{137} as a Source for High Level Gamma Irradiators.

Army Pictorial Service. Production of a Training Film on Industrial Applications of Radioisotopes.

Associated Nucleonics, Inc. Phosphor Stability to High-Energy Beta Radiation.

Associated Nucleonics, Inc. Study of Medical Gamma Facility.

Battelle Memorial Institute. Development of Radioactive Tracer Quality Control System and the Chemistry of Hydrocarbons Trapped in Inclusion Compounds.

Battelle Memorial Institute. Development of Process Control by Use of Intrinsic Radioactive Tracers.

Battelle Memorial Institute. Effect of Phase on the Radiation Induced Nitration of Hydrocarbons.

Battelle Memorial Institute. Radiation-Induced Changes in Polymers Leading to Graft Copolymerization as Influenced by Structural Factors.

Battelle Memorial Institute. Present Status and Proposed Future Research on Development of Radioactive-Tracer Quality-Control Systems and Radiation Chemistry of Inclusion Compounds.

Bituminous Coal Research, Inc. A Study of the Potential Application of Radioisotopes to the Mining, Transportation, Storage and Use of Coal.

Booz-Allen Applied Research, Inc. Study of Feasibility and Economics of Production of Radioisotopes in Power Reactors.

Bureau of Mines. Use of Ruthenium as a Tracer for Ground Water.

University of California. Nuclear Isotopes Institute for College Teachers.

Cem Group (Chemicals-Electronics-Metallurgy). Conversion of Grain to Valuable Chemicals Through the Use of Ionizing Radiation.

University of Chicago (*Chicago Midway Lab.*). Isotope Development Laboratory.

Consolidation Coal Co. Utilization of Radioactive Isotopes in Coal Process Research.

Crucible Steel Co. of America. Radioisotopes in the Study of Metal-to-Metal Wear of Hardened Iron Based Alloys.

Crucible Steel Co. Use of Radioactive Calcium 45 to Determine the Source of Exogenous Inclusions in Low-Carbon Bearing Steels.

Curtiss-Wright Corp. High Intensity Food Irradiator.

Engelhard Industries, Inc. Effect of Irradiation of Solid Catalysts.

Evans Research and Development Corp. Development of a Particle Size Analyser for Industry using Radioisotopes.

General Atomic. Development of Szilard-Chalmers Processes for Production of Short-lived, High Specific Activity Radioisotopes.

General Motors Corp. General Motors Radioisotopes in Industry Training Program.

Georgia Institute of Technology. Isotope Development Program.

Goodyear Tire and Rubber Co. Development of a Method Utilizing Small Quantities of 2 Radioisotopes of Greatly Differing Half-Lives and Radiation Intensities for Dating and Age Determination of a Wide Variety of Industrial Products on which Serial-Number Dating is Cumbersome or Impractical.

Isotopes, Inc. Development of Radioactive Tracer Gas Injection System.

Isotopes, Inc. Gas Industry Survey for Application of Radioactivity.

Isotopes, Inc. The Application of Radioactive Tracers to the Study of Water Resources.

Jarrell-Ash Company. On the Use of a Radioisotope Source for X-Ray Fluorescence Spectroscopy.

Johnston, William H. Laboratories, Inc. Development of a Curriculum of Study for an Industrial Radioisotope Training Course.

Johnston, William H. Laboratories, Inc. Research and Development of Instrumentation and Processes Leading to Large Scale Industrial Applications of Low Level Radioisotope Technology in Research, Development, Manufacturing and Control.

Johnston, William H. Laboratories, Inc. Theoretical and experimental research and development studies of high-level radiation phenomena (Phase 1).

The Library of Congress. Monitoring-type Survey of World Literature on Industrial Radioisotopes Applications.

Lockheed Aircraft Corp. Development Work Relating to a Device for Inspection of Tubes by Gamma Backscatter Techniques.

The Martin Co. Development of Sr 90 Power Sources for Industrial Uses.

Massachusetts Institute of Technology. Radioisotope Development Lab Plus 10^4 curies Co 60.

Midwest Research Institute. Industry Survey for Applications of Radioactivity.

National Canners Association. Investigation of Radioisotopic Tracer Techniques To Detect and Measure Detergent Residues on Washed Food Products and To Evaluate Commercial Food Washing Practices.

National Industrial Conference Board. Radioisotope Applications Economic Study.

Nuclear-Chicago Corp. Exploration of Radiometric Methods for Industrial Process Control.

Nuclear-Chicago Corp. Commercial Instrumentation for Teaching Applied Uses of Isotopes in Industry to College Students.

Nuclear Science and Engineering Corp. Development and Expansion of Radioisotope Applications in Pharmaceutical and Allied Industries.

Picker X-Ray. An X-Ray Generator Using Radioisotope Energy Source.

Purdue Research Foundation. The Applications of Radioactive Isotopes to the Pharmaceutical Industry.

Radiation Applications, Inc. Study of Technology of Fission Beta Sources and Development of Planar Sources of Beta Radiation.

Radiation Applications, Inc. A Study of the Mechanism of Radiation Induced Reactions of Organic Polymers with Inorganic Salts and Organometallic Compounds.

Radiation Applications, Inc. Research and Development Relating to the Application of Foam Separation to Fission Products Separation and Purification.

Research Triangle Institute of North Carolina, Inc. Establishment of a Radioisotope Development Laboratory.

Stanford Research Institute. Survey and Analysis of the Applications of Radioisotopes in Agriculture.

Stanford Research Institute.—To Develop a Training Program for Journeyman Personnel in Radioisotope-using Industries. (Sponsored jointly by the Office of Isotopes Development and the Office of Industrial Relations.)

Technical Operations, Inc. Design and Development of an Oil Testing Machine.

Technical Research Group (TRG, Inc.). Proposal for the Synthesis of Semiconductor Materials by Radiation Induced Reactions.

Texas Engineering Experiment Station. An Investigation of Automatic Activation Analysis (Changed by ltr. of 2/16/59 to: An Investigation of the Development of Computer Coupled Activation Analysis Techniques To Permit the

Measurement of Tracer Quantities of Manganese in Sa Water Samples Containing Large Quantities of Sodium, Chlorine and Bromine.

Textile Research Center. Applications of Nuclear Radiation and Radioisotopes to Textile Materials and Processes.

Textile Research Institute. A Survey of Potential Uses of Radioactive Isotopes in the Textile Industry.

Tracerlab, Inc. Research and Development Program for a Radiochemical Analyzer for Nonradioactive Gases and Study of Radioactive Clathrate Compounds.

U.S. Radium Corp. Development of Krypton 85 Static Elimination Equipment.

Westinghouse Electric Corp. A Proposal for the Development of Transparent Polythylene by Nuclear Radiation to the U.S. Atomic Energy Commission, Office of Isotopes Development.

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APPENDIX 5

COMMISSION-OWNED PATENTS

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING [1]

The following 488 U.S. Letters Patents owned by the United States Government as represented by the Atomic Energy Commission are in addition to the 257 patents listed in the 25th Semiannual report. The patents listed are available for licensing. The total number of patents available for licensing is 2225. Licenses are granted on a non-exclusive, royalty-free basis.

PATENT NO.	TITLE	PATENTEE
2,862,862	Formation by Irradiation of an Expanded, Cellular, Polymeric Body.	A. Charlesby, Headington, England, and M. Ross, London, England.
2,862,526	Method of Separating Hydrogen Isotopes	O. N. Salmon, Schenectady, N.Y.
2,863,062	Method of Measuring the Integrated Energy Output of a Neutronic Chain Reactor.	W. J. Sturm, Chicago, Ill.
2,863,716	Sulphur Dioxide Leaching of Uranium Containing Material.	A. Thunaes, F. T. Rabbits, K. D. Hester and H. W. Smith, Ottawa, Canada
2,863,718	Plutonium Concentration and Decontamination Method.	D. C. Overholt, Putnam County, W. Va. and F. W. Tober, Aiken, S.C.
2,863,719	Method of Improving the Carrier Precipitation of Plutonium.	H. J. Kamack, Richland, Wash., and J. H. Balthis, Oak Ridge, Tenn.
2,863,729	Combination of Hydrogen and Oxygen	H. F. McDuffie, Oak Ridge, Tenn., and C. R. Secoy, Kingston, Tenn.
2,863,735	System for Conversion of UF_4 to UF_6	D. C. Brater, Oak Ridge, Tenn., and J. W. Pike, Chicago, Ill.
2,863,814	Neutronic Reactor Fuel Element	K. A. Kesselring, Schenectady, N.Y., and A. U. Seybolt, Scotia, N.Y.
2,863,815	Nuclear Reactor	R. V. Moore, Appleton, England, J. H. Brown and K. H. Dent, Culcheth, England.
2,863,816	Neutronic Reactor Fuel Element	J. T. Stacy, Columbus, Ohio.
2,863,817	Reactor Coolant Tube Seal	W. J. Morris, Richland, Wash.
2,863,818	Jacketed Reactor Fuel Element	K. F. Smith, Downers Grove, and R. J. Van Thyne, Oak Lawn, Ill.
2,863,830	Process for Decontaminating Liquid Fluorocarbons of Oil Suspended Therein.	H. Schneider, Brooklyn, N.Y., and B. J. Massey, Charleston, W. Va.
2,863,892	Separation of Plutonium from Lanthanum by Chelation-Extraction.	R. A. James and S. G. Thompson, Richmond, Calif.
2,864,042	Servomotor Control System	S. M. MacNeille, Oak Ridge, Tenn.
2,864,664	Separation of Uranium, Plutonium, and Fission Products.	R. Spence and M. W. Lister, Didcot, England.
2,864,665	Reduction of Plutonium to PU+3 by Sodium Dithionite in Potassium Carbonate.	D. R. Miller, Ithaca, N.Y., and H. R. Hookstra, Chicago Heights, Ill.
2,864,666	Production of Uranium Tetrachloride	V. P. Calkins, Oak Ridge, Tenn.
2,864,667	Anionic Exchange Process for the Recovery of Uranium and Vanadium from Carbonate Solutions.	R. H. Bailes, Walnut Creek, D. A. Ellis and H. S. Long, Concord, Calif.
2,864,668	Uranium Extraction Process	W. H. Baldwin and C. E. Higgins, Oak Ridge, Tenn.
2,864,731	Forming Protective Films on Metal	D. H. Gurinsky, Center Moriches, O. F. Kammerer, St. James, J. Sadofsky, Patchogue, and J. R. Weeks, Port Jefferson, N.Y.
2,864,758	Neutronic Reactor Fuel Element	M. H. Shackelford, Schenectady, N.Y.
2,864,759	Nuclear Reactors	E. Long, Warrington, and J. W. Ashley, Appleton, England.
2,864,841	Process for the Recovery of Plutonium	H. A. Potratz, St. Louis, Mo.
2,865,291	Pumps for Liquid Current-Conducting Material	D. A. Watt, Oxford, England.
2,865,703	Process of Purifying Uranium	G. T. Seaborg, Berkeley, Calif.
2,865,704	Method of Separating Uranium, Plutonium, and Fission Products by Bromination and Distillation.	A. H. Jaffey, Chicago, Ill., and G. T. Seaborg, Berkeley, Calif.
2,865,705	Improvement upon the Carrier Precipitation of Plutonium Ions from Nitric Acid Solutions.	R. A. James and S. G. Thompson, Chicago Ill.

[1] Patents listed as of Nov. 24, 1959. Applicants for licenses should apply to Assistant General Counsel for Patents, Office of the General Counsel, U.S. Atomic Energy Commission, Germantown, Md., identifying the subject matter by patent number and title.

PATENT NO.	TITLE	PATENTEE
2,865,737	Method of Purifying Uranium Metal	R. E. Blanco, Oak Ridge, Tenn., and B. H. Morrison, Los Alamos, N. Mex.
2,865,826	Neutronic Reactor	H. B. Stewart, Scotia, N.Y.
2,865,827	Power Generation from Liquid Metal Nuclear Fuel.	O. E. Dwyer, Wading River, N.Y.
2,865,829	Slug Ejector	H. W. Bellas, Richland, Wash., and R. W. Lyon, Oak Ridge, Tenn.
2,865,832	Electrolytic Dissolution of Stainless Steel	E. C. Pitzer, Richmond, Wash.
2,866,680	Alkyl Pyrophosphate Metal Solvent Extractants and Process.	R. S. Long, Concord, Calif.
2,866,741	Control Rod for a Nuclear Reactor and Method of Preparation.	H. H. Hausner, New York, N.Y.
2,866,939	Zero Suppression for Recorders	W. G. C. Fort, Oak Ridge, Tenn.
2,867,500	Method for Removing Contamination from Precipitates.	G. W. Stahl, Waynesboro, Va.
2,867,501	Volatile Chloride Process for the Recovery of Metal Values.	W. R. Hanley, Bronx, N.Y.
2,867,530	Plutonium-Cerium Alloy	A. S. Coffinberry, Los Alamos, N. Mex.
2,867,640	Oxalate Process for Separating Element 94	J. W. Gofman, San Francisco, Calif.
2,867,729	Secondary Electron Multipliers	G. A. Morton and M. W. Green, Princeton, N.J.
2,867,748	Heavy Ion Linear Accelerator	C. M. Van Atta and L. Smith, Berkeley, Calif.; E. R. Beringer, Hamden, Conn.
2,867,803	Circular Cavity Slot Antenna	P. L. Kerley, Albuquerque, N. Mex.
2,868,619	Process for the Recovery of Plutonium	D. M. Ritter, Oak Ridge, Tenn.
2,868,620	Method of Making Plutonium Dioxide	C. S. Garner, Redondo Beach, Calif.
2,868,636	Process of Preparing Uranium Metal	C. H. Prescott, Jr., Berkeley, and F. L. Reynolds, San Francisco, Calif.
2,868,706	Device for Charging or Discharging	S. Untermyer, Downers Grove and E. Hutter, Chicago, Ill.
2,868,707	Process of Making a Neutronic Reactor Fuel Element Composition.	H. W. Alter, Danville, Calif.; J. K. Davidson, R. S. Miller and J. L. Mewherter, Schenectady, N.Y.
2,868,708	Neutronic Reactor	H. C. Vernon, Wilmington, Del.
2,868,817	Plutonium-Cupferron Complex and Method of Removing Plutonium from Solution.	H. A. Potratz, Boulder, Colo.
2,868,974	Resonant Cavity Excitation system	W. R. Baker, Berkeley and J. Riedel, San Pablo, Calif.
2,868,987	Liquid Target	W. W. Salsig, Jr. and M. D. Martin, Berkeley, Calif.
2,868,990	Neutron Source	W. A. Reardon, Park Forest, D. H. Lennox, Chicago, and R. G. Nobles, Lemont, Ill.
2,868,991	High Energy Gaseous Plasma Containment Device.	V. Josephson, Palos Verdes Estates, Calif. and J. E. Hammel, Los Alamos, N. Mex.
2,868,992	Reactor Viewing Apparatus	G. S. Monk, Chicago, Ill.
2,869,784	Multiplier Circuit	R. E. Thomas, Walnut Creek, Calif.
2,869,786	Adder Circuit	D. H. Jacobsohn, Chicago, Ill., and L. C. Merrill, Fort Wayne, Ind.
2,869,979	Slurry Solvent Extraction Process for the Recovery of Metals from Solid Materials.	R. R. Grinstead, Concord, Calif.
2,869,980	Process for the Recovery of Metals from High-Lime Carnotite Ores.	R. R. Grinstead, Concord, Calif.
2,869,981	Process for the Purification of Uranium	S. Rosenfeld (deceased).
2,869,982	Recovery of Pu Values by Fluorination and Fractionation.	H. S. Brown, Oak Ridge, Tenn., and D. S. Webster, Richland, Wash.
2,869,983	Separation of Metal Salts by adsorption	D. M. Gruen, Downers Grove, Ill.
2,870,031	Graphite Extrusions	T. M. Benziger, Los Alamos, N. Mex.
2,870,075	Nuclear Reactor Unloading	M. C. Leverett, Oak Ridge, Tenn., and J. P. Howe, Richland, Wash.
2,870,076	Method and Apparatus for Improving Performance of a Fast Reactor.	L. J. Koch, Clarendon Hills, Ill.
2,870,339	Fabrication of Neutron Sources	J. H. Birden, Dayton, Ohio.
2,870,484	Spherical Die	J. P. Livingston, Los Alamos, N. Mex.
2,870,907	Forming Tubes and Rods of Uranium Metal by Extrusion.	E. C. Creutz, Chicago, Ill.
2,871,042	Supporting and Heat Insulation Means	B. W. Birmingham, E. H. Brown, E. B. Scott and P. C. Vander Arend, Boulder, Colo.
2,871,092	Niobium-Tantalum Separation	H. A. Wilhelm, Ames, Iowa, and R. A. Foos, Kenmore, N.Y.
2,871,176	Nuclear Reactor Component Cladding Material	J. E. Draley, Clarendon Hills and W. E. Ruther, Skokie, Ill.
2,871,251	Process for the Separation of Heavy Metals	J. W. Gofman and R. E. Connick, Berkeley, Calif.; A. C. Wahl, Los Alamos, N. Mex.
2,871,361	Calutron Assembling and Disassembling Apparatus.	R. E. Andrews, Watertown, Mass.
2,871,362	Calutron Assembling and Disassembling Means	R. E. Andrews, Watertown, and J. Thornton, Squantum, Mass.
2,871,363	Calutron Assembling and Disassembling Apparatus.	R. E. Andrews, Watertown, Mass.

PATENT No.	TITLE	PATENTEE
2,871,364	Calutrons	E. O. Lawrence (deceased).
2,871,555	Method of Jacketing Fissionable Materials	L. M. Foster, Providence, R. I.
2,871,558	Sheathing Uranium	E. W. Colbeck, Northwich, England.
2,872,105	Rotor End Cap	F. C. Rushing, Pittsburgh, Pa.
2,872,284	Recovery of Protactinium	K. A. Kraus, Oak Ridge, and G. E. Moore, Martel, Tenn.
2,872,285	Solvent Extraction of Uranium Values	H. M. Feder and M. Ader, Park Forest; L. E. Ross, Naperville, Ill.
2,872,286	Bismuth Phosphate Carrier Process for Pu Recovery.	T. G. Finzel, Cleveland, Ohio.
2,872,287	Method of Separating Tetravalent Plutonium Values from Cerium Subgroup Rare Earth Values.	R. B. Duffield, Champaign, Ill., and R. W. Stoughton, Oak Ridge, Tenn.
2,872,288	Carbonate Method of Separation of Tetravalent Plutonium from Fission Product Values.	R. B. Duffield, Champaign, Ill., and R. W. Stoughton, Oak Ridge, Tenn.
2,872,296	Continuous Dissolver Extractor for Processing Metal.	R. B. Lemon and J. A. Buckham, Idaho Falls, Idaho.
2,872,307	Thorium-Carbon Alloys	H. A. Wilhelm and R. E. Rundle, Ames, Iowa.
2,872,308	Metal Compositions	A. U. Seybolt, Scotia, N.Y.
2,872,310	Zirconium Alloy	H. A. Wilhelm, and D. Peterson, Ames, Iowa; R. F. Russi, Jr., Livermore, Calif.
2,872,343	Method of Protectively Coating Uranium	L. D. Eubank, South Euclid, Ohio, and E. R. Boller, Marion, Ind.
2,872,348	Fused Salt Method for Coating Uranium with a Metal.	L. D. Eubank, South Euclid, Ohio.
2,872,361	Stripping Metal Coatings	H. T. Siefen, Jackson, Mich., and J. M. Campbell, Burlington, Iowa.
2,872,363	Method of Working Beryllium	R. E. Macherey, Chicago, Ill.
2,872,387	Anodic Treatment of Uranium	M. Kolodney, New York, N.Y.
2,872,389	Treatment of Uranium Surfaces	C. J. Slunder, Columbus, Ohio.
2,872,394	Recovery of Uranium from Tungsten	K. C. Newnam, Angola, Ind.
2,872,398	Neutron-Irradiated Structures	E. L. Ashley, J. W. Ashley, H. W. Bowker, R. H. Hall and J. W. Kendall, Strand, London, England.
2,872,399	Self-Reactivating Neutron Source for a Neutronic Reactor.	H. W. Newsom, Durham, N.C.
2,872,400	Reactor Monitoring	S. J. Bugbee, Morgantown, W. Va., V. Hanson, Yorklyn, and D. F. Babcock, Wilmington, Del.
2,872,401	Jacketed Fuel Element	E. P. Wigner and L. Szilard, Chicago, Ill.
2,872,402	Method of Preparation of Material for Neutron Bombardment.	C. L. Ura, Hamtramck, Mich.; O. Sisman and R. B. Briggs, Oak Ridge, Tenn.
2,872,467	Preparation of Oxalates of Metals of Atomic Number Greater Than 88.	R. B. Duffield, Champaign, Ill.
2,872,545	Remote Controlled Switching Device	J. C. Hobbs, Coral Gables, Fla.
2,872,574	Cloverleaf Cyclotron	E. M. McMillan and D. L. Judd, Berkeley, Calif.
2,872,719	Method of Fabricating Small Spherical Pellets	H. C. Brassfield, Fosters, Ohio, C. T. Durham, Jr., Roanoke, Va.
2,873,065	Differential Analyzer	E. G. Sorensen, Alban, and C. M. Gordon, San Pablo, Calif.
2,873,108	Apparatus for High Purity Metal Recovery	T. T. Magel, Cambridge, Mass.
2,873,165	Uranium Recovery Process	R. H. Bailes, Walnut Creek, R. S. Long, Vallejo, R. S. Olson, San Francisco and H. O. Kerlinger, Berkeley, Calif.
2,873,167	Processes of Reclaiming Uranium from Solutions	L. R. Zumwalt, Oak Ridge, Tenn.
2,873,168	Recovery of Pu from Cerium Trifluoride by Fluorination.	H. S. Brown and E. G. Bohlmann Oak Ridge, Tenn.
2,873,169	Basic Peroxide Precipitation Method of Separating Plutonium from Contaminants.	G. T. Seaborg, Albany and I. Perlman, Berkeley, Calif.
2,873,170	Anion Exchange Method for Separation of Metal Values.	E. K. Hyde, Berkeley, Calif., and B. A. Raby, Dayton, Ohio.
2,873,174	Reactor Nozzle Assembly	F. C. Capuder, Cincinnati, Ohio, and J. R. Dearwater, Park Hills, Ky.
2,873,184	Thermal Decomposition of Uranium Compounds.	T. T. Magel, Cambridge, Mass., and L. Brewer, Berkeley, Calif.
2,873,185	Deposition of Metal on Nonmetal Filament	T. T. Magel, Cambridge, Mass.
2,873,186	Thorium-Silicon-Beryllium Alloys	F. G. Foote, Plandome, N.Y.
2,873,209	Leveling Metal Coatings	H. A. Gage, E. Cleveland, Ohio.
2,873,238	Method of Making Jacketed Fuel Slug	L. A. Ohlinger and G. J. Young, Chicago, Ill.
2,873,242	Neutronic Reactor System	M. Treshow, Hinsdale, Ill.
2,873,243	Means for Shielding and Cooling Reactors	E. P. Wigner, L. A. Ohlinger, G. J. Young, Chicago, Ill., and A. M. Weinberg, Oak Ridge, Tenn.
2,873,375	Thermally Operated Vapor Valve	J. G. Dorward, Jr., Alameda, Calif.
2,873,376	Ion Producing Mechanisms	W. M. Brobeck, Berkeley, Calif.
2,873,388	Pulse Counter	D. E. Trumbo, Pleasant Hill, Calif.
2,873,400	Ion Switch	B. Cook, Livermore, Calif.
2,873,603	Method of Testing Hermetic Containers	L. B. Borst, Oak Ridge, Tenn.

PATENT NO.	TITLE	PATENTEE
2,873,853	Canned Slug	M. Burton, Mishawaka, Ind.
2,874,025	Oxidation of Transuranic Elements	R. L. Moore, Richland, Wash.
2,874,026	Process of Preparing a Fluoride of Tetravalent Uranium.	E. J. Wheelwright, Richland, Wash.
2,874,106	Homogeneous Nuclear Reactor	R. P. Hammond and H. M. Busey, Los Alamos, N. Mex.
2,874,107	Device for Treating Materials	L. A. Ohlinger and G. J. Young, Chicago, Ill.; F. Seitz, Pittsburgh, Pa.
2,874,108	Test-Hole Construction for a Neutronic Reactor	L. A. Ohlinger and G. J. Young, Chicago, Ill.; F. Seitz Pittsburgh, Pa.
2,874,109	Means for Terminating Nuclear Reactions	C. M. Cooper Newark, Del.
2,874,235	Ultra-Stabilized D.C. Amplifier	E. C. Hartwig, Walnut Creek, R. W. Kuenning, Livermore and R. C. Acker, Berkeley, Calif.
2,874,295	Mass Separators	F. Oppenheimer, Pagosa Springs, Colo., and J. W. Bell, Berkeley, Calif.
2,874,296	Calutron Ion Source	E. J. Lofgren, Berkeley, Calif.
2,874,305	Radiation Integrator	H. N. Wilson, Oak Ridge, and F. M. Glass, Norris, Tenn.
2,874,306	Measuring Apparatus	T. P. Kohman and B. B. Weissbourd, Chicago, Ill.
2,874,307	Reactor Shield	E. P. Wigner, L. A. Ohlinger, and G. J. Young, Chicago, Ill.; A. M. Weinberg, Oak Ridge, Tenn.
2,874,459	Method and Apparatus for Fabricating Tubular Units.	G. W. Haldeman, Chicago, Ill.
2,874,852	Elevating Mechanism	H. S. Frederick, Middlesex County, Mass., and M. A. Kinsella, Wilmington Manor, Del.
2,874,860	Hand Truck for Handling Equipment	D. W. King, Knoxville, Tenn.
2,875,021	Method of Separating Uranium Values, Plutonium Values and Fission Products by Chlorination.	H. S. Brown and G. T. Seaborg, Chicago, Ill.
2,875,022	Method of Forming Plutonium-Bearing Carrier Precipitates and Washing Same.	B. F. Faris, Richland, Wash.
2,875,023	Process of Recovering Uranium from Its Ores	P. Galvanek, Jr., Boston, Mass.
2,875,024	Separation of Barium Values from Uranyl Nitrate Solutions.	E. R. Tompkins, Oak Ridge, Tenn.
2,875,025	Process of Forming Plutonium Salts from Plutonium Oxalates.	C. S. Garner, Redondo Beach, Calif.
2,875,026	Precipitation Method of Separating Plutonium from Contaminating Elements.	R. B. Duffield, Champaign, Ill.
2,875,041	Method of Making Alloys of Beryllium with Plutonium and the Like.	O. J. C. Runnalls, Deep River, Ontario, Canada.
2,875,143	Push-Pull Power Reactor	D. K. Froman, Los Alamos, N. Mex.
2,875,285	Detector for Telephone Surreptitious Listening Techniques.	E. D. Hightower, Kensington, Md.
2,875,339	Calutron Ion Sources	W. M. Brobeck, Berkeley, Calif.
2,875,343	Personnel Dosimeter	R. D. Birkhoff, Knoxville, and H. H. Hubbell, Jr., Oak Ridge, Tenn.; R. M. Johnson, Jr., Pittsburgh, Pa.
2,875,345	Method and Apparatus for Handling Radioactive Products.	D. Nicoll, Downers Grove, Ill.
2,875,346	Overall Optical Viewer	G. S. Monk, Chicago, Ill.
2,876,867	Brake Device	T. J. O'Donnell, Chicago, Ill.
2,876,949	Centrifugal Separators	C. Skarstrom, Pearl River, N.Y.
2,877,087	Uranium Separation Process	W. H. McVey and W. H. Reas, Berkeley, Calif.
2,877,088	Method and Apparatus for Making Uranium-Hydride Compacts.	W. W. Wellborn and J. R. Armstrong, Los Alamos, N. Mex.
2,877,089	Elution of Uranium from Resin	C. D. McLean, Springdale, Conn.
2,877,090	Process Using Bismuth Phosphate as a Carrier Precipitate for Fission Products and Plutonium Values.	T. G. Finzel, Cleveland, Ohio.
2,877,091	Dehydration of Deuterium Oxide Slurries	C. F. Hiskey, New York, N.Y.
2,877,092	Coordination Compound-Solvent Extraction Process for Uranium Recovery.	W. H. Reas, Berkeley, Calif.
2,877,093	Adsorption Method for Separating Metal Cations	E. R. Tompkins and G. W. Parker, Oak Ridge, Tenn.
2,877,094	Adsorption Method for Separating Metal Cations	J. X. Khym, Santa Fe, N. Mex.
2,877,109	Process for Separating Uranium Fission Products	F. H. Spedding and T. A. Butler, Ames, Iowa; I. B. Johns, Santa Fe, N. Mex.
2,877,131	Method and Coating Composition for Protecting and Decontaminating Surfaces.	D. C. Overholt and M. D. Peterson, Oak Ridge, Tenn.
2,877,149	Method of Hot Rolling Uranium Metal	A. R. Kaufmann, Lexington, Mass.
2,877,170	Support Device for Use in a Nuclear Reactor	F. G. Greenhalgh, Wigan, and E. Long, Warrington, England.
2,877,171	Means for Shielding Reactors	M. Burton and L. T. McClinton, Oak Ridge, Tenn.; and W. M. Garrison, Richland, Wash.
2,877,250	Recovery of Uranium Values	K. B. Brown and D. J. Crouse, Jr., Oak Ridge; and J. G. Moore, Clinton, Tenn.

PATENT NO.	TITLE	PATENTEE
2,877,314	Electric Contact Means	J. W. Grear, Jr., Albuquerque, N. Mex.
2,877,348	Logarithmic Amplifier	E. J. Wade, Scotia, N.Y., and R. S. Stone, San Diego, Calif.
2,877,406	Non-Destructive Method and Means for Flaw Detection.	R. Hochschild, Richland, Wash.
2,877,408	Inspection Means for Induction Motors	A. W. Williams, Paducah, Ky.
2,877,447	Binary Excess-3 Converter	C. M. Kenrich, Livermore, Calif., and B. L. Crew, Philadelphia, Pa.
2,878,100	Formation of Uranuim Precipitates	J. M. Googin, Jr., Oak Ridge, Tenn.
2,878,382	Precision Time-Delay Circuit	R. Creveling, Albuquerque, N. Mex.
2,878,387	Beam Control Probe	A. W. Chesterman, Livermore, Calif.
2,878,401	High Voltage Generator	A. J. Schemin, Oakland, Calif.
2,879,130	Process for Recovering Uranium	C. E. MacWood, Berkeley, Calif., C. W. Wilder, Oak Ridge, Tenn., and D. Altman, Pasadena, Calif.
2,879,144	Pumps	J. D. Thornton, Abingdon, England.
2,879,216	Neutronic Reactor	H. Hurwitz, Jr., C. Mannal and E. A. Luebke, Schenectady, N.Y.; J. H. Payne, Ballston Spa, N.Y., and H. Brooks, Cambridge, Mass.
2,879,228	Process for Purifying Crude Perfluorocarbons	R. E. Holeton, Woodstown, N.J.
2,879,247	Molded Sealing Element	B. W. Bradford and W. J. Skinner, Norton on-Tees, England.
2,879,664	Annular Impactor Sampling Device	G. W. C. Tait, Deep River, Ontario, Canada.
2,880,059	Production of Uranium-Calcium Fluoride	W. B. Tolley, Tuscon, Ariz.
2,880,155	Control for Neutronic Reactor	H. V. Lichtenberger, Idaho Falls, Idaho, and R. A. Cameron, Danville, Calif.
2,880,262	Structure for Sub-Assemblies of Electronic Equipment.	P. R. Bell and C. C. Harris, Oak Ridge, Tenn.
2,880,318	Peak Limiting Amplifier	W. W. Goldsworthy, Orinda, and J. B. Robison, Richmond, Calif.
2,880,636	Cutting and Wedging Jacket Remover	M. Freedman and S. Raynor, Chicago, Ill.
2,881,094	Process of Coating with Nickel by the Decomposition of Nickel Carbonyl.	T. B. Hoover, Oak Ridge, Tenn.
2,881,391	Velocity Indicator for Extrusion Press	F. J. Digney, Jr., N. Augusta, S. Dak. and F. Bevilacqua, Fort Worth, Tex.
2,881,619	Coaxial Control Rod Drive Mechanism for Neutronic Reactors.	R. J. Fox and L. C. Oakes, Knoxville, Tenn.
2,882,123	Process for the Recovery of Uranium from Phosphatic Ore.	R. S. Long, Concord, Calif.
2,882,124	Solvent Extraction Process for Plutonium	G. T. Seaborg, Chicago, Ill.
2,882,125	Volatile Fluoride Process for Separating Plutonium from Other Materials.	F. H. Spedding and A. S. Newton, Ames, Iowa.
2,882,129	Nitric Acid Recovery from Waste Solutions	A. S. Wilson, Richland, Wash.
2,882,248	Ion Exchange Substances by Saponification of Allyl Phosphate Polymers.	J. Kennedy, Harwell, England.
2,882,396	High Energy Particle Accelerator	E. D. Courant, Blue Point, and H. S. Snyder, Bayport, N.Y.; M. S. Livingston, Belmont, Mass.
2,882,406	Ion Source Unit for Calutron	D. H. Sloan, Silver Spring, Md., H. F. Yockey, Oak Ridge, Tenn. and F. H. Schmidt, Berkeley, Calif.
2,882,407	Calutron	E. O. Lawrence (deceased) and W. M. Brobeck, Berkeley, Calif.
2,882,408	Ion Source for a Calutron	E. J. Lofgren, Richmond, Calif.
2,882,409	Dual Heated Ion Source Structure Having Arc Shifting Means.	E. O. Lawrence (deceased).
2,882,410	Ion Source	W. M. Brobeck, Berkeley, Calif.
2,882,411	Ion Producing Mechanism	F. F. Oppenheimer, Pagosa Springs, Colo.
2,882,442	Method for Stabilizing Klystrons	D. W. Magnuson, Knoxville, and DeF. F. Smith, Kingston, Tenn.
2,883,264	Solvent Extraction of Thorium Values from Aqueous Solutions.	J. C. Warf, Los Angeles, Calif.
2,883,330	Liquid Metal Compositions Containing Uranium	R. J. Teitel, E. Patchogue, N.Y.
2,883,535	Thyratron Switch	R. Creveling and N. A. Bourgeois, Jr., Albuquerque, N. Mex.
2,883,536	Electronic Phase Control Circuit	J. D. Salisbury, Livermore, and W. W. Klein, Fullerton, Calif.; C. F. Hansen, Bountiful, Utah.
2,883,541	Ion Producing Mechanism (charge cups)	W. M. Brobeck, Berkeley, Calif.
2,883,551	High Voltage Generator	G. V. Zito, Jersey City, N.J.
2,883,552	Particle Beam Tracking Circuit	O. A. Anderson, Oakland, Calif.
2,883,553	Fabrication of Neutron Sources	J. H. Birden, Dayton, Ohio.
2,883,580	Pulsed Ion Source	W. D. Kilpatrick, Livermore, Calif.
2,884,305	Plutonium Purification Process Employing Thorium Pyrophosphate Carrier.	E. L. King, Madison, Wis.

PATENT NO.	TITLE	PATENTEE
2,884,364	Method of Electroplating on Uranium	E. W. Rebol, Richland, Wash., and R. F. Wehrmann, Dayton, Ohio.
2,884,529	Gaseous Scintillation Counter	C. Eggler, Downers Grove, and C. M. Huddleston, Naperville, Ill.
2,885,260	Method for Decontamination of Reactor Solutions.	W. J. Maraman, H. R. Baxman and R. D. Baker, Los Alamos, N. Mex.
2,885,283	Plutonium-Aluminum Alloys	F. W. Schonfeld, Los Alamos, N. Mex.; C. R. Tipton, Jr., Columbus, Ohio.
2,885,329	Method for Electro-Nickel Plating Wolfram Carbide.	H. L. Slatin, New York, N.Y.
2,885,335	Nuclear Reactor Fuel Element	R. V. Moore, Appleton, and G. Packman, Risley, England.
2,885,496	Low-Level Direct Current Amplifier	Q. A. Kerns, Berkeley, Calif.
2,885,497	Drift Compensated Direct Coupled Amplifier	A. A. Windsor, Berkeley, Calif.
2,885,893	Reactor Control Mechanism	J. A. Lane, R. E. Engberg, J. M. Welch, Oak Ridge, Tenn.
2,886,406	Recovery of Plutonium and Neptunium from Aqueous Solutions.	G. T. Seaborg, Chicago, Ill.; R. C. Thompson and F. W. Albaugh, Richland, Wash.
2,886,407	Treatment of Plutonium Solution with NO or NO_2 Prior to Removal of Tetravalent Plutonium from Said Solution by Carrier Precipitation.	G. E. Moore, Oak Ridge, Tenn.
2,886,408	Enhancing Precipitations by Applying Soluble Complex Fluorine-Containing Reagents.	G. W. Stahl, Richland, Wash.
2,886,409	Improved Processes for Recovering and Purifying Uranium.	T. D. Price and A. V. Henrickson, Oak Ridge, Tenn.
2,886,410	Non-Aqueous Dissolution of Massive Plutonium	J. G. Reavis and J. A. Leary, Los Alamos, N. Mex.; K. A. Walsh, Lakeland, Fla.
2,886,429	Method for the Reduction of Uranium Compounds.	W. H. Cooke (deceased); J. W. C. Crawford, Frodsham, England.
2,886,430	Uranium Compositions	N. P. Allen and J. D. Grogan, Teddington, England.
2,886,431	Vanadium Alloys	K. F. Smith, Downers Grove, and R. J. Van Thyne, Oak Lawn, Ill.
2,886,433	Production of Sheet from Particulate Material	A. Blainey, Strand, London, England.
2,886,468	Nickel Plating Process	T. B. Hoover and T. E. Zava, Oak Ridge, Tenn.
2,886,503	Jacketed Fuel Elements for Graphite Moderated Reactors.	L. Szilard, Chicago, Ill., E. P. Wigner, Princeton, N.J., and E. C. Creutz, Santa Fe, N. Mex.
2,886,504	Plutonium-Cerium-Copper Alloys	A. S. Coffinberry, Los Alamos, N. Mex.
2,886,775	Variable Time-Interval Generator	J. E. Gross, Albuquerque, N. Mex.
2,887,355	Method of Preparing Protactinium Values	L. I. Katzin, Chicago, Ill., R. G. Larson, Valparaiso, Ind., R. C. Thompson, Austin, Tex. and Q. V. Winkle, Columbus, Ohio.
2,887,357	Dry Fluorine Separation Method	G. T. Seaborg, Chicago, Ill., J. W. Gofman, Berkeley, Calif., and R. W. Stoughton, Oak Ridge, Tenn.
2,887,358	Large Scale Method for the Production and Purification of Curium.	G. H. Higgins and W. W. T. Crane, Livermore, Calif.
2,887,373	Method of Cleaning Metal Surfaces	H. W. Winkler, Battle Creek, Mich., J. W. Morfitt, Oak Ridge, Tenn., and T. H. Little, Philadelphia, Pa.
2,887,876	Apparatus for Testing Expansion of Movable Members.	M. Frankel and W. B. Shank, Los Angeles, Calif.
2,888,563	Calutron Cathode Interlock Circuit	L. W. Baldwin, San Diego, Calif.
2,888,564	Calutron Protective Circuit	F. H. Schmidt, Berkeley, Calif.
2,888,565	Calutron	W. M. Brobeck, Berkeley, Calif.
2,888,566	Ion Source Slit Cleaner for Calutron	E. O. Lawrence (deceased).
2,888,878	Neutronic Reactor Fuel Pump	W. G. Cobb, Oak Ridge, Tenn.
2,889,462	Calutron Ion Source	F. F. Oppenheimer, Pagosa Springs, Colo.
2,890,098	Reduction of Plutonium Values in an Acidic Aqueous Solution with Formaldehyde.	C. M. Olson, Newark, Del.
2,890,099	Recovery of Uranium from Low Grade Uranium Bearing Ores.	H. B. Rhodes, Buffalo, N.Y., W. F. Pesold, Wyandotte, Mich. and J. M. Hirshon, Doylestown, Pa.
2,890,110	Production of Plutonium from Plutonium Fluoride.	R. D. Baker, Los Alamos, N. Mex.
2,890,158	Neutronic Reactor	L. A. Ohlinger, E. P. Wigner, A. M. Weinberg, and G. J. Young, Chicago, Ill.
2,890,221	Method for Preparing Normorphine	H. Rapoport, Berkeley, Calif., and M. Look, San Francisco, Calif.
2,890,337	Ion Beam Focusing Means for Calutron	J. G. Backus, Los Angeles, Calif.
2,890,338	High Voltage Regulator	B. T. Wright, Oakland, Calif.
2,890,339	Ion Producing Mechanism	F. F. Oppenheimer, Pagosa Springs, Colo.
2,890,340	Calutron	W. M. Brobeck, Berkeley, Calif., E. J. Lofgren, Albany, Calif., and R. L. Thornton, Berkeley, Calif.
2,890,348	Particle Accelerator	T. Ohkawa, Madison, Wis.
2,890,932	Separation by Adsorption	C. S. Lowe, Germantown, Ohio.
2,890,933	Recovery of Uranium Values from Uranium Bearing Raw Materials.	E. J. Michal, Corpus Christie, Tex., and E. R. Porter, Johannesburg, Union of South Africa

PATENT NO.	TITLE	PATENTEE
2,890,954	Plutonium Alloys	W. Chynoweth, White Plains, N.Y.
2,891,155	Precision Time Delay Generator	B. J. Carr and V. D. Peckham, Albuquerque, N. Mex.
2,891,161	Calutron	W. E. Parkins, Los Angeles, Calif.
2,891,162	Calutron Receiver	S. W. Barnes, Rochester, N.Y.
2,891,163	Calutron	A. F. Clark, Berkeley, Calif.
2,891,168	Portable Source of Radioactivity	R.C.Goertz and L. M. Safranski, Downers Grove, K. R. Ferguson, Lisle, E.W. Rylander, Lemont, Ill.
2,891,839	Production of Curium 245	E. K. Hulet,Walnut Creek,Calif, and S. G. Thompson, Concord, Calif.
2,891,840	Method of Processing Neutronic Reactor Fuel Elements.	M. H. Curtis, Richland, Wash.
2,891,841	Recovery of Plutonium Values from Dilute Solution by Partial Precipitation of Carrier Compounds.	D. M. Ritter, Seattle, Wash.
2,892,044	Linear Amplifier	E. Fairstein, Oak Ridge, Tenn.
2,892,091	Continuous Alpha Air Monitor	D. R. Sawle, Oakland, Calif.
2,892,114	Continuous Plasma Generator	W. K. Kilpatrick, Livermore, Calif.
2,892,387	Internal Cutting Device	W. H. Russell, Jr.,Tullahoma,Tenn.
2,892,676	Improved Process of Plutonium Carrier Precipitation.	B. J. Faris, Chatham, Pa.
2,892,677	Separation of Uranium from Thorium and Protactinium.	W. K. R. Musgrave, Durham, England.
2,892,678	Method of Maintaining Plutonium in a Higher State of Oxidation During Processing.	S. G. Thompson and D. R. Miller, Richmond, Calif.
2,892,679	*Ion-Exchange Method for Separating Radium* from Radium-Barium Mixtures.	M. E. *Fuentevilla, Woodbury*, N.J.
2,892,680	Recovery of Cesium from Waste Solution	W. H. Burgus, Idaho Falls, Idaho
2,892,681	Separation Process for Zirconium and Compounds Thereof.	H.W.Crandall, Berkeley,Calif., and J. R. Thomas, Silver Spring, Md.
2,892,701	Pyrochemical Decontamination Method for Reactor Fuel.	A. G. Buyers, Woodland Hills, Calif.
2,892,765	Neutron Density Control in a Neutronic Reactor	G. J. Young, Chicago, Ill.
2,892,855	Recovery of Uranium by Cycloalkyldi-Thiocarbamate Complexing.	O. R. Neville, Oak Ridge, Tenn.
2,893,575	Loading Machine for Reactors	S. L. Simon, Cleveland, Ohio.
2,893,822	Separation of Uranium from Other Metals	H. H. Hyman, Chicago, Ill.
2,893,823	Separation of Uranium from Thorium	N. N. Hellman, Peoria, Ill.
2,893,824	Uranium Recovery Process	H. H. Hyman, Chicago, Ill., and J. H. Dreher, El Cerrito, Calif.
2,893,825	Separation of Protactinium from Contaminants	J. G. Malm and S. Fried, Chicago, Ill.
2,893,826	Platinum Hexafluoride and Method of Fluorinating Plutonium Containing Mixtures Therewith.	J. G. Malm, Chicago, B. Weinstock,Western Springs, and H. H. Claasen, Wheaton, Ill.
2,893,827	Separation of Americium from Promethium	R. S. Pressly, Loudon, Tenn.
2,893,863	Process for Removing Aluminum Coatings	J. Flox, Chicago, Ill.
2,893,928	Preparation of Plutonium	M. Kolodney, New York, N.Y.
2,893,936	Process for Continuously Separating Irradiation Products of Thorium.	L. P. Hatch, F.T. Miles,T.V. Sheehan, R. J. Heus and R. H. Wiswall, Suffolk County, N.Y.
2,894,135	Charge Bottle for a Mass Separator	P. H. Davidson, Millbrae, Calif.
2,894,137	Calutron Receiver	H. F. York, Berkeley, Calif.
2,894,138	Slit Adjustment Clamp	K. R. McKenzie, Richmond, Calif.
2,894,320	Coating Uranium from Carbonyls	D. H. Gurinsky, Center Moriches, N.Y., and S. Steingiser, Storrs, Conn.
2,894,647	Positioning Device	W. H. McCorkle, Chicago, Ill.
2,894,688	*Electronic Analog Computer for Determining* Radioactive Disintegration.	H. P. *Robinson, Lafayette*, Calif.
2,894,804	Process of Extracting Uranium and Radium from Ores.	C.W. Sawyer, Butte, Mont.; R.W. Handley (deceased).
2,894,805	Separation Process for Actinide Elements and Compounds Thereof.	L. B. Werner, I. Perlman, and M. Calvin, Berkeley, Calif.
2,894,806	Recovery of Protactinium from Aqueous solutions.	R. E. Elson, Park Forest, Ill.
2,894,807	Cation Exchange Method for the Recovery of Protactinium.	J. C. Sullivan and M. H. Studier, Chicago, Ill.
2,894,808	Method for Recovering Uranium from Oils	L. H. Gooch, Norris, Tenn.
2,894,810	Columbic Oxide Adsorption Process for Separating Uranium and Plutonium Ions.	R. H. Beaton, Oak Ridge, Tenn.
2,894,811	Process for Making Uranium Hexafluoride	R. Rosen, Elizabeth, N.J.
2,894,812	Dissolution of Plutonium Containing Carrier Precipitate by Carbonate Metathesis and Separation of Sulfide Impurities Therefrom by Sulfide Precipitation.	R. B. Duffield, Champaign, Ill.
2,894,816	Solvent Extraction of Ruthenium	H. H. Hyman, Chicago, Ill., and G. R. Leader, Lexington, Ky.
2,894,817	Polonium Separation Process	D. G. Karraker, Berkeley, Calif.
2,894,818	Separation of Ruthenium from Aqueous Solutions	M. Beederman, S. Vogler and H. H. Hyman, Chicago, Ill.
2,894,827	Uranium Separation Process	E.K. Hyde, Berkeley, Calif., L. I. Katzin, Chicago, Ill., and M. J. Wolf, Peoria, Ill.

PATENT No.	TITLE	PATENTEE
2,894,832	Process of Producing Actinide Metals	T. T. Magel, Cambridge, Mass.
2,894,837	Method for Producing Cemented Carbide Articles.	E. I. Onstott, Le Roig, Ill., and G. D. Cremer, Pelham Manor, N.Y
2,894,866	Method for Annealing and Rolling Zirconium Base Alloys.	M. L. Pickelsimer, Knoxville, Tenn.
2,894,883	Method of Electropolishing	D. E. Walker, Chicago Hghts., and R. A. Noland, Chicago, Ill.
2,894,884	Method of Applying Nickel Coatings on Uranium.	A. G. Gray, Cleveland, Ohio.
2,894,885	Method of Applying Copper Coatings to Uranium.	A. G. Gray, Cleveland, Ohio.
2,894,889	Jacketed Uranium Slugs and Method	S. H. Paine, Jr., Oak Park, Ill.
2,894,890	Jacketed Uranium	H. A. Saller (deceased) and J. R. Keeler, Columbus, Ohio.
2,894,891	Nuclear Reactor	J. J. Grebe, Midland, Mich.
2,894,892	Neutronic Reactor Charging and Discharging	W. H. Zinn, Chicago, Ill.
2,894,993	Fuel Element for Nuclear Reactor	K. G. Carney, Jr., Scotia, N.Y.
2,895,047	Timing Circuit	J. W. Heyd, Dayton, Ohio.
2,895,051	Apparatus for Measuring Neutron Cross Sections.	L. Cranberg, Los Alamos, N. Mex.
2,895,053	Measuring Projector	J. V. Franck and P. S. Broadhead, Lafayette, and E. W. Skiff, Pleasant Hill, Calif.
2,895,791	Separation Process for Protactinium and Compounds.	Q. Van Winkle, Columbus. Ohio.
2,895,798	Barium Recovery Process	R. E. Blanco, Oak Ridge, Tenn.
2,895,806	Method of Determining the Stability of Fluorocarbon Oils.	Z. D. Sheldon, Rochester, N.Y., and H. M. Haendler, Durham, N.H.
2,895,849	Method of Preparing Coated Refractory Ware	M. L. Perlman, Blue Point, N.Y., D. Lipkin and S. I. Weissman, St. Louis, Mo.
2,897,045	Extraction of Uranium	R. D. Kesler and D. D. Rabb, Columbus, Ohio.
2,897,046	Separation of Thorium from Uranium Extraction.	E. G. Bohlmann, Oak Ridge, Tenn.
2,897,047	Method of Dissolving Metallic Uranium	W. W. Schulz, Richland, Wash.
2,897,048	Uranium Recovery Process	J. W. Stevenson, Webster Groves, Mo., and R. G. Werkema, Granite City, Ill.
2,897,049	Treatment of Fission Product Waste	J. B. Huff, Blackfoot, Idaho
2,897,077	Plutonium-Uranium-Titanium Alloys	A. S. Coffinberry, Los Alamos, N. Mex
2,897,124	Pretreating Thorium for Electroplating	J. G. Beach and G. R. Schaer, Columbus, Ohio.
2,897,605	Method and Apparatus for Determining Charged Particle Motion.	Q. A. Kerns, Orinda, Calif.
2,897,697	Method of Rolling Uranium	C. S. Smith, Chicago, Ill.
2,897,718	Dimension Measuring Optical Sighting Device	G. E. Kerr, St. Louis, Mo.
2,898,185	Adsorption Method for Separating Thorium Values from Uranium Values.	G. E. Boyd, Oak Ridge, Tenn., E. R. Russell and L. Schubert, Chicago, Ill.
2,898,186	Solubilization of Actinide Metal-Containing Slag	H. H. Hopkins, Jr., Richland, Wash.
2,898,187	Production of Uranium Tetrafluoride	W. E. Shaw, R. M. Spenceley and F. M. Teetzel, Hamilton, Ohio.
2,898,203	Removal of Chloride from Aqueous Solutions	W. W. Schulz, Richland, Wash.
2,898,252	Method of Heat-Treating Uranium-Silicon Alloys.	S. T. Zigler, Chicago, Ill.
2,898,277	Method of Fixing Nitrogen for Producing Oxides of Nitrogen.	P. Harteck and S. Dondes, Troy, N.Y.
2,898,280	Fuel Rod Clusters	A. B. Schultz, Western Springs, Ill.
2,898,281	Neutronic Reactor Control	S. Untermyer, Scotia, N.Y., E. Hutter, Chicago, Ill.
2,898,444	Apparatus and Method for Welding End Closure to Container.	E. C. Frantz and T. B. Correy, Richland, Wash.
2,898,473	Method of Preparing Polonium-Boron Sources	J. H. Birden, Dayton, Ohio.
2,898,497	Airborne Radiation Detector	T. R. Cartmell, Richland, and J. F. Gifford, Seattle, Wash.
2,898,555	Resonant Cavity Excitation System	W. R. Baker, Berkeley, Calif.
2,899,054	Refractory Die for Extruding Uranium	E. C. Creutz, Chicago, Ill.
2,899,268	Recovery of Uranium from Aqueous Phosphate-Containing Solutions.	I. Igelsrud and E. F. Stephan, Columbus, Ohio.
2,899,269	Method of Preparing Metal Fluorides	J. J. Katz, Chicago, and I. Sheft, Oak Park, Ill.
2,899,270	Production of Thorium Fluoride	W. H. Zachariasen, Chicago, Ill.
2,899,295	Separation of Tin from Alloys	W. T. Kattner, Richland, Wash.
2,899,297	Method of Producing Dense Consolidated Metallic Regulus.	T. T. Magel, Cambridge, Mass.
2,899,298	Process of Producing Shaped Plutonium	R. J. Anicetti, Richland, Wash.
2,899,451	Recovery of Uranium by Aromatic Dithiocarbamate Complexing.	O. K. Neville, Oak Ridge, Tenn.
2,899,452	Thorium Oxalate-Uranyl Acetate Coupled Procedure for the Separation of Radioactive Materials.	J. W. Gofman, San Francisco, Calif.
2,899,557	Apparatus for Producing Shadowgraphs	R. R. Wilson, Princeton, N.J.
2,900,226	Recovery of Uranium Values from Residues	W. B. Schaap, Bloomington, Ind.
2,900,228	Selective Separation of Uranium from Thorium, Protactinium and Fission Products by Peroxide Dissolution Method.	G. T. Seaborg, Chicago, Ill., J. W. Gofman, Berkeley, Calif., and R. W. Stoughton, Oak Ridge, Tenn.
2,900,229	Uranium Leaching and Recovery Process	L. A. McClaine, Palo Alto, Calif.
2,900,230	Method of Disintegrating Refractory Bodies	R. P. Larsen, Park Forest, and R. C. Vogel, Hinsdale, Ill.

PATENT No.	TITLE	PATENTEE
2,900,237	Apparatus for Charging a Receptacle with a Dense Sublimate Form of Uranium Chloride.	P. H. Davidson, Visalia, Calif.
2,900,263	Method of Preparing a Fuel Element for a Nuclear Reactor.	J. H. Handwerk, Joliet, and R. A. Bach, La Grange, Ill.
2,900,315	Sheathed Tube and Apparatus and Method of Production Thereof.	L. A. Ohlinger, Los Angeles, Calif.
2,900,316	Reactor Control Device	H. B. Kaufman, Jr., New York, N.Y., and A. Weiss, Whitehall Borough, Pa.
2,900,424	Method for Producing Isotopic Methanes and Partially Halogenated Derivatives Thereof.	J. W. Frazer, Livermore, Calif.
2,900,516	Fast Neutron Spectrometer	F. J. Davis and P. W. Reinhardt, Oak Ridge, and G. S. Hurst, Knoxville, Tenn.
2,900,518	Continuously Sensitive Bubble Chamber	R. H. Good, Berkeley, Calif.
2,900,548	Plasma Generator	W. H. Bostick, Danville, and V. G. McIntosh, Livermore, Calif.
2,901,007	Apparatus for Handling Mixtures of Solid Materials.	J. P. Hubbell, Garden City, N.Y.
2,901,172	Electronic Multiplier Circuit	R. E. Thomas, Walnut Creek, Calif.
2,901,313	Separation of Plutonium from Water Insoluble Fluorides Derived from Nitrate Solutions of Plutonium, Uranium and Fission Products.	A. G. Maddock, Didcot, and F. Smith, Birmingham, England.
2,901,314	Removal of Uranium from Organic Liquids	S. P. Vavalides, Oak Ridge, Tenn.
2,901,315	Process of Oxidizing Plutonium	C. D. Coryell, Oak Ridge, Tenn.
2,901,343	Dissolution of Aluminum Jackets from Uranium Cores by Nitric Acid Containing Mercuric Nitrate.	J. H. Peterson, Oak Ridge, Tenn.
2,901,345	Plutonium-Cerium-Cobalt and Plutonium-Cerium-Nickel Alloys.	A. S. Coffinberry, Los Alamos, N. Mex.
2,901,347	Nickel-Chromium-Germanium Alloys for Stainless Steel Brazing.	J. A. McGurty and E. S. Funston, Oak Ridge, Tenn.
2,901,408	Coating Method	R. G. Townsend, Scotia, N.Y.
2,901,496	Salicylate Process for Thorium Separation from Rare Earths.	G. A. Cowan, Los Alamos, N. Mex.
2,901,613	Detector for Modulated and Unmodulated Signals.	H. H. Patterson, Albuquerque, N. Mex., and G. H. Webber, Syracuse, N.Y.
2,901,617	Calutron Receiver	S. W. Barnes, Rochester, N.Y.
2,901,619	Calutron Ion Source Slit Cleaner	A. M. Starr, Piedmont, Calif.
2,901,620	Isotope Separating Apparatus Control	S. W. Barnes, Rochester, N.Y.
2,901,621	Calutron Face Plate	W. M. Brobeck, Berkeley, Calif.
2,901,622	Calutron Control Device	L. W. Baldwin, San Diego, Calif.
2,901,623	Vapor Valve	L. F. Wouters, Oakland, Calif.
2,901,624	Mass Spectrometry	A. O. C. Nier, Minneapolis, Minn.
2,901,714	Transformer	W. R. Baker, Orinda, Calif.
2,902,338	Separation of Thorium from Uranium	R. W. Bane, Chicago, Ill.
2,902,339	Recovery of Plutonium from Aqueous Solutions	E. J. Reher, Schenectady, N.Y.
2,902,340	Chemical Method of Treating Fissionable Material.	C. M. Olson, Richland, Wash.
2,902,361	Uranium-Tantalum Alloy	R. L. Reed, Chicago, Ill.
2,902,362	Plutonium-Uranium Alloy	F. W. Schonfeld and A. S. Coffinberry, Los Alamos, N. Mex.
2,902,380	Slip Casting Method	A. G. Allison, Columbus, Ohio.
2,902,415	Purification of Uranium Fuels	L. W. Niedrach, Schenectady, and A. C. Glamm, Scotia, N.Y.
2,902,422	Nuclear Reactor Fuel Rod Assembly	E. Hutter, Chicago, Ill.
2,902,423	Neutronic Reactor Producing Thermoelectric Power.	E. A. Luebke and L. B. Vandenburg, Schenectady, N.Y.
2,902,424	Homogeneous Nuclear Power Reactor	L. D. P. King, Los Alamos, N. Mex.
2,902,503	Recovery of Uranium by Secondary Xanthate Complexing.	O. K. Neville, Oak Ridge, Tenn.
2,902,590	Method of Making Composite Fuel Elements	R. A. Noland, Chicago, and C. C. Stone, Downers Grove, Ill.
2,902,614	Accelerated Plasma Source	W. R. Baker, Orinda, Calif.
2,903,331	Uranium Solvent Extraction Process	C. D. Harrington, Normandy, Mo.
2,903,332	Separation of Ruthenium from Aqueous Solutions.	C. F. Callis and R. L. Moore, Richland, Wash.
2,903,333	Rare Earth-Actinide Separation by Adsorption	C. S. Lowe, Germantown, Ohio, and W. H. McVey, Berkeley, Calif.
2,903,334	Preparation of Uranium Trioxide	J. S. Buckingham, Richland, Wash.
2,903,335	Separation of Fission Products from Plutonium by Precipitation.	G. T. Seaborg, Albany, S. G. Thompson, Richmond, and N. R. Davidson, Sierra Madre, Calif.
2,903,351	Thorium-Beryllium Alloys and Method of Producing Same.	F. H. Spedding and H. A. Wilhelm, Ames Iowa, W. H. Keller, St. Louis, Mo.
2,903,383	Radioactive Object and Method of Making Same.	L. M. Dorfman, Riverside, Ill., and F. J. Shipko, Indiana, Pa.
2,903,402	Recovery of Valuable Material from Graphite Bodies.	L. W. Fromm, Jr. River Forest, Ill.
2,903,581	Phase Detector	D. O. Kippenhan, Castro Valley, Calif.
2,903,586	Tapered Defining Slot	F. W. Pressey, Oak Ridge, Tenn.
2,903,587	Calutron Receiver Structure	J. L. Roush, W. Asheville, N.C.
2,904,168	Positioning Device	R. R. Wall and D. L. Peterson, Richland, Wash.

PATENT NO.	TITLE	PATENTEE
2,904,429	Plutonium-Thorium Alloys	F. W. Schonfeld, Los Alamos, N. Mex.
2,904,487	Control Device	J. J. Dickson, Brookfield, Ill.
2,904,488	Nuclear Reactor Fuel Systems	B. J. Thamer, R. M. Bidwell and R. P. Hammond, Los Alamos, N. Mex.
2,904,720	Ion Accelerator	J. S. Bell, Birmingham, England.
2,905,338	Indexing Mechanism	L. J. Koch, Elmhurst, Ill.
2,905,525	Method of Separation of Plutonium from Carrier Precipitates.	L. R. Dawson, Lexington, Ky.
2,905,527	Method of and Apparatus for Withdrawing Light Isotope Product from a Liquid Thermal Diffusion Plant.	M. Dole, Evanston, Ill.
2,905,528	Method for Preparation of UO_2 Particles	J. R. Johnson, White Bear, Minn., and A. J. Taylor, Oak Ridge, Tenn.
2,905,552	Production of Uranium Metal by Carbon Reduction.	R. B. Holden, Whitestone, N.Y., R. M. Powers, Cold Spring Harbor, N.Y., and O. J. Blaber (deceased).
2,905,599	Electrolytic Cladding of Zirconium on Uranium	J. J. Wick, Cleveland, Ohio.
2,905,611	Fuel Element for a Nuetronic Reactor	L. Tonks, Scotia, N.Y.
2,905,612	Central Control System	L. B. Borst, Oak Ridge, Tenn.
2,906,597	Reduction in Pu Recovery Processes	D. M. Ritter, Seattle, and R. P. S. Black, Richland, Wash.
2,906,598	Preparation of High Density UO_2	J. M. Googin, Oak Ridge, Tenn.
2,906,618	Process for Production of Uranium	J. W. C. Croom, Frodsham, England.
2,906,683	Reactor Cooling	C. F. Quackenbush, Richland, Wash.
2,906,872	Rise Time Delay Discriminator	C. W. Johnstone, Los Alamos, N. Mex.
2,906,876	Calutron Receiver	W. O. Brunk, Berkeley, Calif.
2,906,877	Calutron	F. F. Oppenheimer, Pagosa Springs, Colo.
2,906,903	Low Voltage 14 Mev. Neutron Source	E. R. Graves, Los Alamos, N. Mex., and R. M. Little, Jr., Ft. Worth, Tex.
2,907,017	Impedance Alarm System	R. G. Cowen, Silver Spring, Md.
2,907,023	Ground Clearance Indicator	L. V. Skinner, Albuquerque, N. Mex.
2,907,628	Neptunium Solvent Extraction Process	L. R. Dawson, Lexington, Ky., and P. R. Fields, Chicago, Ill.
2,907,629	Continuous Process for the Conversion of UF_6 to UF_4.	S. H. Smiley, D. C. Brater and R. H. Nimmo, Oak Ridge, Tenn.
2,907,630	Preparation of Uranium Hexafluoride	S. Lawroski and R. K. Steunenberg, Naperville, Ill. and A. A. Jonke, Elmhurst, Ill
2,907,631	Method of Reducing Plutonium with Ferrous Ions.	J. L. Dreher, El Cerrito, Calif., D. E. Koshland, Chicago, Ill., S. G. Thompson Richmond, Calif., and J. E. Willard, Madison, Wis.
2,907,689	Method of Controlling Corrosion in a Neutronic Reactor.	C. P. Kidder, Wilmington, Del., and C. K. Sloan, Thornton, Pa.
2,907,700	Stripping Process for Plutonium	M. Kolodney, New York, N.Y.
2,907,705	Thermal Fission Reactor Compositions and Method of Fabricating Same.	A. Blainey, Chilton, England.
2,907,706	Neutronic Reactor Fuel Element	W. A. Horning, Playadel Rey, Calif., D. D. Lanning, Watertown, Mass., and D. J. Donahue, Richland, Wash.
2,907,897	Pressure Transducer	H. H. Sander, Albuquerque, N. Mex.
2,908,547	Separation of Uranium, Plutonium, and Fission Products.	C. M. Nicholls and I. Wells, Deep River, Canada; R. Spence, Didcot, England.
2,908,548	Manufacture of UF_4	W. S. Calcott, Woodstown, N.J.
2,908,563	Process for Production of Plutonium from Its Oxides.	S. I. Weissman, Chicago, Ill., M. L. Perlman, New Orleans, La., and D. Lipkin, O'Neals, Calif.
2,908,621	Producing Energy and Radioactive Fission Products.	E. Segre, Santa Fe, N. Mex., J. W. Kennedy (deceased), and G. T. Seaborg, Chicago, Ill.
2,908,822	Apparatus for Measuring Total Neutron Cross Sections.	L. Cranberg, Los Alamos, N. Mex.
2,909,405	Method for the Recovery and Purification of Berkelium.	E. K. Hulet, Walnut Creek, Calif.
2,909,406	Process for Decontaminating Thorium and Uranium with Respect to Ruthenium.	A. B. Meservey, Oak Ridge, and R. H. Rainey, Knoxville, Tenn.
2,909,486	Inhibiting the Polymerization of Nuclear Coolants.	E. T. Colichman, Los Angeles, Calif.
2,909,487	Nuclear Reactor Coolant	E. T. Colichman, Los Angeles, Calif.
2,909,488	Nuclear Reactor Coolant	E. T. Colichman, Los Angeles, Calif.
2,909,731	Cavity Excitation Circuit	J. V. Franck, Lafayette, Calif.
2,910,177	Reactor Component	E. C. Creutz, Chicago, Ill.
2,910,344	Method of Preparing UF_6	N. R. Davidson, Sierra Madre, Calif., and S. Fried, Chicago, Ill.
2,910,345	Preparation of Polonium, Protactinium or Mixtures Thereof in Aqueous Solution from Bismuth, Lead, Zirconium and/or Columbium Values.	Q. Van Winkle, Oak Ridge, Tenn., and K. A. Kraus, Columbus, Ohio.
2,910,379	Method of Coating Graphite with Stable Metal Carbides and Nitrides.	D. H. Gurinsky, Center Moriches, N.Y.
2,910,416	Neutronic Reactor	F. Daniels, Madison, Wis.
2,910,417	Uranium Bismuthide Dispersion in Molten Metal.	R. J. Teitel, East Patchogue, N.Y.

PATENT NO.	TITLE	PATENTEE
2,910,418	Neutronic Reactor	E. C. Creutz, L. A. Ohlinger, A. M. Weinberg and G. J. Young, Chicago, Ill.
2,910,442	Solvent for Extracting Actinide Salts	L. Kaplan, Park Forest, Ill.
2,910,519	Method for Producing Isotopic Methanes from Lithium Carbonate and Lithium Hydride.	J. W. Frazen, Livermore, Calif.
2,911,282	Method of Recovering Plutonium Values from Aqueous Solutions by Carrier Precipitation.	R. A. James, Santa Monica, Calif., and S. G. Thompson, Concord, Calif.
2,911,283	Process for Recovery of Uranium Values from Impure Solutions Thereof.	S. B. Kilner, Oak Ridge, Tenn.
2,911,290	Multistage Fluidized Bed Reactor	A. A. Jonke and J. E. A. Graae, Elmhurst, Ill.; N. M. Levitz, Bellwood, Ill.
2,911,344	Nuclear Reactor Control System	E. P. Epler, Oak Ridge, S. H. Hanauer, Kingston, and L. C. Oakes, Knoxville, Tenn.
2,911,533	Electron Irradiation of Solids	A. C. Damask, Ventnor, N.J.
2,911,587	Proton Resonance Monitor	J. G. Bayly, Canada.
2,911,598	Variable Time Delay Means	R. E. Clemensen, Livermore, Calif.
2,912,302	Processes for Separation and Recovering Constituent of Neutron Irradiated Uranium.	R. E. Connick and G. C. Pimentel, Berkeley; J. W. Gofman, San Francisco, Calif.
2,912,303	Dissolution of Lanthanum Fluoride Precipitates	B. A. Fries, El Cerrito, Calif.
2,912,577	Multichannel Analyzer	G. G. Kelly, Kingston, Tenn.
2,913,307	Method of Preparing Plutonium Tetrafluoride	R. L. Beede, Ballston Lake, N.Y., and H. H. Hopkins, Jr., Richland, Wash.
2,913,510	Radioactive Battery	J. H. Birden and K. C. Jordan, Dayton, Ohio.
2,913,670	Wide Band Regenerative Frequency Divider and Multiplier.	E. F. Lane, Danville, Calif.
2,914,378	Elution of Uranium Values from Ion Exchange Resins.	R. H. Kennedy, Union of South Africa
2,914,399	Removal of Certain Fission Product Metals from Liquid Bismuth Compositions.	O. E. Dwyer, Wading River, N.Y., H. E Howe, North Plainfield, and E. R. Avrutik, Nixon, N.J.
2,914,425	Method for Soldering Normally Non-Solderable Articles.	J. C. McGuire, Los Alamos, N. Mex.
2,914,433	Heat Treated U-N_6 Alloys	R. K. McGeary, Pittsburgh, Pa., and W. M. Justusson, Dearborn, Mich.
2,914,454	Neutronic Reactor Fuel Element	D. H. Gurinsky, Center Moriches, N.Y. and M. Fox, Bellport, N.Y.
2,914,594	Thermal Couple for Measuring Temperature in a Reactor.	W. R. Kanne, Richland, Wash.
2,914,697	Time Calibrated Oscilloscope Sweep Circuit	V. L. Smith and H. K. Carstensen, Livermore, Calif.

APPENDIX 6

Publications of the U.S. Atomic Energy Commission

Listed here are a number of special publications sponsored by the Atomic Energy Commission. In addition, the Commission encourages project scientists to submit nonclassified articles for publication in the established scientific and technical journals. Hundreds of reports, not published elsewhere, may be obtained from the Office of Technical Services, Department of Commerce, Washington 25, D.C. Lists of titles and prices of these reports are available from the Office of Technical Services. Essentially complete collections of the Commission's nonclassified reports are available in a number of libraries (see pp. 441–443). Guides to the published and report literature may be found in Nuclear Science Abstracts (see page 440).

GENERAL PUBLICATIONS

The following is a list of semitechnical and nontechnical publications of interest to the general reader:

Atoms for Peace: U.S.A. 1958. Edited by J. F. Hogerton. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1958. 162 pages. $4.50. A pictorial survey, designed as a type of conducted tour, of the growing industrial and Government atomic energy installations in the United States. Chapters are included on the research and development network; power reactor development; the production network; research on thermonuclear power; isotopes and radiation; research for the future; international cooperation, and the chronology.

Atoms for the World. Laura Fermi. Chicago, University of Chicago Press, 1957. 227 pages. $3.75. An intimate and informative account, by the historian for the United States delegation, of United States participation in the International Conference on the Peaceful Uses of Atomic Energy, which was held in 1955 at Geneva, Switzerland.

A Guide for Contracting of Construction and Related Engineering Services. U.S. Atomic Energy Commission. Revised March 1955. Washington, U.S. Government Printing Office, 1955. 16 pages. 15 cents. This booklet gives the Commission's policy on awarding contracts for construction and architect-engineering services, procedures followed when requests for bids are formally advertised and when contracts are negotiated. Operations offices and officials responsible for letting such contracts are listed.

Prospecting With a Counter. Robert J. Wright. U.S. Atomic Energy Commission. Revised July 1954. Washington, U.S. Government Printing Office, 1954. 68 pages. 30 cents. A summary of information on field counters, their operation, use, abuse, and their application to prospecting, mining and geologic problems.

Prospecting for Uranium. U.S. Atomic Energy Commission and U.S. Geological Survey. Revised January 1957. Washington, U.S. Government Printing Office, 1957. 217 pages. 75 cents. A nontechnical booklet describing the

uranium-bearing minerals, where to look for them, and instruments to use in prospecting and in laboratory testing and analysis of ores. It contains six color plates of principal minerals. Laws, regulations, and price schedules for uranium-bearing ores are included.

Research and Development in Reactor Safety. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1959. 66 pages. 65 cents. This booklet is a review of the current status of AEC research and development specifically directed toward making nuclear reactors safe for use in electric power generation, propulsion, and research. The essential features of the AEC reactor safety research program are presented for the first time in one compact reference work. Major projects, both experimental and theoretical, are described and results obtained thus far are summarized. Primarily intended for reactor design specialists, nuclear engineers, technical administrators, students, and others interested in reactor development, this booklet is extensively referenced and illustrated with diagrams, charts, and photographs.

Selected Readings on Atomic Energy. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, March 1958. 74 pages. 25 cents. A bibliography of official publications, books, magazines, pamphlets and teaching units for educators, and indexes and bibliographies on atomic energy.

Selling to AEC. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1958. 34 pages. 25 cents. This publication provides certain basic information helpful to those who want to do business with the Commission or its contractors. It indicates who does the buying, what is bought, where procurement offices are located, and other general information.

Teaching With Radioisotopes. U.S. Atomic Energy Commission, Washington, U.S. Government Printing Office, 1959. 60 pages. 40 cents. Based on materials submitted by teachers in many schools and colleges, this manual of experiments with radioisotopes was prepared to supplement and extend the initial publication, *Laboratory Experiments With Radioisotopes—For High School Demonstrations.* As an aid to teachers using the publication, Part I is an extensive introductory section that contains definitions and notes on equipment and techniques and gives special attention to proper procedures and safety. Part II gives 16 suggested experiments. Each experiment begins with pertinent questions and answers and each is written in an "open-ended" manner with the hope that variations will occur to teachers and students. Five appendixes are: Some References on Radioactivity; Licensing of Byproduct Material; Radioactive Isotopes for Sale Under a General AEC License; Some Suppliers of Radioisotopes; Radioactive Decontamination Procedures.

TECHNICAL PUBLICATIONS

The items listed below are selections of recent publications of scientific and technical interest.

Books

Boiling Water Reactors.[1] Andrew W. Kramer, Editor. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 563 pages. $8.50. This reference

[1] A U.S. Government presentation volume for the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958.

work on the history and technology of boiling water reactors was prepared under the auspices of the Argonne National Laboratory, with the cooperation of the many scientists and engineers there who conceived and developed this type of reactor. It presents a brief history of the boiling water concept and of the early experiments of the Argonne Laboratory, including the development and operation of the Experimental Boiling Water Reactor. The various BORAX experiments are described in detail. A thorough explanation is given of the physics underlying the design of the reactor, and a lengthy description of the General Electric Co.'s Vallecitos plant is included. The book concludes with a discussion of present and future research and development programs for boiling reactors.

Cryogenic Engineering. Russell B. Scott. Princeton, N.J., D. Van Nostrand Co., 1959. 368 pages. $5.60. The book covers the entire range of cryogenic engineering and is intended primarily for students, engineers, and scientists who are unfamiliar with low-temperature techniques. It outlines the practical aspects of cryogenic processes and equipment, at the same time providing a careful discussion of the underlying theory. The book describes, in easily understood form, the development and improvement of low-temperature processes and equipment; the determination of the physical properties of materials used to produce, maintain, and utilize low temperatures; and the practical application of low-temperature techniques and processes.

The Elements of Nuclear Reactor Theory. Samuel Glasstone and Milton C. Edlund. New York, D. Van Nostrand Co., 1952. 416 pages. $4.80. This is an introduction to nuclear reactor theory intended for the use of scientists, engineers, and advanced students interested in the field of nuclear reactors. It explains the physical concepts and processes involved in a nuclear chain reaction and the methods for calculating critical conditions for chain reacting systems.

Energy in the Future. Palmer Cosslett Putnam. New York, D. Van Nostrand Co., 1953. 556 pages. $12.75. This book presents a study of the problem of where we can find sources of low-cost energy in an abundance equal to the maximum plausible demands by the expanding and industrializing populations of the future, and what is the maximum plausible role that nuclear fuels may be called on to play in the next 50 to 100 years.

Fluid Fuel Reactor.[1] Edited by J. A. Lane, H. G. MacPherson, and Frank Maslan. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 1008 pages. $11.50. Comprehensive discussion of three basic types of fluid fuel reactors which summarizes results of research carried on in the United States for almost 10 years. A unique feature of this work is its approach to the subject from the chemical standpoint rather than from the point of view of mechanical engineering.

The Metal Beryllium. Edited by D. W. White and J. E. Burke. Cleveland American Society for Metals, 1955. 703 pages. $8.00. Presents basic information on the element beryllium, and covers all aspects of beryllium technology for the use of workers in the field, with emphasis on the possible uses of beryllium in atomic energy work.

Nuclear Reactor Experiments. Edited by J. B. Hoag. Princeton, N.J., D. Van Nostrand Co., Inc., 1958. 480 pages. $6.75. A laboratory manual detailing

[1] A U.S. Government presentation volume for the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958.

49 experiments involving the theory and practice of fission reactor measurements.

Physical Metallurgy of Uranium.[1] A. N. Holden. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 272 pages. $5.75. A comprehensive and unified treatment of the physical metallurgy of uranium, which summarizes, correlates, and critically evaluates the wealth of information that has become available in the field during the past several years. Although important experimental techniques and results are thoroughly described, emphasis has been placed upon interpretation in terms of fundamental properties and mechanisms.

Principles of Nuclear Reactor Engineering. Samuel Glasstone. New York, D. Van Nostrand Co., 1955. 861 pages. $7.95. A text written for the student and the practicing engineer. An overall review of the fundamental scientific principles upon which reactor engineering is based.

Project Sherwood—The U.S. Program in Controlled Fusion.[1] Amasa Bishop. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 228 pages. $5.75. Account of the extensive research and development undertaken by the U.S. Atomic Energy Commission for harnessing the energy of thermonuclear reactions. It presents a factual and readable account of Project Sherwood, including its origin, its development, its problems, and the outlook for its eventual success. The book describes the basic principles involved in a fusion reaction, and the various methods now being studied to control thermonuclear energy, with the hope of eventually producing net power.

Radiation Biology and Medicine: Selected Reviews in the Life Sciences.[1] Edited by W. D. Claus. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 968 pages. $11.50. A review of advances in thought and research in the uses and effects of nuclear radiation in the life sciences in the United States. Chapters are included on basic mechanisms of biological reaction to radiation, mutational effects of radiation, mathematical biology, mamalian response to radiation, radiation safety, medical uses of atomic radiation, agricultural uses of radiation, tracer applications, instrumentation and dosimetry.

The Shippingport Pressurized Water Reactor.[1] By personnel of the Naval Reactors Branch, Division of Reactor Development, U. S. Atomic Energy Commission; Bettis Plant Westinghouse Electric Corp.; and Duquesne Light Co. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 600 pages. $9.50. An account of the research and development for and construction of the first large-scale central station nuclear powerplant to be built and operated in the U.S. This is the basic sourcebook for this plant and its technology. For those who want more detailed information, selected references are given at the end of each chapter.

Sodium Graphite Reactors.[1] Chauncey Starr and R. W. Dickinson. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 304 pages. $6.50. A unified and coherent presentation of sodium graphite reactor technology. Emphasis has been placed on the design and development of the Sodium Reactor Experiment (SRE); however, information applicable to sodium graphite systems and, in many cases, to reactor design in general is included. The Hallam Nuclear Power Facility, a full-scale sodium graphite plant on which construction has started, is described.

[1] A U.S. Government presentation volume for the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958.

Solid Fuel Reactors.[1] By J. R. Dietrich and W. H. Zinn, Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 864 pages. $10.75. Reviews are basic concepts, present status of development in the United States, and technical and economic outlooks in this country for five projected solid fuel nuclear power reactor types. Chapters are included on the fast-neutron power reactor; the experimental breeder reactor; the Enrico Fermi Atomic Power Plant; heavy-water power reactors; gas-cooled reactors, organic-cooled and moderated reactors; and plutonium recycling in thermal reactors.

Sourcebook on Atomic Energy, Second Edition (revised and updated). Samuel Glasstone. New York, D. Van Nostrand Co., 1958. 641 pages. $4.40. This is considered the standard sourcebook on atomic and nuclear science today. It presents a comprehensive technical description of the theory, history, development, and uses of atomic and nuclear energy. Chapters are included on the structure of the atom, radioactivity, isotopes, nuclear reactors, neutron research, acceleration of charged particles, new elements, radiation protection and health physics, and other phases of nuclear science.

Thorium Production Technology.[1] F. L. Cuthbert. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 320 pages. $6.50. This book contains practically all the information currently available on thorium production technology. Chapters are included on thorium history, sources, and uses; properties of thorium; thorium-bearing ores; their deposits and methods of concentration; extraction of thorium from ores; purification of thorium concentrates; preparation of thorium metal by reduction; melting of thorium; fabrication of thorium; health and safety aspects of thorium production; testing procedures.

The Transuranium Elements.[1] Glenn T. Seaborg. Reading, Mass., Addison-Wesley Publishing Co., 1958. 354 pages. $7.00. This book provides a complete summary of the chemical and nuclear properties of the known synthetic transuranium elements, as well as the prospects for future transuranium elements. It is divided into four parts, the first of which begins with the discovery of plutonium in 1940 as the result of the bombardment of natural uranium with deuterons in the University of California's 60-inch cyclotron. The next discusses the chemical properties of the actinide elements, ranging from one of the heaviest elements, thorium, to Mendelevium. The third part is devoted to the nuclear properties of the transuranium elements, and the fourth to the as yet undiscovered elements.

Uranium Ore Processing.[1] Edited by J. W. Clegg and D. D. Foley. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 448 pages. $7.50. Here, for the first time in book form, is a condensed but essentially complete description of practices and in winning uranium from its ores. While the emphasis is on a well-rounded presentation of current practices in the United States, techniques in other countries are also described. Because of its comprehensive and authoritative nature, the volume should be a valuable reference for all workers in the field. Various processes are described in full, and there are many helpful comments and observations. Each chapter is accompanied by an extensive reference list.

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[1] A U.S. Government presentation volume for the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958.

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Uranium Production Technology. Edited by Charles D. Harrington and Archie E. Ruehle. Princeton, N.J., D. Van Nostrand Co., Inc., 1959. 579 pages. $17.50. Presents the entire field of technology in the United States of uranium metal production from uranium concentrates or high-grade uranium ore. It includes a description of the diethyl ether and tributyl phosphate solvent extraction, deoxidation, hydrofluorination, reduction and casting processes. Rolling, forging, extrusion, and machining fabrication techniques are also discussed along with the chemistry and physical metallurgy of uranium. Chapters on uranium alloys, producing uranium hexafluoride, producing enriched uranium, new technology, and health hazard control complete the book. Limited amounts of history, pertinent production details, and development work are included. This comprehensive book, the first in its field, includes work done at many AEC installations throughout this country. It is written for the student of metallurgy both in an academic institution and in industry.

U.S. Research Reactor Operation and Use.[1] Edited by J. W. Chastain, Jr. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1958. 384 pages. $7.50. This book is intended primarily for scientists, engineers, and administrators owning or using a reactor. It also may serve as a text or reference for introductory courses in reactor engineering. It sets forth information not only about technical aspects, characteristics, and operating problems but also on administrative, legal and cost problems.

The Actinide Elements.[2] Edited by G. T. Seaborg. New York, McGraw-Hill Book Co., Inc., 1954. 870 pages. $11.75. Provides a comprehensive survey of the chemistry and nuclear properties of the actinide elements.

Analytical Chemistry of the Manhattan Project.[2] Edited by C. J. Rodden. New York, McGraw-Hill Book Co., Inc., 1950. 748 pages. $10.00. Outlines the analytical chemistry methods used on the Manhattan Project.

Bibliography of Research on Heavy Hydrogen Compounds.[2] Compiled by Alice H. Kimball. New York, McGraw-Hill Book Co., Inc., 1949. 350 pages. $4.75. A bibliography of research on heavy hydrogen and its compounds, arranged alphabetically according to the name of the senior author of each work.

Biological Effects of External Beta Radiation.[2] Edited by R. E. Zirkle. New York, McGraw-Hill Book Co., Inc., 1951. 242 pages. $3.50. Reports the findings of an intensive radiobiological program carried out during World War II at the Clinton Laboratories.

Biological Effects of External Radiation.[2] Edited by H. A. Blair. New York, McGraw-Hill Book Co., Inc., 1954. 508 pages. $7.00. Deals with the biological effects of X radiation and the chronic effects of neutron irradiation.

Biological Effects of External X and Gamma Radiation (Part I).[2] Edited by R. E. Zirkle. New York, McGraw-Hill Book Co., Inc., 1954. 530 pages. $7.25. Reports the findings of an intensive radiobiological program carried on during World War II at the Metallurgical Laboratory and the National Cancer Institute.

Biological Studies with Polonium, Radium, and Plutonium.[2] Edited by R. M. Fink. New York, McGraw-Hill Book Co., Inc., 1950. 411 pages. $5.50.

[1] A U.S. Government presentation volume for the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958.

[2] This is a volume in the National Nuclear Energy Series, written by scientists who performed research and development work on the atomic energy enterprise under the Manhattan Engineer District and later under the Atomic Energy Commission.

Deals with the distribution and excretion of polonium and radium, as well as the comparative toxicities of polonium, plutonium, and radium.

The Chemistry of Uranium: Part I. The Elements, Its Binary and Related Compounds.[2] Edited by J. J. Katz. New York, McGraw-Hill Book Co., Inc., 1951. 609 pages. $8.25. Results of a program of experimental research in uranium chemistry undertaken at the inception of the Atomic Energy Project.

Electronics: Experimental Techniques.[2] Edited by W. C. Elmore and Matthew Sands. New York, McGraw-Hill Book Co., Inc., 1949. 417 pages. $5.50. Presents circuits designed for electronics group at Los Alamos Scientific Laboratory from 1943 to 1945.

Engineering Developments in the Gaseous Diffusion Process.[2] Edited by Manson Benedict and Clarke Williams. New York, McGraw-Hill Book Co., Inc., 1949. 129 pages. $2.00. Describes research and engineering developments relative to auxiliary devices necessary in the development of the gaseous diffusion process.

Histopathology of Irradiation from External and Internal Sources.[2] Edited by William Bloom. New York, McGraw-Hill Book Co., Inc., 1948. 808 pages. $10.75. A report of three years of intensive war research undertaken to compare histological changes that result from various types of radiations originating externally and internally.

Industrial Medicine on The Plutonium Project. Survey and Collected Papers.[2] Edited by R. S. Stone. New York, McGraw-Hill Book Co., Inc., 1951. 511 pages. $7.00. Describes the problems faced by the Medical Section of the Metallurgical Laboratory at the outset of the Atomic Energy Project in determining the injuries that could result from exposure to radiation, some of the clinical tests devised, and the results of special studies.

Ionization Chambers and Counters. Experimental Techniques.[2] Edited by B. B. Rossi and H. H. Staub. New York, McGraw-Hill Book Co., Inc., 1949. 243 pages. $3.25. Presents the fundamental features of ionization and the general properties of detectors based upon the ionization process. A description is also given of the construction of some typical detectors and their operation.

Medical Effects of the Atomic Bomb in Japan.[2] Edited by A. W. Oughterson and Shields Warren. New York, McGraw-Hill Book Co., Inc., 1956. 477 pages. $8.00. Presents the results of the investigations by the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan following the bombing of Hiroshima and Nagasaki.

The Metallurgy of Zirconium.[2] Edited by Benjamin Lustman and Frank Kerze, Jr. New York, McGraw-Hill Book Co., Inc., 1955. 776 pages. $10.00. Provides a critical presentation of many aspects of zirconium technology.

The Metal Thorium.[2] Edited by H. A. Wilhelm. Cleveland, American Society for Metals, 1958. 397 pages. $10.00. A unified collection of detailed information on both the fundamental scientific and the technological and engineering aspects of thorium.

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[2] This is a volume in the National Nuclear Energy Series, written by scientists who performed research and development work on the atomic energy enterprise under the Manhattan Engineer District and later under the Atomic Energy Commission.

Nuclear Reactor Metallurgy.[2] Edited by W. D. Wilkinson and W. F. Murphy. Princeton, D. Van Nostrand Co., Inc., 1958. 382 pages. $5.60. Course material in applied reactor metallurgy developed at the International School of Nuclear Science and Engineering of Argonne National Laboratory.

Optical Instrumentation.[2] Edited by G. S. Monk and W. H. McCorkle. New York, McGraw-Hill Book Co., Inc., 1954. 262 pages. $3.75. Discusses in detail the principles of design and institute research into the development of optical glasses to withstand the destructive effects of high-energy radiations, as well as the use of plastic lenses in instruments of high quality and resolution.

Pharmacology and Toxicology of Uranium Compounds (Parts I and II).[2] Edited by Carl Voegtlin and H. C. Hodge. New York, McGraw-Hill Book Co., Inc., 1949. 1,084 pages. $14.25. Reports the comprehensive experimental studies on uranium compounds and includes some observations on the toxic action of fluorine and hydrogen fluoride.

Pharmacology and Toxicology of Uranium Compounds (Parts III and IV).[2] Edited by Carl Voegtlin and H. C. Hodge. New York, McGraw-Hill Book Co., Inc., 1953. 1,379 pages. $18.00. Concerned chiefly with chronic inhalation toxicity of uranium compounds and the mechanism of uranium poisoning.

Preparation, Properties, and Technology of Fluorine and Organic Fluoro Compounds.[2] Edited by Charles Slesser and S. R. Schram. New York, McGraw-Hill Book Co., Inc., 1951. 868 pages. $11.50. Describes how organic fluoro compounds of various types were prepared in the laboratory, studied as to their physical and chemical properties, and rapidly brought to industrial-scale production.

Production of Heavy Water.[2] Edited by G. M. Murphy, H. C. Urey, and Isidor Kirshenbaum. New York, McGraw-Hill Book Co., Inc., 1955. 394 pages. $5.25. Presents a survey of heavy-water plants and their operation and describes the results of pilot-plant studies on development processes.

Radiochemical Studies: The Fission Products.[2] Edited by C. D. Coryell and Nathan Sugarman. New York, McGraw-Hill Book Co., Inc., 1951. 2,086 pages. $27.75. Presents results of research completed at Ames, Chicago, Oak Ridge, Berkeley, Bloomington, Hanford, and Los Alamos.

Spectroscopic Properties of Uranium Compounds.[2] Edited by G. H. Dieke and A. B. F. Duncan. New York, McGraw-Hill Book Co., Inc., 1949. 290 pages. $4.25. Discusses the spectra and preparation of a number of uranium compounds.

The Theory of Isotope Separation as Applied to the Large-Scale Production of U^{235}.[2] Edited by Karl Cohen. New York, McGraw-Hill Book Co., Inc., 1951. 165 pages. $2.50. Covers work done by the theoretical division of the SAM Laboratories, with emphasis placed on the general principles and concepts of the separation of uranium isotopes by gaseous diffusion.

Toxicology of Uranium: Survey and Collected Papers.[2] Edited by Albert Tannenbaum. New York, McGraw-Hill Book Co., Inc., 1951. 333 pages. $4.75. Contains reports of investigations on the toxicology of uranium compounds together with associated studies and is not intended as a complete textbook of uranium pharmacology and toxicology.

Vacuum Equipment and Techniques.[2] Edited by A. Guthrie and R. K. Wakerling. New York, McGraw-Hill Book Co., Inc., 1949. 264 pages. $3.75. Presents

[2] This is a volume in the National Nuclear Energy Series, written by scientists who performed research and development work on the atomic energy enterprise under the Manhattan Engineer District and later under the Atomic Energy Commission.

studies and developments of high-vacuum equipment and practice made by the University of California.

The Attenuation of Gamma Rays and Neutrons in Reactor Shields. Herbert Goldstein, Nuclear Development Corp. of America. Washington, U.S. Government Printing Office, 1957. 295 pages. $2.00. This is a thorough exposition of the fundamental processes involved in shielding against neutron and gamma radiation. The book is intended to serve as a solid scientific base for the steadily advancing art of reactor shield design covering the factors affecting permissible radiation levels; the sources and characteristics of the radiation encountered; bulk shielding facilities and measurements; and, at greatest length, the methods for calculating—either theoretically or empirically—the attenuation of neutron and gamma rays in shield materials.

A Directory to Nuclear Data Tabulations. R. C. Gibbs and Katharine Way. U. S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1958. 185 pages. 70 cents. This is a compilation of comprehensive tabulations of experimental and theoretical information in the fields of basic nuclear physics and chemistry which have been published in the last few years. Tabulations described in the publication are grouped into 34 sections covering 295 tables. In addition to the usual bibliographical information, each entry includes authors' institutions, prices and details on availability and ordering procedures for the data cited. A topical index and an author index have been included to aid the reader in locating entries of special interest. Among the topics covered are abundances, coulomb functions, cross sections, fission, masses and mass differences, nuclear properties, radiochemistry and X-rays.

The Effects of Nuclear Weapons. Edited by Samuel Glasstone. Washington, U.S. Government Printing Office, 1957. 579 pages. $2.00. A publication prepared by the Armed Forces Special Weapons Project of the Department of Defense at the request of the Atomic Energy Commission. It updates information appearing in *The Effects of Atomic Weapons,* 1950, and provides the latest knowledge of weapons effects obtained by observation and experiment in laboratory work and nuclear test detonations since 1950. It also includes data on radiological, blast and heat effects of nuclear detonations. Requirements of the Federal Civil Defense Administration for information necessary for civil defense planning are taken into account.

The Experimental Boiling Water Reactor. Washington, U.S. Government Printing Office, 1957. 232 pages. $2.25. A detailed engineering description of this experimental atomic powerplant written by the designers at the Argonne National Laboratory.

Economics of Nuclear and Conventional Merchant Ships. Prepared by David L. Conklin, et al., U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1958. 869 pages. $4.50. In this book, nuclear and conventionally powered oceangoing merchant ships are compared for the period 1957 to 1970, using return on investment and cost per unit carried as the basis for comparison. A "ship family" concept was developed to provide different ship types, sizes, and speeds with which to study the relative costs of the two kinds of propulsion. The five types of ships used in this project were general-cargo, tanker, ore carrier, passenger, and passenger-cargo.

Electromagnetic Separation of Isotopes in Commercial Quantities (TID–5217). Edited by R. K. Wakerling and A. Guthrie. U.S. Atomic Energy Commis-

sion, 1949. 434 pages. $2.65. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, and describes the production of isotopes by the electromagnetic separation process in commercial quantities.

Electrical Circuits for Calutrons (TID–5216). Edited by R. K. Wakerling and A. Guthrie. U.S. Atomic Energy Commission, 1949. 280 pages. $1.85 (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, with emphasis upon electrical circuiting.

Electrical Equipment for Tanks and Magnets (TID–5214). Edited by C. R. Baldock and E. D. Hudson. U.S. Atomic Energy Commission, 1947. 401 pages. $2.65. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Presents an account of the electrical engineering phases of the electromagnetic separation process as they relate to electrical equipment used in the separation of isotopes.

Corrosion and Wear Handbook for Water-Cooled Reactors (TID–7004). Edited by D. J. DePaul. U.S. Atomic Energy Commission, Washington, U.S. Government Printing Office. 293 pages. $2.25. (Commercial edition also available from McGraw-Hill Book Co., Inc., New York. $6.00). A handbook of theory and experimental data on corrosion and wear of materials in water-cooled nuclear reactors. The book presents in one reference book corrosion and wear data resulting from the development of the *Nautilus* submarine reactor and the Shippingport Pressurized Water Reactor projects.

Costs of Nuclear Power (TID–8506). U.S. Atomic Energy Commission, 1959. 29 pages. 50 cents. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This report is concerned only with stationary nuclear plants that are designed primarily for the generation of electricity. It considers data on the cost of electricity from those plants that are presently in operation, being built, or planned for early construction. Major topics covered are capital costs, annual fixed charges, fuel-cycle costs, inventory charges, cost of operation and maintenance and total cost of nuclear power.

Guide to Shipment of U–235 Enriched Uranium Materials (TID–7019). Compiled and edited by H. F. Henry. U.S. Atomic Energy Commission. 75 pages. $1.00. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This guide defines safe nuclear methods of shipping enriched uranium materials. It is written primarily for the guidance of physicists, chemists, engineers, or other personnel who are responsible for nuclear safety in a plant or other facility that ships enriched uranium.

Handling Radioactive Wastes in the Atomic Energy Program. U.S. Atomic Energy Commission. Revised August 1951. Washington, U.S. Government Printing Office, 1951. 30 pages. 15 cents. Discusses the sources and types of radioactive wastes in atomic energy operations, methods developed for their safe handling and disposal, and methods specified for the safe handling of radioisotopes by private users.

High Voltage Problems (TID–5211). J. D. Trimmer and Harry Pearlman. U.S. Atomic Energy Commission, 1951. 226 pages. $1.85. (Available from Office

of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This report represents an account of work done in connection with the high voltage systems used in the electromagnetic separation process. Sparking and insulator breakdowns are treated in detail.

Manuals, Handbooks and Reports

Boiling Water Reactor Study (TID–8500, Parts 1, 2 & 3). U.S. Atomic Energy Commission, 1959. Total pages 522. Total price $5.25. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This is one of four advanced design studies initiated in 1958 to assess the feasibility of power generation through the use of certain type of nuclear reactors. This study deals with the boiling water reactor. Part 1 (Vols. 1 and 2) is entitled "306 mw Power Reactor Conceptual Design"; Part 2 is entitled "Separate Studies"; and Part 3 is entitled "326 mw Case-fired Installation".

Organic Cooled Power Reactor Study (TID–8501, Parts 1, 2, 3, 4 & 5). U.S. Atomic Energy Commission, 1959. Total pages 1500. Total price $15.00. (Available from Office of Technical Services, U.S. Department of Commerce Washington 25, D.C.) This is another of the four advanced design studies initiated in 1958 to assess the feasibility of power generation through the use of certain types of nuclear reactors. This study deals with the Organic-cooled Power Reactor. Part 1 is entitled "Summary of Study"; Part 3 "Reactor Concept Evaluation"; Part 4 "75 mw Power Plant Conceptual Design"; Part 5 "300 mw Coal-fired Power Plant Comparison Study".

Advanced Pressurized Water Reactor Study (TID–8502, Parts 1, 2 & 3). U.S. Atomic Energy Commission, 1959. Total pages 1075. Total price $10.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Another of the four advanced design studies initiated in 1958 to assess the feasibility of power generation through the use of certain types of nuclear reactors. This study deals with the advanced pressurized water reactor. Part 1 "Phase I Report"; Part 2 "Appendixes to Phase I Report"; and Part 3 "235 mw Coal-fired Generating Plant".

Heavy Water Moderated Power Reactor Plant (TID–8503, Parts 1 and 2). U.S. Atomic Energy Commission, 1959. Total pages 1136. Total price $11.25. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Another of the four advanced design studies initiated in 1958 to assess the feasibility of power generation through the use of certain types of nuclear reactors. This study deals with the heavy water moderated power reactor. Part 1 "Design Study"; Part 2 "Preliminary Design of the Prototype Plant".

AEC Summary and Evaluation Report of Four Power Reactor Design Studies (TID–8504). U.S. Atomic Energy Commission, 1959. 60 pages. 60 cents. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This report summarizes and evaluates the four power reactor design and engineering studies completed for the AEC under Public Law 85–590. The report gives economic and technical conclusions, comparative cost analysis, technical analysis of reference designs, assumptions and site data.

Hot Laboratory Equipment. Compiled by L. G. Stang, Jr. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1958. 429 pages.

$2.50. A descriptive, illustrated catalog of enclosures for radioactive operations, manipulators, viewing and optical equipment, chemical equipment, physical-measurement equipment, materials-handling equipment, decontamination and monitoring instruments, shielding devices, and machine tools.

Introduction to the Theory of Neutron Diffusion. Vol. 1. K. M. Case, F. de Hoffmann, and G. Placzek. Numerical work by B. Carlson and M. Goldstein. Washington, U.S. Government Printing Office, 1954. 174 pages. $1.25. A monograph intended for purposes of research in physics and mathematics as well as teaching on the graduate level. This monograph, presenting work sponsored by the Los Alamos Scientific Laboratory, gives a detailed discussion of the general equations of one-velocity neutron diffusion theory and of their solution for the special case of a homogeneous infinite medium with isotropic scattering. Emphasis is placed on fairly complete tables and graphs.

Isotopes—an 8-Year Summary of Distribution. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1955. 357 pages. $2.00. A detailed account of isotope utilization during the first 8 years of the Commission's distribution program. It is also a supplement of the 3-year and 5-year reports of similar title issued by the Commission in 1949 and 1951. This report is a useful reference to the uses of isotopes and a bibliography of published articles on isotope work.

Liquid Metals Handbook; Sodium (NaK) Supplement (TID–5277). Carey B. Jackson, Editor-in-Chief. Sponsored by the Atomic Energy Commission and the Bureau of Ships, Department of the Navy. Washington, U.S. Government Printing Office, 1955. 445 pages. $2.00. This volume, which supplements the *Liquid Metals Handbook* above, presents a significant amount of experimental data and analysis of thermal shock and thermal stresses, convective flow and mass transfer, mainly applicable to Sodium and NaK.

Los Alamos Handbook of Radiation Monitoring. (LA–1835, 3d Ed.). Compiled and edited by Jerome E. Dummer, Jr. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1959. 180 pages. 60 cents. An entirely rewritten and updated version of the "General Handbook for Radiation Monitoring" which was prepared by Los Alamos Scientific Laboratory to provide the Monitoring Group at Los Alamos with the basic data which should be available to them at all times. The book is pocket size and is designed to serve the purposes of the Los Alamos Scientific Laboratory. Some of the topics covered are monitor's check list, emergency monitoring, LASL radiation safety policies, decontamination, table of isotopes, monitoring instruments, alpha, beta-gamma neutron and tritium monitoring and air sampling.

Meteorology and Atomic Energy (AECU–3066). Prepared by U.S. Department of Commerce, Weather Bureau, for U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1955. 169 pages. $1.00. This volume summarizes some of the meteorological techniques that are available and describes their application to problems of atmospheric pollution that might arise in connection with the operation of atomic energy installations.

Neutron and Gamma Irradiation Facilities. Compiled by John H. Martens and F. G. Minuth. Washington, U.S. Government Printing Office, 1957. 79 pages. 60 cents. A compact reference on high level nuclear irradiation facilities in the United States. Forty facilities, currently operative or scheduled to become operative soon, are described, along with information on the services provided and how to obtain them.

Nuclear Level Schemes (TID–5300). K. Way, R. W. King, C. L. McGinnis, R. van Lieshout. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1955. 240 pages. $1.75. A ready reference source of nuclear information consisting of a collection of diagrams showing positions and properties of nuclear energy levels, characteristics of radioactive decay and nuclear reactions, together with a tabular compilation of the experimental data and bibliographic references to the original paper.

Magnets and Magnetic Measuring Techniques (TID–5215). Edited by R. K. Wakerling and A. Guthrie. U.S. Atomic Energy Commission, 1949. 213 pages. $1.45. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, with emphasis upon magnets and associated measuring techniques.

Neutron Cross Sections (BNL–325, Second Edition). Edited by Donald J. Hughes and Robert B. Schwartz, Brookhaven National Laboratory. Washington, U.S. Government Printing Office, 1958. 373 pages. $4.50. This is a completely revised and updated edition of experimentally determined values of neutron cross sections. It is intended for physicists, chemists, and reactor engineers. The book contains tables of thermal cross sections and resonance parameters and plots of curves of total and partial cross sections as functions of energy. The data has been carefully evaluated and the most recent results from many laboratories throughout the world are included.

1959 Nuclear Data Tables. Edited by K. Way. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1959. 151 pages. $1.00. The 1959 Nuclear Data Tables is the successor to the New Nuclear Data Cumulations which were published from 1952 through 1957. A change in the method of presenting and cumulating experimental results for individual nuclei has made it possible to omit from an annual volume data organized according to nucleus and to devote the yearbook instead to information which has been systematized according to some nuclear property or some specific topic. The book presents 10 compilations containing new data in fields of low-energy nuclear physics appearing in the literature during the periods indicated.

Nuclear Power Reactors. Vol. 2. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, March 1955 (submitted October 1953). 30 pages. 15 cents. This publication contains reports to the U.S. Atomic Energy Commission of two teams of industrial representatives. Appraises the practicability of building a nuclear reactor for the generation of central-station power. The study group undertook to determine whether any of the known reactor systems can be shown to be technically and economically feasible, and competitive for central-station power. Studies were made on the projected possibilities of different reactor systems.

Nuclear Power Reactor Technology. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1953. 88 pages. 25 cents. This publication contains reports to the U.S. Atomic Energy Commission by four separate teams of industrial representatives appraising the prospect for possible nuclear power development. Studies were made to determine the engineering feasibility for designing, constructing and operating dual-purpose reactors to to produce fissionable material and power, and to recommend industry's role in designing, building, and operating such reactors.

The Physics of Intermediate Spectrum Reactors. Edited by J. R. Stehn. U.S. Atomic Energy Commission, Washington, 1959. 487 pages. $3.00 (paperbound). U.S. Government Printing Office. This handbook is the third volume of the Naval Reactors Physics Handbook, written for persons having some knowledge of the physics of nuclear reactors. It is an accumulation of physics information obtained from the work on intermediate-spectrum reactors at Knolls Atomic Power Laboratory. Material covers the importance of the properties of critical assemblies and of techniques for obtaining related experimental information; the uses of critical assemblies and reactor theory in making and testing predictions of reactivity variation during operation; the spread of heat generation in space and time; nuclear effects resulting from presence of beryllium or sodium in the reactor; the transient or near transient behavior of intermediate reactors.

Polonium (TID–5221). Edited by Harvey V. Moyer. U.S. Atomic Energy Commission, 1956. 392 pages. $1.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This is a history of the polonium program. Chemical separation methods and separation by distillation are studied for extraction of polonium from irradiated bismuth. Biological research related to polonium and health physics concerned with personnel protection and waste disposal are discussed.

Power Reactors. U.S. Atomic Energy Commission, Washington, 1958. Washington, Superintendent of Documents, U.S. Government Printing Office. 92 pages. 65 cents. A compact summary of technical information, prepared by the Division of Reactor Development, on 10 full-scale nuclear powerplants built, under construction, or being undertaken in the United States. The text is well illustrated and reinforced with lengthy tabulations of data.

Radioactive Contamination of Certain Areas in the Pacific Ocean from Nuclear Tests. Edited by Gordon M. Dunning. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1957. 53 pages. 40 cents. This publication brings together the principal data on environmental contamination from the radioactive fallout following the March 1, 1954 thermonuclear detonation at the Eniwetok Proving Ground. It collates 10 radiological surveys made in the Pacific by the Applied Fisheries Laboratory of the University of Washington, U.S. Naval Radiological Defense Laboratories, Health and Safety Laboratory at the New York Operations Office and the Office of Naval Research. It also contains pertinent excerpts of the findings of American medical teams who examined the exposed Marshallese.

Radioisotope Scanning (ORINS–20). Edited by Marshall Brucer. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1958. 169 pages. $1.00. Presents the principles of the area scan and discusses what can be done and, even more important in diagnosis, what cannot be done with the area scanner.

Reactor Handbook: Vol. I (AECD–3645)—Physics; Vol. II (AECD–3646)—Engineering; Vol. III (AECD–3647)—Materials. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1955. Vol. I, 304 pages. $4.25; Vol II, 1,088 pages. $5.50; Vol. III, 614 pages. $3.50. These volumes provide a condensed and reliable source of nuclear reactor data. Contents: Vol. I—Reactor physics and radiation shielding; Vol. II—Light- and heavy-water cooled systems, liquid-metal cooled systems, gas-cooled systems, aqueous fuel systems, liquid-metal fuel systems, fused salt systems, handling and control, and reactor designs; Vol. III—General properties of materials.

Reactor Materials Specifications. Compiled and edited by R. M. Evans. U.S. Atomic Energy Commission, Washington, 1958. Washington, Office of Technical Services, U.S. Department of Commerce. 246 pages, $4.00. TID–7017. Presents material specifications for tubes, plates, rods, etc., of Iconel, Hastelloy B, and austenitic stainless steel. Procedures for welding these materials to various alloys in different thicknesses are given, as well as inspection requirements.

Report on Cilivian Reactor Fuel Elements (TID–8505). U.S. Atomic Energy Commission, 1959. 191 pages. $1.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) A report prepared by the Civilian Reactor Fuel Element Review Group which was established by the division of Reactor Development to assist the AEC in the formulation of long range plans for the development of fuel element technology. The report contains the following sections: Major conclusions; fuel problems of major reactor types; materials problems; supporting technology; and summary of conclusions.

Production and Separation of U^{233}-Survey (TID–5222). Edited by Glenn T. Seaborg and Leonard I. Katzin. U.S. Atomic Energy Commission, 1951. 219 pages. $5.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This report presents a historical record of early project work done on uranium 233 and is based on a survey of the properties of uranium with mass 233 and the methods for its production. The report brings together in one place most of the known information about uranium 233 up to 1945.

Production and Separation of U^{233}-Collected Papers (TID–5223, Parts 1 & 2). Edited by Leonard I. Katzin. U.S. Atomic Energy Commission, 1952. Part 1—420 pages; Part 2—323 pages. Total price $3.25. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This is the assembled record of the significant work relating to uranium 233 done on the Manhattan Project up to July 1945.

Research Reactors; Selected Reference Material (TID–5275). U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1955. 442 pages. $2.00. This volume presents detailed descriptions of six types of research reactors developed in the national atomic energy program; selected design drawings of reactors, components, and supporting facilities are included. The document was prepared to present the details of the U.S. program to delegates attending the International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955.

Sources and Collectors for Use in Calutrons (TID–5218). Edited by R. K. Wakerling and A. Guthrie. U.S. Atomic Energy Commission, 1949. 273 pages. $1.85. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, and describes the sources and collectors for use in calutrons.

Vacuum Problems and Techniques (TID–5210). C. E. Normand, Frank A. Knox, G. W. Monk, et al. U.S. Atomic Energy Commission, 1950. 265 pages. $1.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This report describes and evaluates the original vacuum equipment required in the operation of the electromagnetic separation process. It presents significant improvements in efficiency resulting from

changes in operating techniques, and brings together information widely spread throughout the literature.

Report of the Fluid Fuel Reactor Task Force (TID–8507). U.S. Atomic Energy Commission, 1959. 188 pages. $1.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This report was prepared by a task force composed of fifteen highly qualified engineers and scientists from the Atomic Energy Commission, its national laboratories and contractor organizations, and representatives of the architect-engineering and utility industry. The task force was organized and commenced to perform a critical evaluation of the three fluid fuel reactor concepts (Aqueous homogeneous—AHR, molton salt—MSR, and liquid metal fuel—LMFR) under development by the Commission. The report represents the group evaluation and judgment of the three fluid fuel reactor concepts.

Radiations from Radioactive Atoms in Frequent Use. L. Slack and Katherine Way. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1959. 75 pages. 55 cents. This book is designed especially for scientists and technicians in the biological and medical sciences who are concerned with estimations and calculations of dose. Tables and graphs for each radioactive atom show explicitly the energies and intensities of all particle and electromagnetic radiations emitted both by the decay in nucleus and also by the orbital electrons in the rearrangements which follow the nuclear transformation. Auxiliary graphs are given on gamma ray dose rates, half-thickness values for gamma rays, electron ranges, average beta ray energies, fluorescence yields, L-shell vacancies per K-shell vacancy, etc.

Some Effects of Ionizing Radiation on Human Beings; A Report on the Marshallese and Americans Accidentally Exposed to Radiation from Fallout and a Discussion of Radiation Injury in the Human Being (TID–5358). Edited by E. P. Cronkite, V. P. Bond, and C. L. Dunham. U.S. Atomic Energy Commission, 1956. 106 pages. $1.25. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Presents an authoritative treatise on the observed effects of the accidental deposition of radioactive materials on inhabited islands and Task Force ships following the detonation of a thermonuclear devise at the Pacific Proving Ground on March 1, 1954.

Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants (WASH–740). U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1957. 105 pages. 65 cents. This is a study of possible consequences if certain assumed accidents, theoretically possible but highly improbable, were to occur in large nuclear powerplants. The study was made in order to gain a more comprehensive understanding of the potential public hazards of nuclear power reactors.

Trilinear Chart of Nuclides. Prepared by W. H. Sullivan. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1957. 9 sheets, each 11½ inches high (can be used in book form or assembled as wall chart). $2.00. A second edition of the chart, completely revised and updated, especially designed for convenient classroom and desk reference work. Presents systematically physical constants for all experimentally identified nuclides known from information available as of July 1956. (Revision sheets for the chart are being issued. The first issue, July 1958, covers significant data changes for the period July 1956 through June 1958. Subsequent sheets will be issued as warranted by the accumulation of new data—probably two to four times a year. This service is being offered initially on an indefinite subscription basis

for $1.00 through the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.)

Constitution of Uranium and Thorium Alloys (BMI–1300). Compiled by F. A. Rough and A. A. Bauer. U.S. Atomic Energy Commission. (Available from the Office of Technical Services, Department of Commerce, Washington 25, D.C.) 138 pages. $2.75. Publication is divided into two major sections, uranium alloys and thorium alloys; each section is preceded by a discussion of the ternary systems which are included. This supersedes "Compilation of US and UK Uranium and Thorium Constitution Diagrams," BMI–1000.

U.S. Research Reactors. U.S. Atomic Energy Commission. 73 pages. $1.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) A compact summary of technical information on the major types of research reactors developed in the United States. Thirty-three reactor facilities are described. A list of research reactors built, building or planned in the United States, including those for foreign locations, is also included.

Biological Effects of External X- and Gamma Radiation (TID–5220, Part 2). Edited by R. E. Zirkle. U.S. Atomic Energy Commission, 1956. 477 pages. $2.10. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) The work reported was part of a large radiobiological research program pursued during World War II under the auspices of the Plutonium Project of the Manhattan District at the Metallurgical Laboratory, University of Chicago, and Clinton Laboratories, Oak Ridge, Tenn. All of the investigations reported were directed toward an understanding of the actions of high-energy radiations on mammals and ultimately on man in particular.

Chemical Processing and Equipment; Selected Reference Material (AECD–5276). U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1955. 302 pages. $2.00. Describes the chemical and engineering aspects of processing materials associated with nuclear reactors. It includes descriptions of radio-chemical laboratories, remote control handling equipment. Like *Research Reactors* described above, this volume was prepared for the benefit of delegates to the International Conference.

The Chemistry and Metallurgy of Miscellaneous Materials (TID–5212). Edited by Laurence L. Quill. U.S. Atomic Energy Commission, 1955. 172 pages. $1.00. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Consists of individual papers dealing with miscellaneous chemical, metallurgical and structural subjects.

Determination of the Isotopic Composition of Uranium (TID–5213). Edited by A. E. Cameron. U.S. Atomic Energy Commission, 1950. 166 pages. $1.52. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Presents some of the solutions to problems encountered in the adaptation of known methods and principals to the routine determination of the isotopic composition of uranium.

Problems of Physics in the Ion Source (TID–5219). Edited by Arthur H. Barnes, S. M. MacNeille, and Chauncey Starr. U.S. Atomic Energy Commission, 1951. 294 pages. $1.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Presents the fundamental processes involved in the operation of calutron source units, and describes the experiments that enabled the investigators to determine these processes.

Proceedings of Meetings and Symposia

Proceedings of the 1958 Atomic Energy Commission and Contractor Safety and Fire Protection Conference (TID–7569). U.S. Atomic Energy Commission, 1959. 121 pages. $2.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises the 16 papers which were presented at the June 1958 conference held at Washington, D.C. Some of the major topics covered were integrated safety organizations in nuclear plants, safety personnel requirements in nuclear energy plants, lessons learned from pressure-vessel accident investigation, metal fire and explosion research. Other accident control and prevention areas were also covered.

Boiling Water Reactor Program (TID–7535). U.S. Atomic Energy Commission, 1957. 164 pages. $2.00. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of papers presented at the May 1957 Technical Briefing Session on Boiling Water Reactor Program held at Argonne National Laboratory and treats such major topics on the EBWR as general description; economic aspects; pressure-vessel design rules, installation history and preliminary performance; physics experiments; plant equipment, leakage and radioactivity; and other aspects on boiling water reactors including program planning for civilian power reactors.

Controlled Thermonuclear Conference (TID–7558). U.S. Atomic Energy Commission, 1958. 528 pages. $4.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This report is a compilation of 80 papers presented at a conference of controlled thermonuclear reactors held in Washington, D.C., February 1958. The primary purpose of the conference was interchange of information between AEC and AEC contractors and briefing of the Sherwood Steering Committee. General reviews and program status are given for the various laboratories in the United States and United Kingdom.

D_2O–Moderated Power Reactors (TID–7575). U.S. Atomic Energy Commission, 1959. 156 pages. $1.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of papers, together with the discussions, of the March 1959 Symposium on D_2O-Moderated Power Reactors held at Washington, D.C. Some of the major topics covered were review of D_2O, future requirements for D_2O, capability of AEC to supply D_2O for future needs, comparison of fuel-cycle costs in D_2O and H_2O-moderated reactors, and many other aspects of D_2O reactor.

Engineering Education and Nuclear Energy (TID–7527). U.S. Atomic Energy Commission, 1957. 206 pages. $1.00. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This is the published proceedings of the September 1956 Conference on Engineering Education and Nuclear Energy held at Gatlinburg, Tenn. Papers are included on the scientific manpower needs in atomic energy programs, the Oak Ridge School of Reactor Technology curriculum, the educational program at Argonne National Laboratory, and educational programs in nuclear science at various universities.

Proceedings of the 1957 Fast Reactor Information Meeting. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1959. 282 pages. $2.00. Comprises a collection of the 38 papers presented at the meeting which was held in Chicago, Ill. The purpose of the meeting was to describe the status of the Fast Breeder Reactor Program and Fast Reactor Safety Pro-

gram for the benefit of access permit holders from industry who had expressed interest in the program.

Fixation of Radioactivity in Stable, Solid Media (TID–7550). U.S. Atomic Energy Commission, 1957. 102 pages. $2.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This is the published proceedings of the June 1957 working meeting held at the Johns Hopkins University on development and progress in treating liquid radioactive wastes so as to fix radioactivity and transform liquids in solid form. Associated problems such as heat evolution and dissipation, air cleaning, and transporting are also discussed.

Fuel Elements Conference (TID–7559, Part I). U.S. Atomic Energy Commission, 1959. 303 pages. $3.00. (Available from Office of Technical Services, Department of Commerce, Washington 25, D.C.) Comprises a collection of 36 papers which were presented at the May 1958 Fuel Elements Conference held in Gatlinburg, Tenn. The specific objection of the conference was to exchange information between contractors to stimulate the over-all development of fuel element technology at AEC sites. The scope of the meeting embraced the design, fabrication, and performance of fuel elements. Materials problems and developments which were of concern and interest in reactor operations were also discussed.

Information Meeting on Gas-Cooled Power Reactors (TID–7564). U.S. Atomic Energy Commission, 1958. 372 pages. $3.50. This meeting was one of a series of Civilian Power Reactor Conferences and was held October 1958. Coincident with an AEC invitation to industry to bid on the construction of a gas-cooled facility. Papers were presented on design studies, hazards, components, costs, materials, and design concepts for specific reactors.

Symposium on Health Physics in Biology and Medicine (TID–7572). U.S. Atomic Energy Commission, 1959. 210 pages. $2.00. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of papers presented at the May 1958 Symposium on Health Physics in Biology and Medicine held at University of Puerto Rico and treats such major topics as the radiological physics program at the University of Puerto Rico, health physics training, problems in the therapy of radiation sickness, health physics aspects of basic medical research, and other areas of health physics in biology and medicine.

Sixth Hot Laboratories and Equipment Conference (TID–7556). U.S. Atomic Energy Commission, 1959. 167 pages. $1.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of 18 papers presented at the March 1958 Sixth Hot Laboratories and Equipment Conference held in Chicago, Ill. Radiochemical cells and process facilities in the United States and at a number of European establishments are described. Irradiation facilities and associated equipment in the United States are described. Hot laboratory practices and equipment, operation, and safety are also discussed.

Fifth International Congress and Exhibition of Electronics and Atomic Energy (TID–7557). U.S. Atomic Energy Commission, 1958. 139 pages. $1.50. Comprises 11 United States papers presented at the Congress and Exhibition held in Rome, Italy, June 1958. Some of the topics covered are: development of nuclear power in the United States; a review of the Boiling Water Reactor performance; fuel recycling in power reactors; the challenge of nuclear power to the life sciences; and growing industrial uses of radioisotopes.

Sixth International Congress and Exhibition of Electronics and Atomic Energy (TID–7579). U.S. Atomic Energy Commission, 1959. 81 pages. $2.25. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises seven United States papers presented at the Congress and Exhibition held in Rome, Italy, June 1959. Papers are included which deal with biological implications of radioactive wastes; ultimate disposal of liquid radioactive wastes; reduction of fuel cycle costs through optimization; safety factors to be considered in reactor siting; dynamic properties of heterogeneous water reactors; meteorology in relation to reactor hazards and site evaluation; and indirect action of ionizing radiation on some organic compounds containing the C–N bond.

1958 Nuclear Merchant Ship Symposium (TID–7563). U.S. Atomic Energy Commission, 1959. 200 pages. $2.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) The objectives of this, the second symposium, held August 1958, on the application of nuclear power to merchant ship propulsion were to acquaint shipping officials with the state of the art of nuclear propulsion for ships, to explore and discuss operational problems of nuclear-powered merchant ships in foreign commerce, to gain the benefit of the views of merchant marine industry officials, and discuss the outlook for nuclear propulsion to meet the specific requirements of the industry. Reports on the construction of the N.S. *Savannah*, the design of a nuclear tanker, maritime reactor propulsion systems, and economic comparison were presented.

Nuclear Powered Ships for American Ship Operators (TID–7539). U.S. Atomic Energy Commission, 1957. 190 pages. $3.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) This is the published proceedings of the July 1957 Symposium on Nuclear Powered Ships for American Ship Operators held at Washington, D.C. Marine applications of nuclear power are discussed with regard to maritime regulations.

A Conference on Radioactive Isotopes in Agriculture (TID–7512). U.S. Atomic Energy Commission, 1957. 416 pages. $3.00. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of papers presented at the January 1956 Conference on Radioactive Isotopes in Agriculture held at the Michigan State University and treats such major topics as waste disposal in agricultural research installations, radiobiological studies, new techniques in tracer use, ionizing radiation in food preservation and lactation.

Radioisotopes in Medicine (ORO–125). Edited by Gould A. Andrews, Marshall Brucer, and Elizabeth B. Anderson. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1953. 817 pages. $5.50. This is the published proceedings of the second advanced training course given by the Oak Ridge Institute of Nuclear Studies. The course was concerned with specialized medical application emphasizing more direct clinical uses of radioisotopes. Chapters include tumor localization, diagnostic and therapeutic uses of radioiodine, therapy with radioactive colloids and other phases of medical utilization of radioisotopes.

Reactor Fuel Measurement Techniques Symposium (TID–7560). U.S. Atomic Energy Commission, 1959. 208 pages. $2.00. Comprises a compilation of the 23 papers presented at the June 1958 Reactor Fuel Measurement Technique Symposium held at Michigan State University and treats such major

topics as sampling controls of reactor fuel alloys, statistical aspects of melt sampling; X-ray spectrographic analysis of reactor fuel alloys; the separation and determination of microgram amounts of zirconium and rhodium in fission alloys and other aspects of reactor fuel measurement techniques.

Reactor Heat Transfer (TID–7529, Part 1—Books 1 and 2). U.S. Atomic Energy Commission, 1957. 635 pages. $7.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of papers and reports presented at the November 1956 Conference on Reactor Heat Transfer held at New York. Some of the major topics covered are a review of methods used in control rod analysis for reactor design at the Bettis Plant of Westinghouse Electric Co., formulas for control rod worth in thermal reactors, half-group theories for control rods, the general application of burnable poisons, experiments with control rods and voids in a pool type reactor, and many other reactor control problems and experiments.

Reprocessing of Irradiated Fuels (TID–7534—Books 1, 2 and 3). U.S. Atomic Energy Commission, 1957. 1,165 pages. $10.50. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of papers presented at the May 1957 International Symposium on the Reprocessing of Irradiated Fuels held at Brussels, Belgium and treats an area of separations development capable of immediate application to the design and operation of facilities for reprocessing irradiated reactor fuels. Five sessions were held covering aqueous reprocessing; auxiliary processes; disposal of plant effluents; nonaqueous processes and engineering and economics.

Roentgens, Rads, and Riddles—A Symposium on Supervoltage Radiation Therapy. Edited by Milton Friedman, Marshall Brucer, and Elizabeth Anderson. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office, 1959. 495 pages. $3.50. Comprises a collection of papers presented at the July 1956 Symposium on Supervoltage Radiation Therapy held at Oak Ridge, Tenn. Major topics covered are: dosage consideration for supervoltage, radiotherapy, dosimetry of moving vehicles, the design of apparatus and sources, installation problems, source production, principles of clinical supervoltage irradiation, case problems, and brachytherapy.

Shielding of High-Energy Accelerators (TID–7545). U.S. Atomic Energy Commission, 1957. 231 pages. $2.75. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of papers presented at the April 1957 Conference on Shielding of High-Energy Accelerators held at New York and treats such major topics as the shielding facilities of accelerators existing at present; factors influencing shielding design and accelerator location; shielding computations; biological effects of high-energy radiation and tolerance levels; and shielding design for accelerators now under construction.

Symposium on Technical Methods in Health Physics (TID–7577). U.S. Atomic Energy Commission, 1959. 124 pages. $1.25. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises a collection of six United States papers presented at the Symposium held at Riso, Denmark, May 1959. The papers cover the use of low level scintillation spectroscopy in the evaluation of radioactive contamination of the human body, the scientific basis for maximum permissible limits of internal contamination, immediate evaluation of doses from external radiation and from internal contamination in the event of a radiation acci-

dent, confinement techniques and handling of Pu in research laboratories, chemical methods in the evaluation of human contamination and, the shielding of high-energy accelerators.

Fifth Tripartite Instrumentation Conference (TID–7543). U.S. Atomic Energy Commission, 1958. 179 pages. $3.00. (Available from Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.) Comprises the collection of 55 papers presented at a meeting of delegates of the United States, Canada and Great Britain held October 1956 at Brookhaven National Laboratory, New York. Papers are included which deal with trends and recent developments in reactor instrumentation and control; recent advances in reactor instrumentation in England; fission counter; radiation monitors; dosimeters; recent work at Chalk River; data printer; and other topics on instrumentation.

Periodicals and Catalogs

Nuclear Science Abstracts. U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office. Available postpaid on subscription and in single copy at the following prices: Semimonthly issues: Annual subscription rate, $18.00, domestic; $22.50, foreign; price per single copy, $1.25, domestic; 25 percent extra for foreign mailing. Cumulated—index issues. Annual subscription rate, $15.00, domestic; $17.50, foreign; price per single copy varies according to the number of pages. Published bimonthly. This bimonthly publication contains abstracts of all current Commission declassified and unclassified reports, of non-Commission reports related to atomic energy, and of articles appearing in both foreign and domestic periodical literature.

Isotopes—Catalog and Price List. Oak Ridge National Laboratory, Oak Ridge, Tenn., January 1957. $1.00. This publication lists and describes radioactive and stable isotopes available from ORNL and includes prices and instructions for ordering the isotopes.

Nuclear Safety (Technical Progress Reviews). Prepared by Oak Ridge National Laboratory for the U.S. Atomic Energy Commission, W. B. Cottrell, editor, R. A. Charpie, advisory editor. Washington, U.S. Government Printing Office. Available on subscription for $2.00 a year, 55 cents per issue. Published quarterly. This quarterly review on nuclear safety is intended for reactor designers, reactor builders, reactor fuel specialists, regulatory and public safety officials, and others concerned with nuclear safety—this new journal in the Commission's Technical Progress Review series summarizes current developments in this important field. Activities of AEC's Advisory Committee on Reactor Safeguards and Hazards Evaluation Branch are also summarized, and recent safeguards reports are reviewed.

Power Reactor Technology (Technical Progress Review). Prepared by the General Nuclear Engineering Corp. for U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office. Available on subscription for $2.00 per year domestic; $2.50 foreign; 55 cents per copy. Published quarterly. This quarterly review of reactor development is intended to assist interested organizations in the task of keeping abreast of new results in reactor technology for civilian application. Each issue of the journal reviews reactor development progress on a current basis.

Reactor Core Materials (Technical Progress Review). Prepared by Battelle Memorial Institute for U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office. Available on subscription for $2.00 per year domestic; $2.50 foreign; 55 cents per copy. Published quarterly. This quarterly review covers significant developments in the field of solid reactor core materials. It provides a convenient condensed source of information to two types of readers: (1) those who wish to keep abreast of developments in a general way and (2) those interested in learning where to find detailed accounts of work in particular areas. Complete bibliographies are provided at the end of each section.

Reactor Fuel Processing (Technical Progress Review). Prepared by Argonne National Laboratory for U.S. Atomic Energy Commission. Washington, U.S. Government Printing Office. Available on subscription for $2.00 per year domestic; $2.50 foreign; 55 cents per copy. Published quarterly. This quarterly review of reactor fuel processing is intended to assist interested organizations in keeping abreast of progress in this field. Each review covers those particular subjects in which significant advances have been made.

Depository Libraries

In order to make the nonclassified results of Commission research and development available to the public, the following libraries serve as depositories for essentially all the Commission's nonclassified reports. A number of other university and public libraries also receive copies of the reports that are sold by the Office of Technical Services.

Alabama
- Auburn, Alabama Polytechnic Institute.
- Birmingham, Birmingham Public Library.

Arizona
- Tucson, University of Arizona.

Arkansas
- Fayetteville, University of Arkansas.

California
- Berkeley, University of California General Library.
- Los Angeles, University of California Library.
- Menlo Park, Stanford Research Institute.
- San Diego, San Diego Public Library.

Colorado
- Denver, The Public Library, The City and County of Denver.

Connecticut
- New Haven, Yale University Library.

Delaware
- Newark, University of Delaware Library.

District of Columbia
- Washington, Library of Congress.

Florida
- Coral Gables, University of Miami Library.
- Gainesville, University of Florida Library.

Georgia
- Atlanta, Georgia Institute of Technology Library.

Hawaii
- Honolulu, University of Hawaii.

Illinois
- Chicago, John Crerar Library.
- Chicago, University of Chicago Library.
- Evanston, Northwestern University Library
- Urbana, University of Illinois Library.

Indiana
- Indianapolis, Indianapolis Public Library.
- Lafayette, Purdue University Library.

IOWA
Ames, Iowa State College Library.
KANSAS
Manhattan, Kansas State College School of Engineering and Architecture.
KENTUCKY
Lexington, University of Kentucky Library.
Louisville, University of Louisville Library.
LOUISIANA
Baton Rouge, Louisiana State University Library.
New Orleans, Tulane University Library.
MARYLAND
Baltimore, The Johns Hopkins University Library.
College Park, University of Maryland Engineering and Physical Sciences Library.
MASSACHUSETTS
Cambridge, Harvard University Library.
Cambridge, Massachusetts Institute of Technology Library.
MICHIGAN
Ann Arbor, University of Michigan Library.
Detroit, Detroit Public Library.
MINNESOTA
Minneapolis, University of Minnesota Library.
MISSOURI
Kansas City, Linda Hall Library.
Rolla, University of Missouri School of Mines and Metallurgy Library.
St. Louis, Washington University Library.
MONTANA
Bozeman, Montana State College Library.
NEVADA
Reno, University of Nevada Library.
NEW JERSEY
Princeton, Princeton University Library.
NEW MEXICO
Albuquerque, University of New Mexico Library.
NEW YORK
Buffalo, University of Buffalo, Lockwood Memorial Library.
Ithaca, Cornell University Library.
New York, Atomic Industrial Forum.
New York, Columbia University Library.
New York, New York Public Library.
Rochester, University of Rochester Library.
Schenectady, Union College Library.
Syracuse, Syracuse University.
Troy, Rensselaer Polytechnic Institute Library.
NORTH CAROLINA
Charlotte, Charlotte and Mecklenburg County Public Library.
Durham, Duke University Library.
Raleigh, North Carolina State College Library.
OHIO
Cincinnati, University of Cincinnati Library.
Cleveland, Cleveland Public Library.
Columbus, Ohio State University Library.
Toledo, University of Toledo Library.
Youngstown, Youngstown University Library.
OKLAHOMA
Stillwater, Oklahoma State University Library.
OREGON
Covallis, Oregon State College Library.
Portland, Portland Public Library.
PENNSYLVANIA
Philadelphia, University of Pennsylvania Library.
Pittsburgh, Carnegie Library of Pittsburgh.
University Park, Pennsylvania State University, Pattee Library.
PUERTO RICO
Rio Piedras, University of Puerto Rico Main Library.
RHODE ISLAND
Providence, Brown University.

SOUTH CAROLINA
Columbia, University of South Carolina, McKissick Memorial Library.
TENNESSEE
Knoxville, University of Tennessee Library.
Memphis, Cossett Memorial Library.
Nashville, Joint University Libraries.
TEXAS
Austin, University of Texas Library.
College Station, Agricultural and Mechanical College of Texas Library.
Dallas, Southern Methodist University.
Houston, Rice Institute.
San Antonio, San Antonio Public Library.
UTAH
Salt Lake City, University of Utah Library.
VIRGINIA
Blacksburg, Virginia Polytechnic Institute.
Charlottesville, University of Virginia, Alderman Library.
WASHINGTON
Pullman, State College of Washington Library.
Seattle, University of Washington Library.
WEST VIRGINIA
Morgantown, West Virginia University Library.
WISCONSIN
Madison, University of Wisconsin Library.
Milwaukee, Milwaukee Public Library.
WYOMING
Laramie, University of Wyoming Library.

CLASSIFIED DEPOSITORIES

The Commission established a series of depository libraries where the access permit holders participating in the Civilian Applications Program can consult classified reports made available to them. These depositories have been located at the Massachusetts Institute of Technology for the Boston area; at the Argonne National Laboratory for the Chicago area; at the National Reactor Testing Station, Idaho Falls, Idaho; at the New York Operations Office, New York City; at the Reference Center, Technical Information Service Extension, Oak Ridge, Tenn.; at the Stanford Research Institute, Palo Alto, Calif.; and at the Atomic Energy Commission Headquarters, Washington, D.C.; Carnegie Library of Pittsburgh, Pittsburgh, Pa.

APPENDIX 7

Film Libraries

The domestic libraries are located at the following Commission offices and cover requests from the following States:

Washington, D.C	Maryland, Virginia, West Virginia, District of Columbia and Delaware.
New York, N.Y	New York, Canada, Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, Pennsylvania and New Jersey.
Aiken, S.C	Alabama, Florida, North Carolina, South Carolina and Georgia.
Idaho Falls, Idaho	Montana, Utah and Idaho.
Oakland, Calif	California and Hawaii.
Grand Junction, Colo	Colorado, Wyoming, Kansas and Nebraska.
Lemont, Ill	North Dakota, South Dakota, Missouri, Iowa, Ohio, Indiana, Michigan, Minnesota, Wisconsin and Illinois.
Oak Ridge, Tenn	Kentucky, Mississippi, Arkansas, Louisiana and Tennessee.
Albuquerque, N. Mex	Nevada, Arizona, New Mexico, Texas and Oklahoma.
Richland, Wash	Washington, Oregon and Alaska.

APPENDIX 8

Regulations of the U.S. Atomic Energy Commission [1]

Part 2—Rules of Practice

INTERMEDIATE DECISIONS

On April 3, 1959, the Commission issued for public comment proposed amendments to Part 2 of the Commission's rules and regulations providing that, unless some longer time is provided in an intermediate decision, (1) briefs in support of exceptions to the decision shall be filed at the same time as such exceptions are filed, and (2) briefs in opposition to such exceptions shall be filed within 10 days after the service of such exceptions.

Because this amendment deals with procedural rules and immediate effectiveness thereof will not adversely affect any person, the Commission has found that good cause exists why this amendment should be made effective without the customary period of prior notice. Pursuant to the Administrative Procedure Act, Public Law 404, 79th Congress, 2d Sess., Title 10, Code of Federal Regulations, Part 2 is amended as follows, effective upon publication in the Federal Register:

1. Section 2.751(c)(5) is amended to read as follows:

§ 2.751 Intermediate decisions and their effect.

* * * * *

(c) Each intermediate decision shall be in writing and shall contain:

* * * * *

(5) In the case of an intermediate decision which may become final unless exceptions are filed, the date when such decision will become final in the absence of exceptions thereto.

2. Section 2.752 is amended to read as follows:

§ 2.752 Exceptions to intermediate decisions.

(a) Within 20 days after service of any intermediate decision, or such longer period as may be fixed therein, any party to a hearing may file with the Commission exceptions to such decision and a brief in support thereof, and shall serve copies of such exceptions and supporting brief on all other parties to the hearing. Each exception shall be separately numbered, shall identify the part of the intermediate decision to which objection is made, shall designate by specific reference the portions of the record relied upon in support of the objections, and shall state the grounds for the exception including the citation of authorities in support thereof. Any objection to a ruling, finding, or conclusion which is not made part of the exceptions shall be deemed to have been waived, and the Commission need not consider such objections.

(b) Within 10 days after service of exceptions to the intermediate decision and brief in support thereof, or such longer period as may be fixed in such decision, any party to a hearing may file with the Commission a brief in opposition to such exceptions.

(Sec. 161, 68 Stat. 948; 42 U.S.C. 2201)

Dated at Germantown, Md., this 28th day of April 1959.

For the Atomic Energy Commission.

A. R. Luedecke,
General Manager.

[1] Policies and regulations of the U.S. Atomic Energy Commission announced prior to this Annual Report can be found in the *Federal Register* and in the following semiannual reports to Congress: Fifth, Sixth, Ninth through the Seventeenth, and Nineteenth through the Twenty-Fifth.

PART 3—RULES OF PROCEDURE IN CONTRACT APPEALS

On February 3, 1959, the Commission published a revision of Part 3, "Rules of Procedure in Contract Appeals," under which the Atomic Energy Commission Hearing Examiner was substituted for the Advisory Board on Contract Appeals with respect to appeals under disputes articles in Commission contracts and subcontracts. All cases pending before the Advisory Board have now been completed.

Commission study of the procedural problems involved in contract appeals, including the rules of the Armed Services Board of Contract Appeals, has resulted in the revised rules of procedure which follow. The Commission will continue to study the problems involved in these rules with a view to making such further changes as may from time to time appear to be desirable. Members of the bar, contractors, and others are invited to submit any further comments and suggestions they may have to the Commission, Attention: General Counsel, Washington 25, D.C.

Because of the procedural nature of these rules, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon are unnecessary, and that good cause exists why these rules should be made effective without the customary period of prior notice.

Pursuant to the Administrative Procedure Act, the following rules are published as a document subject to codification, to be effective upon publication thereof in the Federal Register:

GENERAL PROVISIONS

Sec.
3.1 Purpose.
3.2 Scope.
3.3 Definitions.
3.4 Pleadings.
3.5 Computation of time.
3.6 Service of papers, methods, proof.
3.7 Representation.
3.8 Security.

PRELIMINARY PROCEEDINGS

Sec.
3.10 Initial determination.
3.11 Appeal.
3.12 Notice of appeal.
3.13 Complaint.
3.14 Transmittal of notice of appeal.
3.15 Notification of parties by hearing examiner.
3.16 Answer.
3.17 Admissions.
3.18 Amendments of pleadings.
3.19 Motions.
3.20 Pre-hearing conferences.
3.21 Request for hearing by answering parties.
3.22 Decision by hearing examiner without hearing.

HEARINGS

3.30 Notice of hearing.
3.31 Place of hearing.
3.32 Absence of parties or counsel.
3.33 Official reporter; transcript.
3.34 Conduct of hearings.
3.35 Trial briefs.
3.36 Subpenas.
3.37 Depositions.
3.38 Discovery and production of documents and things for inspection, copying, or photographing.
3.39 Requests for withholding documents from public record.

DECISIONS

3.40 Briefs.
3.41 Record for decision.
3.42 Decision.

COMMISSION REVIEW

3.50 Commission review.

MISCELLANEOUS

3.60 Effective date.

APPENDICES

A. Notice of appeal.
B. Complaint.

AUTHORITY: §§ 3.1 to 3.60 issued under sec. 161, 68 Stat. 948, 42 U.S.C. 2201. Dated at Germantown Md., this 21st day of December 1959.

GENERAL PROVISIONS

§ 3.1 Purpose.

(a) Contracts entered into by the AEC usually contain a disputes article providing that disputes arising under the contract which are not disposed of by mutual agreement shall be decided in the first instance by the contracting officer. Many subcontracts under AEC cost-type contracts contain similar articles. The typical disputes clause

further provides that the contractor or subcontractor may make an appeal in writing to the designated representative of representatives of the Commission, whose decision shall be final.

(b) The rules of procedure contained in this part are designed to provide an orderly and expeditious means for handling contract appeals. The AEC Hearing Examiner is the designated representative to hear, consider, and initially decide, and appeal from the decision of a contracting officer in a dispute arising, or alleged to arise, under a Commission contract and subcontract. Subject to the provisions of 41 U.S.C. sections 321 and 322, his decision is final unless one of the parties to the proceeding requests review thereof by petition and the Commission grants the petition and orders the record and decision submitted to the members thereof for further decision.

§ 3.2 Scope.

The rules contained in this part set forth the procedure which will be followed by the parties and by the Hearing Examiner in arriving at his decision, and by the Commission in the review, if any, of such decision, as to the disposition of an appeal from a decision of a contracting officer in a dispute arising, or alleged to arise, under a contract or subcontract.

§ 3.3 Definitions.

(a) "AEC" means the agency established by the Atomic Energy Act of 1954, as amended, 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.

(b) "Contracting Officer" shall mean the representative of the Commission who, under the contract or subcontract, has the responsibility for determining the dispute in the first instance and from whose decision appeal may be taken.

(c) "Contractor" shall include a subcontractor, and "contract" shall include a subcontract, as the case may be.

(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, as amended.

(e) "Hearing examiner" shall mean the AEC officer designated by the Commission to conduct assigned hearings in accordance with regulations of the Commission under the Atomic Energy Act of 1954, as amended, including the rules set forth in this part.

(f) "Party" or "parties" shall mean (1) the prime contractor and the contracting officer, if the dispute arises, or is alleged to arise, under a prime contract; or (2) the contractor and subcontractor if the dispute arises, or is alleged to arise, under a subcontract: *Provided, however,* The AEC Hearing Examiner may, upon good cause shown, permit the AEC to participate as a party to the appeal.

§ 3.4 Pleadings.

(a) All pleadings shall be simple, concise, and direct. They shall be so construed as to do substantial justice.

(b) All pleadings of the contractor and the notice of appeal provided in § 3.12 shall be dated and shall be signed by the contractor if an individual, by an officer thereof if a corporation, by a partner thereof if a partnership, by a joint venturer if a joint venture, or by the duly authorized attorney-at-law thereof.

(c) All pleadings of the contracting officer or AEC shall be dated and signed by the AEC counsel therefor.

§ 3.5 Computation of time.

The provisions of § 2.701 of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

§ 3.6 Service of papers, methods, proof.

The provisions of § 2.703 of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

§ 3.7 Representation.

(a) The parties may represent them-

selves or may be represented in the proceeding by an attorney-at-law in good standing admitted to practice before any court of the United States, the District of Columbia, or the highest court of any state, territory or possession of the United States.

(b) Notice of appearance by an attorney-at-law, including AEC counsel, shall be given by filing with the Hearing Examiner a statement that the representative is an attorney-at-law in good standing admitted to practice before any court of the United States, the District of Columbia, or the highest court of any state, territory, or possession of the United States. Thereafter, any service of notice or papers upon the authorized representative shall constitute service upon the party, but a copy of all notices and papers served upon the party shall also be sent to the duly authorized representative.

§ 3.8 Security.

All proceedings under this part shall be so conducted as to insure compliance with the security regulations and requirements of the Commission, and the contracting officer, the hearing examiner, and the Commission may take appropriate steps to insure said compliance in accordance with the provisions of the Atomic Energy Act of 1954, as amended, and the regulations issued thereunder, including §§ 2.800 to 2.814 of this chapter (the AEC Rules of Practice).

PRELIMINARY PROCEEDINGS

§ 3.10 Initial determination.

Where a dispute arising, or alleged to arise, under a contract cannot be disposed of by mutual agreement, the contracting officer shall, in all cases and as expeditiously as possible, prepare and serve in writing upon the contractor his specific findings of fact with respect to such dispute, his decision thereon, and a copy of the rules contained in this part and Part 2 of this chapter (the AEC Rules of Practice).

§ 3.11 Appeal.

An appeal from the decision of the contracting officer shall be taken by the contractor by serving upon the contracting officer, from whose decision the appeal is taken, a notice of appeal, together with three copies thereof, within sixty days after service upon the contractor of such decision or within such other period as may be provided by the contract under which the dispute has arisen or is alleged to arise. The complaint provided for in § 3.13 may be filed with the notice of appeal.

§ 3.12 Notice of appeal.

The notice of appeal shall be in writing; shall indicate that an appeal is thereby intended; shall identify (a) the contract, by number, under which the dispute has arisen, or is alleged to arise, and (b) the decision of the contracting officer from which the appeal is taken and the date thereof; and may request that a hearing be held. A suggested form of notice of appeal is set forth in Appendix A, but the notice of appeal may be in such other form as shall conform to the requirements of this section.

§ 3.13 Complaint.

(a) The contractor shall serve an original and three copies of a complaint with respect to the dispute which is the subject of the decision of the contracting officer (1) upon the contracting officer, if the complaint is filed with the notice of appeal; or (2) upon the hearing examiner, if the complaint has not been filed with the notice of appeal, within twenty days after the service of the notice of appeal upon the contracting officer or within such other period of time as may be ordered by the hearing examiner, upon application therefor with due notice to the other party or parties to the dispute.

(b) The complaint shall (1) identify the contract, by number, with respect to which the dispute has arisen, or is alleged to arise; (2) set forth the article

or articles of the contract pertaining to disputes thereunder; (3) identify other articles of the contract relevant to the dispute; (4) identify the decision of the contracting officer from which the appeal is taken; (5) describe the portion or portions of such decision which the contractor claims to be erroneous, with a brief statement therefor; and (6), if the contractor desires an oral hearing before the hearing examiner, contain a request that such hearing be held. A suggested form of complaint is set forth in Appendix B, but the complaint may be in such other form as shall conform to the requirements of this section.

(c) Documentary evidence in support of the allegations of the complaint may be filed as exhibits thereto, subject to a motion to strike by an adverse party at the hearing or, if no hearing is requested or ordered, at the time the answer is filed.

§ 3.14 Transmittal of notice of appeal.

When the contracting officer has been served with a notice of appeal, or with a notice of appeal and complaint, as the case may be, he shall forthwith endorse the date of such receipt on the original and copies thereof and within ten days thereafter forward to the hearing examiner (a) the original and two copies of such notice of appeal or of such notice of appeal and complaint, as the case may be, and (b) three copies of the contract, the findings of fact and decision of the contracting officer, and supporting data, correspondence, or other documents relative to the dispute, together with a list thereof. The contracting officer shall simultaneously serve one copy of each document (except the contract), together with a copy of the list of all such documents, upon the appellant.

§ 3.15 Notification of parties by hearing examiner.

Upon receipt thereby of the material referred to in § 3.14, the hearing examiner shall forthwith docket the appeal and so notify the parties.

§ 3.16 Answer.

(a) Within twenty days after service of the complaint, or within such other period of time as may be ordered by the hearing examiner upon application therefor with due notice to the other party or parties, the contracting officer or other adverse party, as the case may be, shall prepare and serve an original and two copies of an answer to such complaint upon the hearing examiner.

(b) The answer shall state in short and plain terms the defense to each claim asserted and shall admit or deny averments upon which the appellant relies. If the answering party is without knowledge or information sufficient to form a belief as to the truth of an averment, the answer shall so state, and this has the effect of a denial. Affirmative defenses shall be stated separately in the answer.

(c) Lack of jurisdiction of the hearing examiner to hear the appeal and failure to state a claim upon which relief can be granted may be asserted in the answer or may be raised by appropriate motion, as provided in § 3.19.

(d) Documentary evidence in support of defenses contained in the answer may be filed as exhibits thereto, subject to a motion to strike at the hearing or, if no hearing is requested or ordered, within ten days after service of the answer.

§ 3.17 Admissions.

The provisions of § 2.739 of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

§ 3.18 Amendments of pleadings.

(a) At any time before hearing or before submission of a case by the parties without hearing, the hearing examiner in his discretion may permit a party, upon appropriate application and with notice to the other party or parties, to amend his complaint or answer. The hearing examiner may, upon his own initiative or upon application by a party, order another party to make a

more definite statement of its complaint or answer, or to reply to an answer.

(b) When issues within the proper scope of the appeal but not raised by the complaint and answer are tried by express or implied consent of the parties, such issues shall be treated in all respects as if they had been raised in such complaint and answer. Such amendment of the complaint and answer as may be necessary to cause them to conform to the evidence may be made upon motion at any time, even after decision, but failure so to amend will not affect the result of the trial of such issues. If evidence is objected to at the hearing on the ground that it is not within the issues raised by the complaint and answer, the hearing examiner may allow the pleadings to be so amended within the proper scope of the appeal when the presentation of the merits of the action will be served thereby and the objecting party shall not be materially prejudiced in the presentation of his case: *Provided, however,* That the hearing examiner may grant, in appropriate circumstances, a continuance of the hearing to enable the objecting party to meet such evidence.

§ 3.19 Motions.

(a) Unless raised by the answer, lack of jurisdiction and failure to state a claim upon which relief can be granted must be raised by motion before the hearing on the merits. Such motions shall be heard and determined before hearing on the merits unless the hearing examiner orders that determination of the motion be deferred pending hearing on both the merits and the motion. The hearing examiner has the right at any time to recognize his lack of jurisdiction to proceed in a particular case.

(b) With respect to a motion to dismiss for failure to state a claim upon which relief can be granted, the hearing examiner, in his discretion, may permit a party to amend his complaint, within the proper scope of the appeal. If the hearing examiner thereafter finds that the complaint, with such amendments as may be offered and permitted, fails to state a claim upon which relief can be granted, the appeal shall be dismissed.

(c) The hearing examiner may, in his discretion, hear and grant any other proper motion filed by any party.

§ 3.20 Pre-hearing conferences.

The provisions of § 2.740 of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

§ 3.21 Request for hearing by answering party.

If a hearing has not been requested by a party in the notice of appeal or complaint, another party may, not later than the filing date of the answer or in the answer, request that a hearing be held by the hearing examiner.

§ 3.22 Decision by hearing examiner without hearing.

If a hearing has not been requested by any party and the hearing examiner does not order a hearing on his own motion, briefs may be filed with the hearing examiner by each party within such period of time as may be allowed by the hearing examiner. Upon the filing of such briefs and of such reply briefs as he may by order permit, the hearing examiner shall proceed to a decision of the appeal on the basis of the record then before him.

HEARINGS

§ 3.30 Notice of hearing.

If a hearing has been requested by either party or ordered by the hearing examiner on his own motion, the hearing examiner shall fix the time when and the place where such hearing will be conducted and shall serve upon the parties at least thirty days' notice thereof in writing, unless the parties shall stipulate to a shorter time. In fixing a time and place for hearing, the hearing examiner shall give due regard to the convenience and necessity of the parties or their representatives.

§ 3.31 Place of hearing.

Hearings ordinarily shall be held at

the location of the AEC office administering the contract, but may be held at the AEC Headquarters Building at Germantown, Maryland, or such other place as shall be determined by the hearing examiner, on his own motion or upon appropriate application therefor by a party.

§ 3.32 Absence of parties or counsel.

The unexcused absence of a party or his authorized representative at the time and place set for the hearing shall not be the occasion for delay. In such event, the hearing shall proceed, and the appeal shall be deemed as having been submitted without oral testimony or argument on behalf of such absent party.

§ 3.33 Official reporter; transcript.

The provisions of § 2.743 of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

§ 3.34 Conduct of hearings.

(a) The hearing shall be conducted as a trial de novo of (1) the issues of fact raised before the contracting officer with respect to the dispute which is the subject of the appeal, and (2) any relevant issue of law, and the appeal shall be considered by the hearing examiner as though such issues were first tried before him.

(b) The provisions of § 2.733, "Powers of Presiding Officers," and § 2.747, "Evidence," of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

(c) Except as the hearing examiner shall otherwise order in the interests of justice, the party making a claim or claims which is or are the subject of the dispute shall have the burden of proof.

(d) Witnesses shall be examined orally under oath or affirmation, unless the testimony of such witness is stipulated or the hearing examiner shall otherwise order. Attention of the witness shall be invited to the penalties provided in 18 U.S.C. section 1001 or 18 U.S.C. section 1621, as appropriate.

§ 3.35 Trial briefs.

The hearing examiner in his discretion may order any party, prior to the commencement or during the course of the hearing, to file a trial brief, or to supplement or amend such brief, with respect to the issues of fact and law properly presented and tried at such hearing pursuant to the rules contained in this part.

§ 3.36 Subpenas.

The provisions of § 2.744 of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

§ 3.37 Depositions.

The provisions of § 2.745 of this chapter (the AEC Rules of Practice) shall be applicable to proceedings under this part.

§ 3.38 Discovery and production of documents and things for inspection, copying, or photographing.

(a) Upon motion of any party showing good cause therefor and upon notice to all other parties, the hearing examiner may (1) order any party to produce and permit the inspection and copying or photographing, by or on behalf of the moving party, of any designated documents, papers, books, accounts, letters, photographs, objects, or tangible things, not privileged in the opinion of the hearing examiner, which are in such party's possession, custody, or control and which constitute or contain evidence (including the existence, description, nature, custody, condition, and location of any books, documents, or other tangible things and the identity and location of persons having knowledge of relevant facts) regarding any matter that is relevant to the subject matter involved in the pending appeal, whether it relates to the claim or defense of a party; or (2) order any party to permit entry upon designated land or other property in his or its possession or control for the purpose of inspecting, measuring, surveying, or photographing the property or any designated objects or operation thereon which is relevant as described in subparagraph (1) of this paragraph.

(b) It is not ground for objection to the motion that the evidence will be inadmissible at the trial if the evidence sought appears reasonably calculated to lead to the discovery of admissible evidence.

(c) The order shall specify the time, place, and manner of making the inspection and taking the copies and photographs and may prescribe such terms and conditions as are just. The hearing examiner may make an order that the inspection, copying, measuring, surveying, or photographing shall be limited to certain matters, or that secret processes, developments, or research need not be disclosed; or the hearing examiner may make any other order which justice requires to protect the party from annoyance, embarrassment, or oppression.

§ 3.39 Requests for withholding documents from public record.

(a) The hearing examiner may order withheld from the public record in any appeal any document or information therein if disclosure of its contents is not required in the public interest and would adversely affect the interest of the party concerned. Such withholding from the public record shall not, however, affect the right of persons properly and directly concerned to inspect the document.

(b) Any party requesting that any document or information therein be withheld from public disclosure shall make prompt application therefor to the hearing examiner, identifying the material and giving the reasons, with notice to the other parties. The hearing examiner may grant such request upon a finding that public disclosure is not required in the public interest and would adversely affect the interest of the party concerned.

DECISIONS

§ 3.40 Briefs.

The hearing examiner may order such briefs to be filed by each party after the conclusion of the hearing as he may provide, and within such reasonable periods of time as he may allow.

§ 3.41 Record for decision.

The exclusive record for decision by the hearing examiner shall consist of (a) the findings of fact and decision of the contracting officer, (b) the notice of appeal, (c) the contract, supporting data, correspondence, and other documents transmitted by the contracting officer to the hearing examiner pursuant to § 3.14, (d) the pleadings, (e) the transcript of the hearing, if any, and (f) all other written motions, orders, briefs, and other documents of public record. No other evidence shall be considered by the hearing examiner.

§ 3.42 Decision.

(a) When an appeal is taken pursuant to a disputes clause in a contract which provides only for appeals from decisions on questions of fact, the hearing examiner shall consider and decide all questions of law necessary for the complete adjudication of all said questions of fact.

(b) The hearing examiner shall make specific findings of fact and conclusions of law in writing, supported by the substantial evidence of record in the proceeding, and shall render a decision based thereon.

(c) The decision of the hearing examiner shall constitute the final action of the Commission sixty days after the date thereof, unless any party shall within such period file a petition for review of such decision and the Commission, in its discretion, shall thereafter grant such petition.

COMMISSION REVIEW

§ 3.50 Commission review.

(a) The petition for review shall concisely and plainly state (1) the facts upon which the petitioner bases his claim that he has been adversely affected or aggrieved by the decision of the hearing examiner or that review thereof is required in the public interest under applicable statutes and rules, and (2) the

relief or disposition of the appeal which the petitioner seeks by review.

(b) Ten copies of the petition for review and brief in support thereof shall be filed with the Secretary of the Commission, who shall forthwith serve upon each member of the Commission one copy of the petition and brief, together with a copy of the decision of the hearing examiner.

(c) Within twenty days after the filing of the petition for review and brief in support thereof, the respondent may file ten copies of an opposing brief with the Secretary of the Commission, who shall forthwith serve one copy thereof upon each member of the Commission.

(d) In their consideration of the petition for review and briefs filed with respect thereto, the Commission may take into consideration, without limitation, (1) the propriety of the award on its face or the size of the award; (2) compliance by the contractor, contracting officer, and the hearing examiner with the requirements and standards of applicable statutes and rules and the contract involved; and (3) important questions of policy or administration presented by the record in the case.

(e) If the Commission denies the petition for review, the decision of the hearing examiner shall thereupon become the final action of the Commission. If the Commission grants the petition for review, it shall (1) direct the hearing examiner to forthwith certify the record of the case to the Commission and (2) issue an order for review which shall fix a time within which the parties may submit exceptions and briefs with reference to the decision of the hearing examiner.

(f) Each exception submitted pursuant to paragraph (e)(2) of this section shall be separately numbered, shall identify the part of the decision of the hearing examiner to which objection is made, shall designate by specific reference the portions of the record relied upon in support of the objections, and shall state the grounds for the exception, including the citation of authorities in support thereof. Any objection to a ruling, finding, or conclusion which is not made part of the exceptions shall be deemed to have been waived, and the Commission need not consider such objection.

(g) After the expiration of the time provided by Commission order pursuant to paragraph (e)(2) of this section, the Commission shall proceed to a final decision on the appeal, in the manner provided in §§2.750, 2.753(b), 2.754, 2.755, and 2.756 of this chapter (the AEC Rules of Practice).

(h) No AEC officer or employee, other than (1) a Commissioner, (2) a member of his immediate staff, or (3) Commission personnel who have not previously been involved, directly or indirectly, in the subject matter of the proceeding, in the proceeding itself, or in a factually related case, may participate or advise in the consideration of a petition for review or in the final decision of the Commission, except as a witness or counsel in the formal proceeding.

MISCELLANEOUS

§3.60 Effective date.

The revised rules contained in this part shall become prospectively effective, to the extent applicable, upon publication thereof in the FEDERAL REGISTER.

The rules contained in 10 CFR Part 3, "Rules of Procedure of United States Atomic Energy Commission Advisory Board on Contract Appeals", 15 F.R. 5834 (Aug. 30, 1955), are hereby repealed.

APPENDIX A

UNITED STATES ATOMIC ENERGY COMMISSION

Appeal of

(Contractor or subcontractor)

Under Contract (Subcontract) No.----------

Docket No. CA-----

NOTICE OF APPEAL

Notice of appeal hereby is filed by ..... under its
(Name of contractor or subcontractor)
Contract (or Subcontract) No. ..... dated ..... with .....
The decision(s) of the AEC Contracting Officer, ..., from
(Name and location)
which the appeal is taken, with the date(s) thereof is (are) as follows:

(Here insert by numbered paragraphs the decision or decisions, in substantially the following form:

1. The decision of the Contracting Officer dated November 4, 1958, that radiator valves must be furnished and installed on invectors.

2. The decision of the Contracting Officer dated November 4, 1958, denying the Contractor's claim for an equitable adjustment in contract price.)

.....
(Name of contractor or subcontractor)
By: .....
(Authorized Officer of, or Attorney for, Appellant)
Address: .....
Telephone No. .....
Dated: .....

APPENDIX B

UNITED STATES ATOMIC ENERGY COMMISSION

Appeal of

.....
(Name of contractor or subcontractor)

Under Contract (Subcontract) No. .....

Docket No. CA- .....

COMPLAINT

The appellant states to the Commission as follows:

1. This appeal arises under Contract (or Subcontract) No. ..... dated .....

2. Said Contract (or Subcontract) contains a disputes article reading as follows:

3. Other articles of the Contract (or Subcontract) relevant to the dispute which is the subject of this appeal are as follows:

4. This appeal is taken from the decision(s) of the Contracting Officer, ...
(Name and title)
dated .....

5. The portion or portions of said decision(s) which appellant claims to be erroneous, with reasons therefor, is (are) as follows:

6. The following document(s) is (are) submitted in support of the appeal:

NOTE: Here list, by exhibit number, a short description of the document(s) submitted, each copy of which should be marked, as follows:

Exhibit No. ..... to Complaint of .....
.....
(Name of Contractor or Subcontractor)
Docket No. Ca- .....

7. Appellant requests that an oral hearing on the appeal be held by the AEC Hearing Examiner (NOTE: This paragraph should be omitted where the right to hearing is waived).

Signed .....
(Authorized Officer or representative of Appellant)
Address .....
.....
Telephone No. .....
Dated .....

A. R. LUEDECKE,
General Manager.

PART 30—LICENSING OF BYPRODUCT MATERIAL

GENERAL LICENSING OF DEVICES

On January 10, 1959, the Commission issued for public comment a proposed amendment to Part 30 providing for a general license authorizing the possession and use under specified conditions of certain types of measuring, gauging or controlling devices containing byproduct material. Experience has indicated a need for a simplified procedure to allow users of such devices to possess and use byproduct material, when contained in such devices, without obtaining a specific license. The Commission will continue to exercise control over the manufacture and distribution of the devices through its specific licensing procedures. The general license will be applicable only to devices that are manufactured, tested, and labeled in accordance with specifications contained in a specific license authorizing supply of such devices to generally licensed persons.

Each applicant for a specific license to supply to general licensees devices designed and manufactured for the purpose of detecting, measuring, gauging or controlling thickness, density, level, interface location, radiation, leakage, qualitative or quantitative chemical composition, or for producing light or an ionized atmosphere will be required to furnish sufficient information to assure that, among other things, the device can be safely operated by persons not having any training in radiological protection and that under normal conditions of use no person would be likely to receive more than a

limited specified radiation exposure. Furthermore, the specifically licensed supplier will be required to apply quality control procedures to assure that the device meets the required specifications. In most cases, testing of a prototype of the device will also be required prior to the issuance of a license authorizing distribution to general licensees. Specific licensees will be obliged to report to the Commission on all transfers of the devices to generally licensed persons; thereby enabling the Commission to make appropriate inspections of the use of the devices.

Under the amendment the general licensees will be required to comply with certain restrictions which, in general will require that testing and servicing of the devices be accomplished by the manufacturer or other persons holding specific licenses. To assure that the general licensee is informed of the obligations imposed on him, the specifically licensed supplier will be required to furnish a copy of the general license provisions as contained in Title 10, Code of Federal Regulations, Chapter I, Part 30, "Licensing of Byproduct Material" to each generally licensed person to whom he transfers a device containing byproduct material.

Because this amendment establishes additional procedures for authorizing the distribution of devices containing byproduct material, and immediate effectiveness will not adversely affect any person, the Commission has found that good cause exists why this amendment should be made effective without the customary period of prior notice.

Pursuant to the Administrative Procedure Act, Public Law 404, 79th Congress, 2d Session, Title 10, Code of Federal Regulations, Chapter I, Part 30, "Licensing of Byproduct Material," is amended as follows, effective upon filing with the Federal Register Division:

1. Add a new paragraph (c) to § 30.21 to read as follows:

(c)(1) A general license is hereby issued to own, receive, acquire, possess and use byproduct material when contained in devices designed and manufactured for the purpose of detecting, measuring, gauging or controlling thickness, density, level, interface location, radiation, leakage, or qualitative or quantitative chemical composition or for producing light or an ionized atmosphere, when such devices are manufactured in accordance with the specifications contained in a specific license issued to the supplier pursuant to § 30.24(f): *Provided*, That:

(i) The general license contained in this paragraph shall apply only to devices distributed under and in accordance with a specific license which states that such devices when manufactured pursuant to the terms of the specific license may be distributed by the licensee pursuant to this paragraph;

(ii) That such devices are labeled in accordance with the provisions of the specific license which authorizes the distribution of the devices; and

(iii) That the device bear a label containing the following statement:

This device, generally licensed pursuant to § 30.21(c) of 10 CFR, Part 30, has been manufactured and distributed pursuant to AEC license No. _____ by _____.
(Name of supplier)

(2) Persons who own, receive, acquire, possess or use a device pursuant to the general license contained in subparagraph (1) of this paragraph:

(i) Shall not transfer, abandon or dispose of the device, except by transfer to a person specifically licensed by the Commission to receive such device;

(ii) Shall assure that all labels affixed to the device at the time of receipt and bearing the statement, "Removal of this label is prohibited by regulations of the Atomic Energy Commission," are maintained thereon and shall comply with all instructions contained in such labels;

(iii) Shall have the device tested for leakage of radioactive material and

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proper operation of the on-off mechanism and indicator, if any, at no longer than six-month intervals; provided that devices containing only krypton need not be tested for leakage, and devices containing only tritium need not be tested for any purpose;

(iv) Shall have the tests required by subdivision (iii) of this subparagraph and all other services involving the radioactive material, its shielding and containment, performed by the supplier or other person holding a specific license to manufacture, install or service such devices;

(v) Shall maintain records of all tests performed on the devices as required under this section, including the dates and results of the tests and the names of the specific licensees conducting the tests;

(vi) Upon the occurrence of a failure of or damage to, or any indication of a possible failure of or damage to, the shielding or containment of the radioactive material or the on-off mechanism or indicator, shall immediately suspend operation of the device until it has been repaired by the supplier or other person holding a specific license to manufacture, install or service such devices, or disposed of by transfer to a person specifically licensed to receive the byproduct material contained in the device; and

(vii) Shall be exempt from the requirements of Part 20 of this chapter, except that such persons shall comply with the provisions of §§ 20.402 and 20.403.

(3) The general license provided in this paragraph is subject to the provisions of §§ 30.32 to 30.72, inclusive: *Provided*, That persons who possess byproduct material pursuant to this general license shall not export such byproduct material without a specific license from the Commission authorizing such export.

2. Add a new paragraph (f) in § 30.24 to read as follows:

(f) *Distribution of devices to persons generally licensed under § 30.21(c).* An application for a specific license to distribute certain devices of the types enumerated in § 30.21(c) to persons generally licensed under § 30.21(c) will be approved if:

(1) The applicant satisfies the general requirements specified in § 30.23; and

(2) The applicant submits sufficient information relating to the design, manufacture, prototype testing, quality control procedures, labeling, proposed uses and potential hazards of the device to provide reasonable assurance that:

(i) The byproduct material contained in the device will not be lost;

(ii) That no person would receive a radiation exposure to a major portion of his body in excess of 0.5 rem in a year under ordinary circumstances of use;

(iii) The device can be safely operated by persons not having training in radiological protection; and

(iv) The byproduct material within the device would not be accessible to unauthorized persons.

(3) In describing the label or labels and contents thereon to be affixed to the device, the applicant should separately indicate those instructions and precautions which are necessary to assure safe operation of the device. Such instructions and precautions must be contained on labels bearing the statement, "Removal of this label prohibited by regulations of the Atomic Energy Commission."

3. Add a new paragraph (e) in § 30.32 to read as follows:

(e) Each licensee authorized under § 30.24(f) to distribute certain devices to generally licensed persons:

(1) Shall report to the Director, Division of Licensing and Regulation all transfers of such devices to persons generally licensed under § 30.21(c). Such report shall identify each general licensee by name and address, the type of

device transferred, and the quantity and type of byproduct material contained in the device. The report shall be submitted within 30 days after the end of each calendar quarter in which such a device is transferred to generally licensed persons; and

(2) Shall furnish to each general licensee to whom he transfers such device a copy of the general license contained in § 30.21(c).

(Sec. 161, 68 Stat. 948; 42 U.S.C. 2201)

Dated at Germantown, Md., this 9th day of February 1959.

For the Atomic Energy Commission.

A. R. LUEDECKE,
General Manager.

PART 60—DOMESTIC URANIUM PROGRAM

APPLICATIONS FOR CERTIFICATION AND BONUS PAYMENT

Notice is hereby given of amendment of the Commission's regulations relating to bonus payments under this part. The amendment is designed to permit orderly termination of the initial production program described in § 60.6. The amendment establishes time limits extending beyond March 31, 1960 within which applications may be filed under this program; no bonus payments, however, will be made on ores delivered subsequent to March 31, 1960.

Effective upon publication in the Federal Register § 60.6 is amended in the following respects:

1. Section 60.6(i), *Application for certification*, is amended by adding the following sentence at the end thereof: "Applications for certification of mining properties as eligible to receive initial production bonus payments must be received by the Grand Junction Operations Office, U.S. Atomic Energy Commission, Grand Junction, Colorado on or before April 18, 1960."

2. Section 60.6(j), *Application for bonus payment*, is amended by adding the following sentence at the end thereof: "Application for bonus payments for production from certified properties must be received by the Grand Junction Operations Office, U.S. Atomic Energy Commission on or before May 31, 1960 or within forty-five (45) days after certification of the mining property, whichever is later."

A. R. LUEDECKE,
General Manager.

PART 80—GENERAL RULES OF PROCEDURE ON APPLICATIONS FOR DETERMINATION OF REASONABLE ROYALTY FEE, JUST COMPENSATION, OR GRANT OF AN AWARD FOR PATENTS, INVENTIONS, OR DISCOVERIES

MISCELLANEOUS AMENDMENTS

On March 10, 1959, the Commission issued for public comment proposed amendments to Part 80 of the Commission's rules and regulations providing that (1) the Patent Compensation Board be delegated authority to hear and decide cases involving claims for damages and use as the result of patent secrecy orders under 35 U.S.C. section 183, as authorized by 35 U.S.C. section 188, and (2) decisions of the Board be made reviewable by the Commission upon petition for review filed by any party to each such proceeding. Under the review procedure, the decision of the Board would constitute final action of the Commission, unless any party to the proceeding should file a petition for review with the Commission within sixty days after such decision and thereafter the Commission should grant the petition and order the proceeding to be submitted for final decision by the Commission.

Effective thirty days after publication in the Federal Register, Part 80 of the Commission's rules and regulations is hereby amended to read as follows:

§ 80.2 [Amendment]

1. Section 80.2(e) is amended to read as follows:

(e) "Party," "petitioner," and "respondent" shall mean the applicant

(personally or through his counsel) and the Office of the General Counsel of the Commission as the text may indicate. Each applicant shall be entitled to be represented by counsel.

2. Section 80.1 is amended to read as follows:

§ 80.1 Scope of the part.

The regulations in this part provide the rules of procedure to be followed by any person making application to the Atomic Energy Commission for the determination of a reasonable royalty fee, compensation, or the grant of an award, and for the consideration of such applications pursuant to section 157 of chapter 13 of the Atomic Energy Act of 1954 (68 Stat. 947; 42 U.S.C. 2187), section 173 of chapter 15 of the Atomic Energy Act of 1954 (68 Stat. 953; 42 U.S.C. 2223), and section 1 of the Patent Act of July 19, 1952 (66 Stat. 806 and 808; 35 U.S.C. 183 and 188).

§ 80.10 [Amendment]

3. Section 80.10 is amended by adding the following paragraph (e):

(e) Any applicant, his successors, assigns or legal representatives, whose patent is withheld because of an order of secrecy issued at the request of the Commission may, beginning at the date the applicant is notified that, except for such order, his application is otherwise in condition for allowance, make application for compensation for the damage caused by the order of secrecy and/or for the use of the invention by the Government, resulting from his disclosure as provided by 35 U.S.C. 183.

§ 80.11 [Amendment]

4. Section 80.11(c) is amended by adding the following subparagraph (10):

(10) In the case of an application for compensation for the damage caused by an order of secrecy of a patent application and/or for the use of the invention by the Commission, the date of the order of secrecy, the date of the notice that the patent application is in condition for allowance, and, if known to the applicant, the date of the first use of the invention by the Commission.

5. The heading immediately preceding § 80.60 is amended to read "Adjudication and Commission Review."

§ 80.60 [Amendment]

6. Section 80.60(a) is amended to read as follows:

(a) Upon the expiration of the period prescribed in § 80.51, the Board shall proceed to a final consideration of the application on the basis of the entire record, including any exceptions, and the briefs in support filed by either party. The Board shall resolve questions of fact by what it deems to be the greater weight of the evidence and shall make its decision on the entire record. Its findings as to facts shall be supported by reliable, probative, and substantial evidence. The Board shall render an appropriate decision, together with a statement of its reasons or basis, determining as the case may be a reasonable royalty fee, the amount of compensation, or the amount of an award, or such other disposition as its determination requires.

7. Section 80.60(c) is amended to read as follows:

(c) The decision of the Board shall constitute the final action of the Commission sixty (60) days after the date thereof, unless any party shall within such period file a petition for review of such decision.

8. A new § 80.61 should be added as follows:

§ 80.61 Commission review.

(a) The petition for review shall concisely and plainly state (1) the facts upon which the petitioner bases his claims that he has been adversely affected or aggrieved by the decision of the Board or that review thereof is required in the public interest under applicable statutes and rules, and (2) the relief or disposition of the application which the petitioner seeks by review.

(b) Seven copies of the petition for review and brief in support thereof shall be filed with the Clerk of the Board, who shall forthwith serve one copy of the petition and brief upon each of the members of the Commission, together with a copy of the Board's decision. The petition and supporting brief shall be accompanied by a certificate of service thereof upon the respondent.

(c) Within twenty (20) days after the filing of the petition for review and supporting brief, the respondent may file seven copies of an opposing brief with the Clerk of the Board, who shall forthwith serve one copy thereof upon each of the members of the Commission. The opposing brief shall be accompanied by a certificate of service thereof upon the petitioner.

(d) In their consideration of the petition for review and briefs filed with respect thereto, the members of the Commission may take into consideration, without limitation, (1) the propriety of the compensation, royalty, or award on its face or the size thereof; (2) compliance by the claimant or applicant, and the Board, with the requirements and standards of applicable statutes and the regulations of the Commission; and (3) important questions of policy or administration presented by the record in the case.

(e) If the Commission denies the petition for review, the decision of the Board shall thereupon become the final action of the Commission. If the Commission grants the petition for review, it shall (1) direct the Clerk of the Board to forthwith certify the record of the case to the Commission, and (2) issue an order for review which shall fix a time within which the parties may submit exceptions and briefs with reference to the decision of the Board. After expiration of such time, the Commission shall proceed to a final decision in the manner provided in §§ 2.750, 2.753(b), 2.754, and 2.756 of this chapter.

(f) No officer or employee of the Commission, other than (1) a Commissioner, (2) a member of his immediate staff, or (3) Commission personnel who have not previously been involved, directly or indirectly, in the subject matter of the proceeding, in the proceeding itself, or in a factually related case, may participate or advise in the consideration of a petition for review or in the final decision of the Commission, except as a witness or counsel in the formal proceeding.

(Section 161, 68 Stat. 948, 42 U.S.C. 2201)

Dated at Germantown, Md., this 6th day of April 1959.

A. R. LUEDECKE,
General Manager.

APPENDIX 9

AMENDMENTS TO THE ATOMIC ENERGY ACT

Public Law 86-373
86th Congress, S. 2568
September 23, 1959

AN ACT

To amend the Atomic Energy Act of 1954, as amended, with respect to cooperation with States

Atomic Energy Act of 1954, amendments. 68 Stat. 919. 42 USC 2011 note.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following section be added to the Atomic Energy Act of 1954, as amended:

"SEC. 274. COOPERATION WITH STATES.—

"a. It is the purpose of this section—

"(1) to recognize the interests of the States in the peaceful uses of atomic energy, and clarify the respective responsibilities under this Act of the States and the Commission with respect to the regulation of byproduct, source, and special nuclear materials;

"(2) to recognize the need, and establish programs for, cooperation between the States and the Commission with respect to control of radiation hazards associated with use of such materials;

"(3) to promote an orderly regulatory pattern between the Commission and State governments with respect to nuclear development and use and regulation of byproduct, source, and special nuclear materials;

"(4) to establish procedures and criteria for discontinuance of certain of the Commission's regulatory responsibilities with respect to byproduct, source, and special nuclear materials, and the assumption thereof by the States;

73 STAT. 688.

73 STAT. 689.

"(5) to provide for coordination of the development of radiation standards for the guidance of Federal agencies and cooperation with the States; and

"(6) to recognize that, as the States improve their capabilities to regulate effectively such materials, additional legislation may be desirable.

"b. Except as provided in subsection c., the Commission is au-

Agreements with States. 42 USC 2071–2112, 2201.

thorized to enter into agreements with the Governor of any State providing for discontinuance of the regulatory authority of the Commission under chapters 6, 7, and 8, and section 161 of this Act, with respect to any one or more of the following materials within the State—

"(1) byproduct materials;

"(2) source materials;

"(3) special nuclear materials in quantities not sufficient to form a critical mass.

During the duration of such an agreement it is recognized that the State shall have authority to regulate the materials covered by the agreement for the protection of the public health and safety from radiation hazards.

"c. No agreement entered into pursuant to subsection b. shall provide for discontinuance of any authority and the Commission shall retain authority and responsibility with respect to regulation of—

"(1) the construction and operation of any production or utilization facility;

"(2) the export from or import into the United States of byproduct, source, or special nuclear material, or of any production or utilization facility;

"(3) the disposal into the ocean or sea of byproduct, source, or special nuclear waste materials as defined in regulations or orders of the Commission;

"(4) the disposal of such other byproduct, source, or special nuclear material as the Commission determines by regulation or order should, because of the hazards or potential hazards thereof, not be so disposed of without a license from the Commission.

Notwithstanding any agreement between the Commission and any State pursuant to subsection b., the Commission is authorized by rule, regulation, or order to require that the manufacturer, processor, or producer of any equipment, device, commodity, or other product containing source, byproduct, or special nuclear material shall not transfer possession or control of such product except pursuant to a license issued by the Commission.

Conditions.

"d. The Commission shall enter into an agreement under subsection b. of this section with any State if—

"(1) The Governor of that State certifies that the State has a program for the control of radiation hazards adequate to protect the public health and safety with respect to the materials within the State covered by the proposed agreement, and that the State desires to assume regulatory responsibility for such materials; and

"(2) the Commission finds that the State program is compatible with the Commission's program for the regulation of such materials, and that the State program is adequate to protect the public health and safety with respect to the materials covered by the proposed agreement.

Publication in F.R.

"e. (1) Before any agreement under subsection b. is signed by the Commission, the terms of the proposed agreement and of proposed exemptions pursuant to subsection f, shall be published

73 STAT. 690.

once each week for four consecutive weeks in the Federal Register; and such opportunity for comment by interested persons on the proposed agreement and exemptions shall be allowed as the Commission determines by regulation or order to be appropriate.

"(2) Each proposed agreement shall include the proposed effective date of such proposed agreement or exemptions. The agreement and exemptions shall be published in the Federal Register within thirty days after signature by the Commission and the Governor.

Licensing requirements. Exemptions.

"f. The Commission is authorized and directed, by regulation or order, to grant such exemptions from the licensing requirements contained in chapters 6, 7, and 8, and from its regulations applicable to licensees as the Commission finds necessary or appropriate to carry out any agreement entered into pursuant to subsection b. of this section.

"g. The Commission is authorized and directed to cooperate with the States in the formulation of standards for protection against hazards of radiation to assure that State and Commission programs for protection against hazards of radiation will be coordinated and compatible.

Federal Radiation Council.

"h. There is hereby established a Federal Radiation Council, consisting of the Secretary of Health, Education, and Welfare, the Chairman of the Atomic Energy Commission, the Secretary of Defense, the Secretary of Commerce, the Secretary of Labor, or their designees, and such other members as shall be appointed by the President. The Council shall consult qualified scientists and experts in radiation matters, including the President of the National Academy of Sciences, the Chairman of the National Committee on Radiation Protection and Measurement, and qualified experts in the field of biology and medicine and in the field of health physics. The Special Assistant to the President for Science and Technology, or his designee, is authorized to attend meetings, participate in the deliberations of, and to advise the Council. The Chairman of the Council shall be designated by the President, from time to time, from among the members of the Council. The Council shall advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States. The Council shall also perform such other functions as the President may assign to it by Executive order.

Inspections.

"i. The Commission in carrying out its licensing and regulatory responsibilities under this Act is authorized to enter into agreements with any State, or group of States, to perform inspections or other functions on a cooperative basis as the Commission deems appropriate. The Commission is also authorized to provide training, with or without charge, to employees of, and such other assistance, to any State or political subdivision thereof or group of States as the Commission deems appropriate. Any such provision or assistance by the Commission shall take into account the additional expenses that may be incurred by a State as a consequence of the State's entering into an agreement with the Commission pursuant to subsection b.

Termination of agreement.

"j. The Commission, upon its own initiative after reasonable notice and opportunity for hearing to the State with which an agreement under subsection b. has become effective, or upon request of the Governor of such State, may terminate or suspend its agreement with the State and reassert the licensing and regulatory authority vested in it under this Act, if the Commission finds that such termination or suspension is required to protect the public health and safety.

73 STAT. 690.

73 STAT. 691. Notice of filing.

"k. Nothing in this section shall be construed to affect the authority of any State or local agency to regulate activities for purposes other than protection against radiation hazards.

"l. With respect to each application for Commission license authorizing an activity as to which the Commission's authority is continued pursuant to subsection c., the Commission shall give prompt notice to the State or States in which the activity will be conducted of the filing of the license application; and shall afford reasonable opportunity for State representatives to offer evidence, interrogate witnesses, and advise the Commission as to the application without requiring such representatives to take a position for or against the granting of the application.

42 USC 2201.

"m. No agreement entered into under subsection b., and no exemption granted pursuant to subsection f., shall affect the authority of the Commission under subsection 161 b. or i. to issue rules, regulations, or orders to protect the common defense and security, to protect restricted data or to guard against the loss or diversion of special nuclear material. For purposes of subsection 161i., activities covered by exemptions granted pursuant to subsection f. shall be deemed to constitute activities authorized pursuant to this Act; and special nuclear material acquired by any person pursuant to such an exemption shall be deemed to have been acquired pursuant to section 53.

42 USC 2073. Definition.

42 USC 2138.

"n. As used in this section, the term 'State' means any State, Territory, or possession of the United States, the Canal Zone, Puerto Rico, and the District of Columbia."

SEC. 2. Section 108 of the Atomic Energy Act of 1954 is amended by deleting the phrase "distributed under the provisions of subsection 53a.," from the second sentence.

Approved September 23, 1959.

Public Law 86-300
86th Congress, S. 2569
September 21, 1959

AN ACT

73 STAT. 574.

To amend the Atomic Energy Act of 1954, as amended.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That subsection 161 m. of the Atomic Energy Act of 1954, as amended, is amended by striking out "Section 103 or 104" and inserting in lieu thereof "Section 103, 104, 53 a.(4), or 63 a.(4)".

Atomic Energy Act of 1954, amendments.
68 Stat. 950.
68 Stat. 951.
42 USC 2201.
42 USC 2203.

SEC. 2. Section 163 of the Atomic Energy Act of 1954, as amended, is amended by inserting after the words "from receiving compensation" the following words "from a source other than a nonprofit educational institution".

Approved September 21, 1959.

Public Law 86-43
86th Congress, S. 1197
June 11, 1959

AN ACT

73 Stat. 73.

To amend the Atomic Energy Act of 1954, as amended.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 251 of the Atomic Energy Act of 1954, as amended, is amended by deleting the words "and July" in the first sentence thereof.

68 Stat. 960.
42 USC 2016.

Approved June 11, 1959.

APPENDIX 10

Licenses and Access Permits Applications Filed and Actions Taken

SUMMARY OF LICENSING ACTIONS

Facilities [a]	Permits and Licenses Issued				Permits and Licenses in Effect as of Dec. 31, 1959
	Sept. 1, 1954 to Dec. 31, 1956	Jan. 1, 1957 to Dec. 31, 1957	Jan. 1, 1958 to Dec. 31, 1958	Jan. 1, 1959 to Dec. 31, 1959	
Power Reactors:					
Construction permits	4	1	0	0	3
Construction permit amendments	0	1	4	5	
Licenses to operate	0	1	0	1	2
License amendments	0	1	7	7	
Test Reactors:					
Construction permits	0	1	2	0	1
Construction permit amendments	0	1	0	1	
Licenses to operate	0	0	0	2	2
License amendments	0	0	0	3	
Research Reactors:					
Construction permits	6	[b] 14	[c] 11	[d] 5	[e] 16
Construction permit amendments	3	2	9	15	
Licenses to operate	6	13	16	8	26
License amendments	1	13	16	24	
Licenses to acquire, possess and operate	0	9	3	1	13
License amendments (acquire, possess and operate)	0	1	1	10	
Reactor Exports:					
Research Reactor licenses	1	15	5	11	([f])
Test Reactor licenses	0	0	2	0	([f])
Power Reactor licenses	0	0	1	1	([f])
License amendments	0	6	14	10	
Critical Experiment Facilities:					
Construction permits	4	6	4	1	1
Construction permit amendments	0	1	2	1	
Licenses to operate	0	6	[g] 5	3	13
License amendments	0	2	10	16	
Operator licenses	27	121	215	176	465
Operator license amendments and renewals			67	81	
Special Nuclear Material licenses	60	91	115	73	294
SNM license amendments and renewals	26	66	156	194	
Source Material licenses issued or renewed	2,559	1,982	1,303	1,168	1,345
Source Material export licenses	1,656	800	676	721	([f])

[a] Applications to construct and operate are filed simultaneously; conversions from construction permits to licenses to operate are made upon satisfactory completion of construction.
[b] Permits authorize construction of 30 reactors and modification of 2 reactors.
[c] Permits authorize construction of 38 reactors.
[d] Permits authorize construction of 6 reactors and modification of 1 reactor.
[e] Permits authorize construction of 41 reactors.
[f] Export licenses terminate upon completion of shipment.
[g] Two of licenses authorize possession only.

FACILITY LICENSE APPLICATIONS

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
	POWER REACTORS		
Carolinas Virginia Nuclear Power Associates, Inc., Parr, S.C.	17,000-kilowatt, vertical pressure tube, heavy water moderated and cooled reactor.	July 9, 1959	Pending.
Commonwealth Edison Co., Dresden Station, Grundy County, Ill.	180,000-kilowatt, dual cycle, boiling water type reactor.	Apr. 1, 1955	Construction permit issued May 4, 1956; limited license for 1-megawatt (thermal) operation issued Sept. 28, 1959, for 45-day period; amended Nov. 5, 1959, to extend expiration date to Dec. 10, 1959, amended Nov. 16, 1959, to authorize 315-megawatt (thermal) operation after Dec. 10, 1959.
Consolidated Edison Co., Westchester County, N.Y.	163,000-kilowatt, pressurized water (plus 112,000 kw. of conventional superheater capacity.	Mar. 22, 1955 (date of application).	Construction permit issued May 4, 1956.
Florida West Coast Nuclear Group, Inc., Polk County, Florida.	50,000-kilowatt, heavy water moderated, pressure tube type reactor.	Dec. 10, 1959	Pending.
General Electric Co., Alameda County, Calif.	5,000 to 5,000 kilowatt developmental boiling water reactor.	Jan. 10, 1956 (date of application).	Construction permit issued May 14, 1956; license issued for criticality tests July 29, 1957; for power operation, Aug. 31, 1957; license amendment authorizing operation at power levels to 50,000 kw. (thermal) issued Jan. 30, 1959.
Northern States Power Co., Sioux Falls, S. Dak.	66,000-kilowatt, controlled recirculation boiling water reactor.	Apr. 1, 1959	Pending.[a]
Pacific Gas and Electric Co., Humboldt Bay Power Plant, Eureka, Calif.	50,000-kilowatt, single cycle boiling water reactor.	Apr. 30, 1959	Do.
Power Reactor Development Co., Lagoona Beach, Mich.	100,000-kilowatt, fast breeder reactor.	Jan. 7, 1956	Construction permit issued Aug. 4, 1956.
Saxton Nuclear Experimental Corp., Saxton, Pa.	20,000-kilowatt (thermal) pressurized light water reactor.	July 24, 1959	Pending.[b]
Yankee Atomic Electric Co., Rowe, Mass.	134,000-kilowatt pressurized light water type reactor.	July 9, 1956	Construction permit issued Nov. 4, 1957; amended to incorporate financial finding June 10, 1959.[c]

[a] Hearing to be held Feb. 16, 1960 to consider issuance of a construction permit.
[b] Hearing held Dec. 15, 1959, to consider issuance of a construction permit.

	TEST REACTORS		
Aerojet-General Nucleonics, San Ramon, Calif.	10,000-kilowatt light water moderated, pool-type reactor.	Oct. 22, 1958	Application withdrawn by letter dated Sept. 21, 1959.
General Electric Co., Alameda County, Calif.	33,000-kilowatt pressurized water reactor.	June 14, 1957	Construction permit issued Mar. 11, 1958; licenses issued, for criticality tests Dec. 22, 1958, for test reactor operation Jan 7, 1959.
National Aeronautics and Space Administration, Sandusky, Ohio.	60,000-kilowatt pressurized water reactor.	Aug. 20, 1956	Construction permit issued July 21, 1958.
Westinghouse Electric Corp., Waltz Mill, Pa.	20,000-kilowatt pressurized water reactor (MTR type).	Mar. 12, 1956	Construction permit issued July 3, 1957; license issued June 19, 1959.[c]

[c] Notice published Dec. 23, 1959 of proposed issuance of facility license amendment to authorize operation of the Westinghouse Test Reactor at power levels up to 60,000 kilowatts.

FACILITY LICENSE APPLICATIONS—Continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
	RESEARCH REACTORS		
Aerojet-General Nucleonics, San Ramon, Calif. (sold to USNPS).	100-milliwatt self-contained reactor (Model AGN-201, serial 100).	May 28, 1956	Construction permit issued Aug. 16 1956; license issued Oct. 19, 1956.
Aerojet-General Nucleonics, San Ramon, Calif. (serials 101 and 102 sold to other licensees).	Two 100-milliwatt and one 5-watt (later amended to 20-watt) self-contained reactors (Models AGN-201 and AGN-201M, serials 101, 102 and 103).	Sept. 11, 1956	Construction permit issued Feb. 22, 1957; licenses issued Feb. 23, 1957, Mar. 14, 1957, and Mar. 29, 1957, amended for 20-watt operation Aug. 22, 1958 (serial 103).
Aerojet-General Nucleonics, San Ramon, Calif. (sold to other licensees).	Four 100-milliwatt and one 5-watt self-contained reactors (Models AGN-201 and AGN-201M, serials 104 through 108).	Nov. 28, 1956	Construction permit issued July 8, 1957; two licenses issued July 10, 1957 and one July 31, 1957, Aug. 23, 1957 and Sept. 20, 1957.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Twelve 100-milliwatt self-contained reactors (Model AGN-201, serials 109 through 120).	Feb. 12, 1957	Construction permit issued July 8, 1957; six licenses issued Aug. 23, 1957, Oct. 28, 1957, Jan. 22, 1958, May 16, 1958, June 3, 1958 and June 30, 1958.
Aerojet-General Nucleonics, San Ramon, Calif. (sold to licensee).	One 1-watt pool-type reactor (Model AGN-211, serial 100).	Nov. 12, 1957	Construction permit issued Jan. 24, 1958; license issued Feb. 12, 1958.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Fifteen 100-milliwatt self-contained reactors (Model AGN-201, serials 126 through 140).	Dec. 2, 1957	Construction permit issued Feb. 20, 1958.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Five 5-watt (later amended to 20-watt) self-contained reactors (Model AGN-201, serials 121 through 125).	Dec. 3, 1957	Construction permit issued Feb. 20, 1958; amendment increasing operating level to 20 watts issued Nov. 14, 1958.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Ten 15-watt (later amended to 100-watt for 3 reactors) pool-type reactors (Model AGN-211, serials 101 through 110).	Apr. 14, 1958	Construction permit issued Aug. 6, 1958; amendment increasing operating level to 100 watts for serials 103, 104 and 105 issued Mar. 4, 1959.
American Radiator and Standard Sanitary Corp., Mountain View, Calif.	1-watt (UTR-1) graphite moderated reactor (Argonaut type).	July 12, 1957	Construction permit issued Oct. 31, 1957; license issued May 21, 1958.
Armour Research Foundation, Chicago, Ill.	50-kilowatt water boiler type reactor.	Jan. 7, 1955 (date of application)	Construction permit issued Mar. 28, 1955; license issued June 12, 1956, amended Jan. 14, 1959 for operation at power levels up to 100 kilowatts.
The Babcock & Wilcox Co., Lynchburg, Va.	10-kilowatt pool-type reactor.	Mar. 28, 1958	Construction permit issued Sept. 4, 1958; license issued Sept. 5, 1958.
Battelle Memorial Institute, West Jefferson, Ohio.	1,000-kilowatt pool-type reactor.	May 4, 1955 (date of application).	Construction permit issued Aug. 5, 1955; license issued Aug. 10, 1956, amended for continuous operation at power levels up to 2,000 kw. and for intermittent operation at power levels up to 3,000 kw. Feb, 27, 1959.
Catholic University of America, Washington, D.C.	AGN-201 100-milliwatt reactor, serial 101 (purchased from AGN).	July 10, 1957	License issued Nov. 15, 1957.
Colorado State University, Fort Collins, Colo.	AGN-201 100-milliwatt reactor, serial 109 (purchased from AGN).	July 22, 1957	License issued Sept. 12 1957.
Cornell University, Ithaca, N.Y.	10-kilowatt dual core, pool-type reactor.	Feb. 21, 1958	Construction permit issued Nov. 21, 1958.
Curtiss-Wright Corp., Quehanna, Pa.	1,000-kilowatt pool-type reactor.	Oct. 29, 1956	Construction permit issued June 20, 1957; license issued Apr. 29, 1958.
Daystrom, Inc., West Caldwell, N.J.	10-kilowatt Argonaut-type reactor.	Dec. 11, 1956	Construction permit issued Oct. 11, 1957.[d]
The Dow Chemical Co., Midland, Mich.	1,000- to 10,000-kilowatt liquid metal fuel reactor.	Jan. 31, 1956	Application withdrawn by letter dated Oct. 30, 1957.
Ford Motor Co., Dearborn, Mich.	10- to 100-kilowatt pool-type reactor.	Jan. 17, 1956	Application withdrawn by letter dated Oct. 10, 1957.

[d] At applicant's request the construction permit was revoked Feb. 14, 1958, without prejudice to filing of new application at later date.

FACILITY LICENSE APPLICATIONS—Continued

Applicant and Location of Facility	Description of Facility	Date Filed	Status
	RESEARCH REACTORS—Continued		
General Dynamics Corp., Torrey Pines Mesa, San Diego, Calif.	10-kilowatt tank type TRIGA reactor.	Nov. 19, 1957	Construction permit issued May 2, 1958; license issued May 3, 1958.
General Electric Co., Alameda County, Calif.	30-kilowatt, light water cooled and moderated, graphite reflected reactor.	July 1, 1957	Construction permit issued Oct. 24, 1957; license issued Oct. 31, 1957; order suspending operations issued Aug. 13, 1958; license amendment authorizing resumption of operation issued Aug. 18, 1959.
Industrial Reactor Laboratories, Inc., Plainsboro Township, N.J.	5,000-kilowatt pool-type reactor, light water cooled and moderated.	Jan. 12, 1956	Construction permit issued Jan. 22, 1957; license for 100 kw. operation issued Oct. 10, 1958, amended for 5,000 kw. operation June 1, 1959.
Iowa State University, Ames, Iowa.	10-kilowatt Argonaut-type reactor (AR&SSC Model UTR-10).	Sept. 8, 1958	Construction permit issued Oct. 12, 1959; license issued Oct. 16, 1959.
Massachusetts Institute of Technology, Cambridge, Mass.	1,000-kilowatt heavy water moderated reactor.	Feb. 20, 1956	Construction permit issued May 7, 1956; license issued June 9, 1958.
Naval Research Laboratory, Washington, D.C.	100-kilowatt pool-type reactor.	Apr. 5, 1955 (date of application)*	Construction permit issued Apr. 29, 1955; license issued Sept. 14, 1956.
Do	Modification for 1,000-kilowatt operation with forced convection cooling.	July 2, 1959	Construction permit issued Nov. 20, 1959.
North American Aviation, Inc., Atomics International Division, Canoga Park, Calif.	5-watt solution-type laboratory reactor (Model L-47).	Jan. 24, 1957	Construction permit issued Aug. 2, 1957; license issued Aug. 5, 1957. *
North American Aviation, Inc., Atomics International Division Canoga Park, Calif.	10-watt solution-type laboratory reactor (Model L-77).	Jan. 20, 1958	Construction permit issued May 17, 1958; license issued May 17, 1958.
N.C. State College, Raleigh N.C.	100-kilowatt water boiler type reactor.	June 1, 1955	License issued Oct. 1, 1955.†
	Modification for 500-watt operation.	Dec. 13, 1956	Construction permit issued Mar. 6, 1957; amended license for 500-watt operation issued May 1, 1957;
	Relocation and modification for 100-watt operation.	Nov. 19, 1958	Construction permit issued Mar. 18, 1959; amended license for 100-watt operation issued July 13, 1959.
N.C. State College, Raleigh N.C.	10-kilowatt pool-type reactor.	July 21, 1958	Construction permit issued Nov. 26, 1958.
Nuclear Development Corp. of America, Pawling, N.Y.	5-watt heavy water moderated and reflected reactor.	Apr. 7, 1958	Construction permit issued Oct. 7, 1958; license issued Oct. 22, 1958.
Ohio State University, Columbus, Ohio.	10-kilowatt pool-type, light water moderated, graphite reflected reactor.	Nov. 2, 1959	Pending.
Oklahoma State University of Agriculture and Applied Science, Stillwater, Okla.	AGN-201 100-milliwatt reactor, serial 102 (purchased from AGN).	Mar. 20, 1957	License issued Aug. 26, 1957.
Ordnance Materials Research Office, Watertown, Mass.	1,000-kilowatt pool-type reactor.	Jan. 15, 1957	Construction permit issued Oct. 2, 1957.
Oregon State College, Corvallis, Oreg.	AGN-201 100-milliwatt reactor, serial 114 (purchased from AGN).	May 5, 1958	License issued Nov. 13, 1958.
Pennsylvania State Univ., University Park, Pa.	100-kilowatt pool-type reactor.	May 9, 1955	License issued July 8, 1955.†
Stanford University, Stanford, Calif.	10-kilowatt pool-type, light water moderated and reflected reactor.	June 15, 1959	Construction permit issued Nov. 20, 1959; license issued Dec. 4, 1959.

* The Model L-47 reactor was dismantled by the owner, North American Aviation, Inc., and license was terminated at licensee's request on June 30, 1958.

† No construction permit issued. Construction was completed under contractual arrangements made prior to enactment of Atomic Energy Act of 1954.

FACILITY LICENSE APPLICATIONS—Continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
	RESEARCH REACTORS—Continued		
State College of Washington, Pullman, Wash.	100-kilowatt pool-type reactor.	June 22, 1956	Construction permit issued July 8, 1959.
The Texas A&M College System, College Station Tex.	AGN-201 100-milliwatt reactor, serial 106 (purchased from AGN).	Mar. 25, 1957	License issued Aug. 26, 1957.
The Texas A&M College System, College Station, Tex.	5,000-kilowatt pool-type, light water cooled and moderated reactor.	Mar. 17, 1959	Construction permit issued Aug. 4, 1959.
The Prosperity Co., Inc., Coral Gables, Fla.	Pool-type reactor	Mar. 6, 1956	Incomplete application denied without prejudice to applicant's submission of new application Dec. 20, 1957.
Union Carbide Corp., Sterling Forest Orange County, N.Y.	5,000-kilowatt pool-type reactor.	Feb. 15, 1957	Construction permit issued Oct. 31, 1957.
U.S. Naval Hospital, Bethesda, Md.	AGN-201M 5-watt reactor, serial 105 (purchased from AGN).	Mar. 27, 1957	License issued Sept. 13, 1957.
U.S. Naval Postgraduate School, Monterey, Calif.	AGN-201 100-milliwatt reactor, serial 100 (purchased from AGN).	Nov. 28, 1956	License issued Apr. 29, 1957.
University of Akron, Akron Ohio.	AGN-201 100-milliwatt reactor, serial 104 (purchased from AGN).	Apr. 5, 1957	License issued Sept. 5, 1957.
University of Arizona, Tucson, Ariz.	10-kilowatt tank-type reactor (General Dynamics TRIGA).	July 16, 1958	Construction permit issued Nov. 21, 1958; license issued Dec. 5, 1958.
University of Buffalo, Buffalo, N.Y.	1,000-kilowatt pool-type reactor.	Mar. 11, 1957	Construction permit Sept. 15, 1959.
University of California, Los Angeles, Calif.	50-kilowatt water boiler type reactor.	June 2, 1955 (date of application).	Application withdrawn by letter dated June 11, 1958.
University of California, Los Angeles, Calif.	10-kilowatt Argonaut-type reactor.	July 2, 1959	Construction permit issued Nov. 16, 1959.
University of California, Berkeley, Calif.	AGN-201 100-milliwatt reactor, serial 112 (purchased from AGN).	Aug. 26, 1957	License issued Nov. 19, 1957.
University of Delaware, Newark, Del.	AGN-201 100-milliwatt reactor, serial 113 (purchased from AGN).	Mar. 21, 1958	License issued July 3, 1958.
University of Florida, Gainesville, Fla.	10-kilowatt Argonaut-type reactor	Aug. 23, 1957	Construction permit issued Dec. 23, 1957; license issued May 21, 1959.
University of Llinois, Urbana, Ill.	100-kilowatt tank-type reactor (General Dynamics TRIGA Mark II).	Nov. 16, 1959	Pending.
University of Kansas, Lawrence, Kans.	10-kilowatt tank-type, light water cooled and moderated reactor.	Aug. 24, 1959	Pending.
University of Maine, Orono, Maine.	AGN-201 100-milliwatt reactor, serial 132 (to be purchased from AGN).	Sept. 16, 1958	Pending—application incomplete.
University of Michigan, Ann Arbor, Mich.	1,000-kilowatt pool-type reactor.	Jan. 12, 1955	Construction permit issued Feb. 17, 1955; license issued Sept. 13, 1957.
University of Missouri, Rolla, Mo.	10-kilowatt pool-type, light water moderated reactor.	Jan. 29, 1959	Construction permit issued Nov. 20, 1959.
University of Oklahoma Norman, Okla.	5-watt laboratory reactor (Atomics International Model L-47).	Aug. 30, 1957	Application withdrawn by letter dated Aug. 22, 1958.
University of Oklahoma, Norman, Okla.	AGN-211 15-watt pool-type reactor, serial 102 (purchased from AGN).	July 25, 1958	License issued Dec. 29, 1958.
University of Virginia Charlottesville, Va.	1,000-kilowatt pool-type reactor.	Mar. 29, 1957	Construction permit issued Sept. 13, 1957.
University of Tennessee, Knoxville, Tenn.	10-kilowatt heavy water moderated reactor.	Sept. 5, 1958	Pending—application incomplete.
University of Utah, Salt Lake City, Utah.	AGN-201 100-milliwatt reactor, serial 107 (purchased from AGN).	June 24, 1957	License issued Sept. 12, 1957.
University of Washington, Seattle, Wash.	10-kilowatt Argonaut-type reactor.	June 15, 1959	Construction permit issued Oct. 13, 1959.
University of Wyoming, Laramie, Wyo.	AGN-201 100-milliwatt reactor, serial 111 (to be purchased from AGN).	Aug. 21, 1957	Application withdrawn by letter dated Nov. 3, 1958.

FACILITY LICENSE APPLICATIONS—Continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
RESEARCH REACTORS—Continued			
University of Wyoming, Laramie, Wyo.	10-watt laboratory reactor (Atomics International Model L-77).	Nov. 14, 1958	Construction permit issued Feb. 24, 1959; license issued Feb. 25, 1959.
Vanderbilt University, Nashville, Tenn.	AGN-201 100-milliwatt reactor, serial 116 (to be purchased from AGN).	Jan. 30, 1958	Application withdrawn by letter dated Sept. 28, 1959.
Veterans Administration, Hospital, Omaha, Nebr.	10-kilowatt tank-type reactor (General Atomic TRIGA).	Apr. 10 1959	Construction permit issued June 24, 1959; license issued June 26, 1959.
Virginia Polytechnic Institute, Blacksburg, Va.	10-kilowatt Argonaut-type reactor (AR&SSC Model UTR-10).	Feb. 9, 1959	Construction permit issued Nov. 16, 1959; license issued Dec. 18, 1959
Walter Reed Army Institute of Research, Washington, D.C.	50-kilowatt homogeneous solution-type (Atomics International Model L-54).	May 20, 1959	Pending. [g]
West Virginia University, Morgantown, W. Va.	AGN-211P 75-watt, pool-type reactor, serial 103.	Mar. 30, 1959	Construction permit issued June 19, 1959; license issued July 28, 1959.
Wm. M. Rice Institute, Houston, Tex.	AGN-211 15 watt, pool-type reactor, serial 101 (purchased from AGN).	Aug. 4, 1958	License issued Jan. 8, 1959.
Worcester Polytechnic, Worcester, Mass.	1-kilowatt pool-type reactor.	May 1, 1959	Construction permit issued Nov. 23, 1959; license issued Dec. 16, 1959.
CRITICAL EXPERIMENT FACILITIES			
Alco Products, Inc., Schenectady, N.Y.	Critical experiment facility.	Oct. 13, 1958	License issued Mar. 25, 1959.[h]
Allis-Chalmers Mfg. Co., Greendale, Wis.	Northern States Power Co. critical experiments.	June 16, 1958	Construction permit issued Nov. 13, 1958; license issued Nov. 3, 1959.
The Babcock and Wilcox Co., Lynchburg, Va.	Consolidated Edison Co. critical experiments.	Oct. 27, 1955	Construction permit issued Dec. 9, 1955; license issued Mar. 20, 1957.
The Babcock and Wilcox Co., Lynchburg, Va.	Nuclear Merchant Ship Reactor critical experiments.	Feb. 1, 1957	Construction permit issued Oct. 2, 1957; license issued Jan. 22, 1958.
The Babcock and Wilcox Co., Lynchburg, Va.	Liquid Metal Fuel Reactor (LMFRE) critical experiments.	May 20, 1958	Construction permit issued Sept. 24, 1958; license issued Sept. 24, 1958.
Battelle Memorial Institute, West Jefferson, Ohio.	----------	Oct. 28, 1955	Construction permit issued Dec. 28, 1955; license (to possess only) issued Jan. 16, 1958.
General Dynamics Corp., Torrey Pines Mesa, San Diego, Calif.	Critical experiments for General Dynamics research reactors.	Oct. 25, 1956	Construction permit issued June 18, 1957; license issued Aug. 13, 1957.
General Electric Co., Alameda County, Calif.	Critical experiments for Commonwealth Edison reactor.	Mar. 27, 1956	Construction permit issued June 29, 1956; license issued Aug. 30, 1957.
General Electric Co., Alameda County, Calif.	Nuclear checkout tests for Spanish reactor.	June 14, 1957	Construction permit issued Sept. 20, 1957; license issued Oct. 16, 1957 (expired May 20, 1958).
Lockheed Aircraft Corp., Palo Alto, Calif.	----------	June 20, 1956	Construction permit issued Mar. 14, 1957 (expired Sept. 30, 1957).[i]
The Martin Co., Middle River, Md.	Martin Power Reactor (MPR) and Engineering Research and Development Lab. (ERDL) critical experiments.	Oct. 26, 1956	Construction permit issued May 13, 1957; license for MPR experiments issued Dec. 6, 1957; amended license for ERDL experiments issued June 12, 1958.
National Aeronautics and Space Administration, Cleveland, Ohio.	Series of critical experiments.	July 8, 1957	Construction permit issued Jan. 22, 1958; license issued Jan. 5, 1959.

[g] Construction permit issued Jan. 6, 1960.
[h] Facility constructed in 1956 under contract with and for the account of the Atomic Energy Commission. License covers conduct of private work.
[i] Lockheed advised by letter dated Feb.11, 1958, that it does not intend to proceed with construction of the facility as originally designed.

FACILITY LICENSE APPLICATIONS—Continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
CRITICAL EXPERIMENT FACILITIES—Continued			
North American Aviation, Inc., Ventura County, Calif.	Critical experiments relating to Advanced Epithermal Thorium Reactor Program.	Aug. 20, 1959	Construction permit issued Dec. 24, 1959.
Nuclear Development Corp. of America, Pawling, N.Y.	.....	Mar. 14, 1956	Construction permit issued June 11, 1956; license (to possess only) issued Jan. 22, 1958.
Westinghouse Electric Corp., Waltz Mill, Pa. (CRX Facility).	Yankee critical experiments.	Sept. 21, 1956	Construction permit issued Oct. 17, 1957; license issued for Yankee criticals Nov. 25, 1957, with license amendments for additional experiments issued June 30, 1958, and Aug. 22, 1958.
	Belgian Reactor-3 critical experiments.	Sept. 8, 1958	License amendment authorizing BR-3 experiments issued Oct. 17, 1958.
	Two-region critical experiments.	Nov. 13, 1958	License amendment issued Dec. 18, 1958.
	Reactor Fuel Measurement Facility experiments.	Apr. 30, 1959	License amendment issued June 3, 1959.
	Loose Lattice critical experiments.	May 25, 1959	License amendment issued July 10, 1959.
	Proof Test critical experiments.	Aug. 7, 1959	License amendment issued Oct. 12, 1959.
Westinghouse Electric Corp., Waltz Mill, Pa. (Critical Experiment Station).	Westinghouse Test Reactor critical experiments.	Oct. 24, 1957	Construction permit issued June 14, 1958; license issued June 17, 1958, with license amendments for additional experiments Jan. 7, 1959, and Oct. 29, 1959.
Westinghouse Electric Corp., Waltz Mill, Pa. (LRX Facility).	Carolinas Virginia Tube Reactor Critical Experiments.	Dec. 23, 1959	Pending.
PRODUCTION FACILITIES			
Thor-Westcliffe Development, Inc., Pittsburg, Kans.	Multi-stage gas centrifuge production facility for the separation of isotopes of uranium.	July 14, 1959	Pending—application incomplete.
EXPORT LICENSES			
ACF Industries, Inc., New York, N.Y.	1-watt pool-type, light water cooled and moderated research reactor for export to Tecnicas Hispano Americanas S.A., Madrid, Spain.	Feb. 4, 1958	Application withdrawn by letter dated Apr. 23, 1958.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor, serial 110, for export to Laboratoires R. Derveaux, Boulogne, France.	July 9, 1957	Application withdrawn by letter dated Mar. 14, 1958.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor or AGN-211 1-watt pool-type research reactor for export to Government of Belgium for exhibit at 1958 World's Fair, Brussels, Belgium.	Dec. 9, 1957	Application withdrawn by letter dated Mar. 14, 1958.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor, serial 110, for export to Instituto di Fisica, Facolta D' Ingegneria, University of Palermo, Palermo, Sicily.	Apr. 21, 1958	License issued Jan. 7, 1959.

FACILITY LICENSE APPLICATIONS—Continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
	EXPORT LICENSES—Continued		
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor, serial 111, for export to Universite de Geneve, Geneva, Switzerland.	Apr. 24, 1958	Application withdrawn by letter dated June 25, 1958.
Aerojet-General Nucleonics, San Ramon, Calif.	20-watt AGN-201P research reactor, serial 121, for export to University of Zurich, Zurich, Switzerland.	Oct. 16, 1958	Pending.
Allis-Chalmers Manufacturing Co., Milwaukee, Wis. (formerly ACF Industries).	5,000-kilowatt tank-type heavy water cooled and moderated research reactor for export to Comitato Nazionale per le Ricerche Nucleari, Milan, Italy.	Dec. 12, 1956	License issued May 16 1957.
Allis-Chalmers Manufacturing Co., Milwaukee, Wis. (formerly ACF Industries).	20,000-kilowatt tank-type materials testing reactor for export to Reactor Centrum Nederland, Pettin, Netherlands.	Apr. 23, 1957	License issued Jan. 17, 1958.
Allis-Chalmers Manufacturing Co., Milwaukee, Wis. (formerly ACF Industries).	30,000-kilowatt tank-type materials testing reactor for export to Aktiebolaget Atomenergi of Sweden, Tystberga, Sweden.	June 18, 1957	License issued May 14, 1958.
American Intercontinental Trade and Service Co., New York, N.Y.	43,000-kilowatt pressurized light water power reactor for export to Centre d'Etudes de l'Energie Nucleaire, Brussels, Belgium.	July 8, 1958	License issued Nov. 6, 1958.
American Machine and Foundry Co., New York, N.Y.	10-kilowatt light water moderated research reactor for export to Ministry of Education, Kingdom of the Netherlands, Amsterdam, Netherlands.	Sept. 27, 1956	License issued Feb. 1, 1957.
American Machine and Foundry Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Laboratorium fur Technische Physik der Technischen Hochschule, Munich, Germany.	July 2, 1956	License issued Mar. 15 1957.
American Machine and Foundry Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Hamilton College, McMaster University, Hamilton, Canada.	May 17, 1957	License issued Aug. 27, 1957.
American Machine nd Foundry Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Junta de Energia Nuclear, Lisbon, Portugal.	July 22, 1957	License issued Sept. 13 1957.
American Machine and Foundry Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Greek Atomic Energy Commission, Athens, Greece.	May 7, 1957	License issued Sept. 25, 1957.
American Machine and Foundry Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Societa Ricerche Impianti Nucleari, Milan, Italy.	July 3, 1957	License issued Dec. 6, 1957
American Machine and Foundry Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Commissariat a L'Energie Atomique, Tel-Aviv, Israel.	Apr. 11, 1958	License issued June 12, 1958.

FACILITY LICENSE APPLICATIONS—Continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
	EXPORT LICENSES—Continued		
American Machine and Foundry Co., New York, N.Y.	5,000-kilowatt tank-type research reactor for export to Osterreichische Studiengesellschaft m. b.h., Seibersdorf, Austria.	June 19, 1958	License issued Sept. 3, 1958.
American Machine and Foundry Co., New York, N.Y.	5,000-kilowatt pool-type research reactor for export to University of Teheran, Teheran, Iran.	Apr. 20, 1959	License issued Aug. 5, 1959.
American Machine and Foundry Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Turkish Atomic Energy Commission, Istanbul, Turkey.	June 10, 1959	License issued Sept. 4, 1959.
The Babcock and Wilcox Co., New York, N.Y.	5,000-kilowatt pool-type research reactor for export to Conselho Nacional de Pesquisas do Brasil, for Comissao de Energia Atomica, Sao Paulo, Brazil.	Oct. 5, 1956	License issued Jan. 22, 1957.
The Babcock and Wilcox Co., New York, N.Y.	5,000-kilowatt pool-type research reactor for export to Society for the Utilization of Nuclear Energy in Shipbuilding & Navigation, Inc., Hamburg, Germany.	Feb. 1, 1957	License issued June 10 1957.
Curtiss-Wright Corp., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to Thai Atomic Energy Commission for Peace, Bangkok, Thailand.	June 12, 1959	License issued Nov. 5, 1959.
Foster Wheeler Corp., New York, N.Y.	5,000-kilowatt tank-type research reactor for export to Danish Atomic Energy Commission, Christiansborg, Copenhagen, Denmark.	Jan. 25, 1957	License issued Apr. 4, 1957.
General Dynamics Corp., San Diego, Calif.	100-kilowatt tank-type research reactor (TRIGA Mark II) for export to Comitato Nazionale per le Ricerche Nucleari, Rome, Italy.	Nov. 7, 1958	License issued Jan. 8, 1959.
General Dynamics Corp., San Diego, Calif.	100-kilowatt tank-type research reactor (TRIGA Mark II) for export to Government of the Republic of Korea, Seoul, Korea.	Mar. 4, 1959	License issued May 21, 1959.
General Dynamics Corp., San Diego, Calif.	30-kilowatt TRIGA research reactor for export to Escola de Engenharia da Universidade de Minas Gerais, Belo Horizonte, Brazil.	Mar. 4, 1959	License issued Aug. 3, 1959.
General Dynamics Corp., San Diego, Calif.	100-kilowatt tank-type research reactor (TRIGA Mark II) for export to Republic of Austria, Federal Ministry of Education, Vienna, Austria.	Mar. 4, 1959	License issued Nov. 24, 1959.
General Dynamics Corp., San Diego, Calif.	100-kilowatt tank-type research reactor (TRIGA Mark II) for export to the Office of Atomic Energy of the Republic of Viet Nam, Dalat, Viet Nam.	June 16, 1959	License issued Oct. 20, 1959.

FACILITY LICENSE APPLICATIONS—Continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
	EXPORT LICENSES—Continued		
General Electric Co., New York, N.Y.	3,000-kilowatt pool-type research reactor for export to Junta de Energia Nuclear, Madrid, Spain.	May 22, 1957	License issued July 29, 1957.
General Electric Co., New York, N.Y.	3,000-kilowatt pool-type research reactor for export to Instituto Venezolano de Investigaciones Cientificas, Caracas, Venezuela.	Oct. 3, 1957	License issued Jan. 16, 1958.
General Electric Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to National Tsing-Hua University, Taipei, Taiwan, Republic of China.	Apr. 4, 1958	License issued June 5, 1958.
General Electric Co., New York, N.Y.	15,000-kilowatt (electrical) boiling water type power reactor for export to Allgemeine Elektricitats-Gesellschaft AG, Frankfurt, Germany.	June 9, 1959	License issued Sept. 30, 1959.
General Electric Co., New York, N.Y.	1,000-kilowatt pool-type research reactor for export to the Philippine Atomic Energy Commission, Manila, Republic of the Philippines.	July 7, 1959	License issued Nov. 16, 1959.
Intercontinental Chemical Corp., New York, N.Y.	50-kilowatt solution-type research reactor (Atomics Int'l. Model L-54) for export to Farbwerke Hoechst AG, Frankfurt, Germany.	Apr. 1, 1957	License issued June 11, 1957.
Loretz and Company, Los Angeles, Calif.	500-watt solution-type research reactor (Atomics Int'l. Model L-55) for export to Danish Atomic Energy Commission, Christiansborg, Copenhagen, Denmark.	Jan. 17, 1957	License issued Apr. 4, 1957.
James Loudon and Co., Inc., Los Angeles, Calif.	50-kilowatt solution-type research reactor (Atomics Int'l. Model L-54) for export to the Senate of the Land Berlin, Berlin. Germany.	Mar. 28, 1957	License issued Sept. 7, 1957
Luigi Serra, Inc., New York, N.Y.	5,000-kilowatt pool-type research reactor for export to Centro Autonomo Militare Energia Nucleare (C.A.M.E.N.), Accademia Navale, Lovorne, Italy.	Sept. 3, 1959	License issued Dec. 17 1959.
Marubeni-Iida Co. (N.Y.), Inc., New York, N.Y.	50-kilowatt solution-type research reactor (Atomics Int'l. Model L-54) for export to The Japan Atomic Energy Research Institute, Tokyo, Japan.	Sept. 13, 1956	License issued Nov. 2, 195
Mitsubishi International Corp., New York, N.Y.	10,000-kilowatt tank-type research reactor for export to The Japan Atomic Energy Research Institute, Tokyo, Japan.	Aug. 12, 1957	License issued Oct. 11 1957.
S. A. Innocente Mangili Adriatica, Inc., New York, N.Y.	50-kilowatt solution-type research reactor (Model L-54) for export to Politecnico Di Milano, Milan, Italy.	June 2, 1958	License issued Aug. 13, 1958.

Business or Occupation of Access Permit Holders

	Dec. 31, 1958	Dec. 31, 1959		Dec. 31, 1958	Dec. 31, 1959
Aircraft and/or components	34	32	Petroleum and petroleum products	19	18
Beverage industry	1	1	Printing and publishing	12	9
Chemical-general	75	70	Professors, teachers, and scientists	56	48
Chemical-pharmaceutical	5	4	Railroads and railway equipment	10	11
Chemical-processing equipment	11	11	Research-general	49	48
Coal industry	4	3	Research-medical	5	5
Communications	1	1	Rubber and rubber products	5	5
Consultants	89	77	Scrap and waste disposal	7	8
Educational institutions	28	25	Shipbuilding and/or components	22	20
Electronic industry	38	36	Special carriers and warehousing	2	4
Engineering-construction	44	40	Stone, clay, and glass products	21	17
Engineering-consulting	93	86	Tobacco and tobacco products	1	1
Engineering-design	47	38	Unions, trade associations, chambers of commerce, and manufacturers' representatives	21	21
Federal, State, and city governments or departments	49	45	Utilities	176	174
Financial organizations	15	11	Weapons, explosives, and propellants	5	4
Food companies	1	1	Others (not elsewhere classifiable)	10	7
Information services	21	15	Total[1]	1,439	1,305
Instrument manufacturer	64	56			
Insurance companies	90	82			
Lawyers and public accountants	37	31			
Machinery-general	44	33			
Machinery-special	28	26			
Metal products manufacturer	136	122			
Mining and refining	52	51			
Motor vehicles and/or components	7	6			
Paper and pulp companies	4	2			

[1] Some permittees have been classified in more than one category.

Access Permit Holders by Principal Fields of Interest

	Dec. 31, 1958	Dec. 31, 1959		Dec. 31, 1958	Dec. 31, 1959
Batteries (Nuclear)	0	0	Ore refining and production of Feed Materials	72	63
Chemical Processing and Equipment	46	46	Radiation hazards and effects	53	47
Components (except reactor components)	76	65	Radioactive waste	46	41
Consultants	213	186	Reactor—central station	196	190
Controlled thermonuclear field	28	24	Reactor—components	43	40
Design and construction of atomic energy facilities	93	78	Reactor—heating	4	4
Electronic systems	10	10	Reactor—other	23	22
Fuel element fabrication	28	24	Reactor—propulsion	45	41
General nuclear research and development	63	60	Reactor—research	17	16
Information services	38	29	Shield materials	17	17
Instruments	85	78	Special materials	98	89
Insurance evaluation	93	85	Surveys for potential use or need	18	21
Investment and banking	17	12	Training and education	17	14
Isotope production and utilization	78	70	Transportation and storage	6	6
Legal assistance and accounting	35	30	Weapons and components	0	0
Machinery	12	12	Others (not elsewhere classifiable)	9	9
			Total	1,579	1,429

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

Access Permit Holders by Geographic Areas

	Dec. 31, 1958	Dec. 31, 1959		Dec. 31, 1958	Dec. 31, 1959
New England	126	118	Mountain	41	37
Middle Atlantic	470	432	Pacific	152	138
East North Central	296	256	Hawaii, Alaska, and Puerto Rico	6	5
West North Central	73	68			
South Atlantic	142	132			
East South Central	36	28	Total	1,402	1,268
West South Central	60	54			

NOTE: Standard Department of Commerce Areas.

Number of Permittees Having Access to Secret Restricted Data by Categories

	Dec. 31, 1958	Dec. 31, 1959		Dec. 31, 1958	Dec. 31, 1959
Chemistry—general	505	466	Metallurgy—raw materials	103	33
Chemistry—radiation and radiochemistry	549	515	Particle accelerators and high-voltage machines	197	187
Chemistry—separation processes for plutonium and uranium	401	379	Physics and mathematics	511	503
Chemistry—transuranic elements	262	249	Radiation effects on reactor materials	564	546
Controlled thermonuclear processes	120	102	Radioactive waste	545	548
Criticality hazards	410	406	Reactors—power	579	592
Hanford—fuel element technology	2	3	Reactors—production	337	322
Hanford—reactor technology	1	1	Reactors—research and testing	521	513
Hanford—separations process technology	5	5	Savannah River—fuel element technology	2	2
Health and safety	590	577	Savannah River—reactor technology	1	1
Instrumentation	520	497	Savannah River—separations process technology	5	5
Isotope separation	101	98	Technology—feed materials	280	279
Metallurgy and ceramics	594	572	Technology—plutonium	267	267
			Technology—tritium	67	60

NOTE: As of December 31, 1959, 583 permittees had 500 employees or less, while 685 had over 500 employees. A year ago permittees with 500 or less employees numbered 792 while 610 had over 500 employees.

Personnel Security Clearances Granted for Access to Secret and Confidential Restricted Data

	Total as of Dec. 31, 1958	Total as of Dec. 31, 1959
Q (X) Clearance actions:		
New clearances granted	9,233	10,717
Clearances reinstated	2,128	2,477
Clearances extended	6,122	6,465
Total	17,483	19,659
Clearances terminated	3,340	4,936
Active clearances	14,143	14,723

For Access to Confidential Restricted Data

L (X) Clearance actions:		
New clearances granted	8,981	9,906
Clearances reinstated	706	826
Clearances extended	1,679	1,737
Total	11,366	12,469
Clearances terminated	2,035	3,020
Active clearances	9,331	9,449

APPENDIX 11

Formal Hearings on License Applications

Power Reactor Development Co., Lagoona Beach, Mich. Exceptions (and supporting briefs) to the Commission's Opinion and Initial Decision, dated December 10, 1958, were filed by the Intervenors. In compliance with the Commission's order, also dated December 10, 1958, technical data were furnished to the parties to this proceeding and were filed with the Commission by the AEC separated staff and by PRDC, who also filed the supplementary financial data required by the order. On May 26 the Commission rendered an Opinion and Final Decision and ordered that the construction permit as issued August 4, 1956, be continued in effect with such modifications and additions as shown in the permit made a part of that order. In July 1959, the Intervenors appealed the Commission's decision; the appeal is now pending before the United States Court of Appeals for the District of Columbia.

Yankee Atomic Electric Co., Rowe, Mass. On April 9, 1959, the Commission held a hearing to consider whether Yankee is financially qualified to construct its reactor and whether Commission consent should be given to the mortgage lien on the facility as proposed in an application amendment filed by Yankee. On May 19 the Presiding Officer rendered an Intermediate Decision and ordered, subject to review by the Commission on appeal or its own motion, (1) that a construction permit amendment be issued to include a finding that Yankee is financially qualified to design and construct the reactor and to receive an allocation of special nuclear material, and (2) that the Commission consents to creation of the proposed mortgage lien on the facility. The Presiding Officer's decision became effective on June 10, 1959.

Westinghouse Electric Corp., Waltz Mill, Pa. A hearing was held on March 25, 1959, to consider the issuance of a license to operate the 20-megawatt (thermal) Westinghouse Test Reactor. No petitions for leave to intervene were filed with the Commission. On April 29 the Presiding Officer rendered an Intermediate Decision and ordered, subject to review by the Commission on appeal or its own motion, that a license to operate the reactor be issued. On May 6 the Commission ordered that the proceedings be reopened for the receipt of additional evidence concerning the final inspection of the facility. Final preoperational inspection was made on June 6, and on June 11 the hearing was reopened for the presentation and reception of evidence bearing on the inspection. In a Supplemental Intermediate Decision of June 15 the Presiding Officer determined and ordered, subject to review by the Commission on appeal or its own motion, that a license is issued to Westinghouse Electric Corp. in the form provided in the Intermediate Decision of April 29, such decision to become final on July 7, 1959. The Commission on June 19 granted a motion by Westinghouse that the waiting period be waived, and issued, effective June 19, the license to Westinghouse to operate the WTR at thermal power levels up to 20,000 kilowatts.

Commonwealth Edison Co., Grundy County, Ill. A hearing was held on July 16 and 17 to consider the proposed issuance of a license to Commonwealth Edison Co. to operate the Dresden nuclear reactor. Proposed findings and conclusions were submitted by the parties on August 7. The parties did not agree on the proposed findings and conclusions with respect to the need for evidence of com-

pletion of construction being on the record. On August 17 the Presiding Officer issued a notice of hearing to be held September 2 for presentation of further evidence which would reflect completed construction of the facility as defined in the construction permit. The notice was accompanied by a memorandum setting forth the Presiding Officer's views with respect to completion of construction. By stipulation between Commonwealth and the Staff of the Commission, filed on September 2, the hearing scheduled for September 2 was postponed until September 23 when testimony was presented to prove the completed construction. An amendment to the proposed findings and conclusions, concurred in by the parties, was filed by the AEC staff on September 25. On September 26 the Presiding Officer issued an Intermediate Decision and ordered the Division of Licensing and Regulation to issue Commonwealth Edison Co. a limited operating license authorizing the initial loading of nuclear fuel and operation of the reactor to the extent of but not to exceed a power level of 1 megawatt (thermal) during a period of time not in excess of 45 days, as provided by order of the Commission dated September 14. The limited license was issued on September 28. On the same date the Presiding Officer issued an Intermediate Order directing the parties to submit at the earliest date possible a proposed provisional license for operation of this boiling water reactor, calling for four or more gradations of power including the requirement for Commission review of each such attained level of power and for Commission approval before operations proceed to successively increased power levels, in attaining the full and projected 630 megawatts of power. Pursuant to the Hearing Examiner's order dated November 5 a license amendment was issued on November 5 extending to December 10, 1959 the limited license for one-megawatt operation of the Dresden reactor. In a Supplemental Intermediate Decision of November 12 the Hearing Examiner ordered that an amended license be issued to authorize operation of the reactor at power levels up to 315 megawatts (thermal), and to require, when that power level is obtained, Commonwealth to file with Commission a report on operation of the facility. The amended license was issued Nov. 16, 1959.

Walker Trucking Co., New Britain, Conn. In November 1958, a hearing was held on the application of the Walker Trucking Co. to package and store low-level radioactive waste in Portland, Conn., and to dispose of such waste in the Atlantic Ocean. Subsequently, the Presiding Officer issued an Intermediate Decision ordering that a license be issued. The license was issued in March 1959. On April 2, 1959, the Walker Trucking Co. filed an application for an amendment to its license which would authorize the packing and storage of byproduct and source material waste at an additional site in New Britain, Conn. By Commission order, the matter was scheduled for hearing to commence June 3. Intervenors in the matter include the Mayor of the City of New Britain. On June 3, 1959, the hearing was begun in New Britain; it was adjourned until June 24. In response to a request for postponement of the continuation of the hearing filed by the intervenors, the Presiding Officer issued an Order Postponing Hearing from June 24 until after September 1, 1959. On December 17,1959, the Presiding Officer issued a notice that the hearing would be resumed on February 9, 1960, in New Britain to allow the intervenors to cross-examine witnesses and to present direct evidence.

Industrial Waste Disposal Corp., Houston, Tex. A hearing was held January 22 and 23, 1959, on the proposed issuance of a license to the Industrial Waste Disposal Corp., Houston, Tex., authorizing the receipt, possession, packaging, and disposal of low-level byproduct material waste in the Gulf of Mexico. In view

of the public interest in this case, the Commission directed the holding of this hearing. In addition to the applicant for the license and Commission staff, Harris County, the City of Corpus Christi, Nueces County, the Nueces County Navigation District, and the Sportsmen's Clubs of Texas formally intervened and participated. Also, observers or representatives of the following were officially recognized and, in some instances, participated by statements or otherwise: The Government of Mexico, the Governor of Texas, Texas State Department of Health, Texas Game and Fish Commission, City of Houston, University Oaks Civic Club, and the McGregor Trail Civic Club. On May 29, 1959, an Intermediate Decision recommending issuance of the license was filed by the Presiding Officer in the case. Exceptions to the Intermediate Decision were filed by the intervenors. In a Memorandum and Order date July 1, 1959, the Commission provided for briefs to be filed by the parties and for oral arguments on October 13, 1959, also filed exceptions to the Intermediate Decision. By order dated September 25, 1959, the Commission postponed the date for oral argument until December 17, 1959. The postponement was to allow time for consideration of the protest of the Government of Mexico against disposal of radioactive waste in the Gulf.

Oral argument was further postponed to January 20, 1960, due to receipt by the Commission of a letter from the Department of State concerning disagreement by the Government of Mexico with the issuance of the proposed license. The order of postponement, dated November 20, 1959, also allowed the parties to file briefs concerning the foreign affairs matters involved in the proceeding.

Advance Industrial X-Ray Laboratories, A Division of Air Frame Inspection, Inc., and Advance Industrial X-Ray Laboratories, Inc., Los Angeles, Calif. AEC has been notified that Air Frame Inspection, Inc., had sold its Division known as Advance Industrial X-Ray Laboratories to Edwin Y. Martindale who has incorporated a separate business known as Advance Industrial X-Ray Laboratories, Inc. An application for a byproduct material license has been received from Advance Industrial X-Ray Laboratories, Inc. Mr. Martindale had formerly been associated with the Advance Division of Air Frame. On June 24, 1959, the AEC staff filed a Notice of Motion for Remand to the Presiding Officer and for Hearing concerning the pending compliance action against the Advance Division of Air Frame and the application for license from Advance Industrial X-Ray Laboratories, Inc. (the new corporation). On July 15, 1959, the Commission issued a Memorandum and Order consolidating for hearing and decision the application from Mr. Martindale with the matters concerning the Advance Division of Air Frame and remanded the matter to the Presiding Officer for further hearing and action. On August 10, 1959, the Presiding Officer, upon motion of the AEC staff, issued an Order to Show Cause why AEC should not direct Advance Industrial X-Ray Laboratories, Inc., to cease and desist from use of byproduct material in its possession, and to store such material pending further order. On September 16 and 17, hearings were held on the show cause order and on matters concerning the Advance Division of Air Frame Inspection, Inc. On September 25, 1959, the Presiding Officer issued an Interim Order for Temporary License to be issued to Advance Industrial X-Ray Laboratories, Inc. The Interim Order stated that it may be construed as a trial period and is without prejudice to the final order to be entered in the proceeding or to action which the Commission may take. Briefs have been filed by Advance and the AEC staff and the matter is now pending before the Presiding Officer.

Nuclear Advisers, Inc., New York, N.Y. A hearing was held May 28, 1959, in the matter of the proposed denial of the application of Nuclear Advisers, Inc., for a byproduct material license. On July 2, 1959, the Presiding Officer issued an Intermediate Decision ordering that a byproduct material license be issued to Nuclear Advisers, Inc., and that further proceedings in the matter be dismissed as stipulated between the parties. The Intermediate Decision became final on July 23, 1959.

Electro Chemical Laboratories Corp., Tulsa, Okla. On August 10, 1959, upon request of the applicant, the Commission issued a Notice of Hearing to consider the proposed denial of an application by Electro Chemical Laboratories Corp. for a license to receive and possess waste byproduct material for disposal by burial at sites located in Oklahoma and Kansas. On September 25, 1959, the Presiding Officer issued an order permitting intervention for G. H. Billue, doing business as Gas Underground Storage Co., in suport of the application, and the Kansas State Board of Health, opposing the application. On October 14, 1959, at a prehearing conference this proceeding was dismissed with the consent of all parties and without prejudice to the submittal by Electro Chemical of a different type of license. The order formally dismissing the proceeding was issued by the Presiding Officer October 21, 1959.

X-Ray Engineering Co., South San Francisco, Calif. An Order to Show Cause and Order Suspending Licensed Operations was issued by the Commission on October 16, 1959, in the matter of the apparent violation by X-Ray Engineering Co. of the Atomic Energy Act, the Commission's regulations and an order issued to the licensee by the Commission on August 25, 1959. Among other things, the Order stated that X-ray Engineering should show cause at a hearing in San Francisco, Calif., why its license, authorizing the use of byproduct material in widespread radiographic operations, should not be modified, suspended, or revoked. Effective on issuance, the order suspended all operations under the license, except those conducted in two of the licensee's laboratories On November 9, 1959, the AEC staff filed a motion citing further alleged violations and requesting an order to enlarge the issues in the matter; the Presiding Officer on November 27 issued an order adding issues to be determined and, in accordance with that order, the hearing was held on December 2–4, 1959.

Mines Development, Inc., Denver, Colo. On November 2, 1959, the Commission issued a letter order directing Mines Development, Inc., to take prompt steps to correct apparent violations of the Commission's radiation safety regulations in connection with the operation of a uranium processing mill at Edgemont, S. Dak. On Nov. 30, 1959, upon request of the licensee, the Commission ordered that a hearing be held on the matter on January 7, 1960. At a prehearing conference held December 28, 1959, it appeared that Mines Development proposed to introduce extensive evidence. In view of this fact and pursuant to a stipulation of the parties, the Presiding Officer ordered that the hearing be postponed until February 17, 1960 and that it be held in Denver, Colo.

Saxton Nuclear Experimental Corporation, Saxton, Pa. A hearing was held December 15 to consider the issuance of a construction permit to construct at Saxton, Pa., a 20-megawatt (thermal) facility to be used for research and development purposes. Proposed findings and conclusions were submitted by the applicant on December 29, 1959, and by the AEC staff on January 7, 1960.

APPENDIX 12

Current Commission Unclassified Research Contracts in Physical and Biological Sciences, Raw Materials, and Reactor Development

DIVISION OF RESEARCH CONTRACTS

	As of November 1958			As of November 1959		
	Number of contracts	Amount	Scientific man-years	Number of contracts	Amount	Scientific man-years
Physics:						
New contracts	15	$1,741,047		25	$3,547,842	
Renewal contracts	81	12,099,446		83	13,569,412	
Subtotal	96	13,840,493	297.7	108	17,117,254	420.7
Chemistry:						
New contracts	38	632,656		52	931,557	
Renewal contracts	166	4,055,754		184	4,887,131	
Subtotal	204	4,688,410	225.1	236	5,818,688	295.6
Metallurgy:						
New contracts	20	535,904		34	1,178,013	
Renewal contracts	78	2,368,525		85	2,980,015	
Subtotal	98	2,904,429	119.9	119	4,158,028	143.4
Controlled Thermonuclear:						
New contracts	8	160,256		7	229,176	
Renewal contracts	10	1,237,749		13	1,140,966	
Subtotal	18	1,398,005	32.0	20	1,370,142	44.7

SUMMARY

New contracts	81	$3,069,863		118	$5,886,588	
Renewal contracts	335	19,761,474		365	22,577,524	
Total	416	22,831,337	674.7	483	28,464,112	904.4
Total contract termination		21			36	

Note: Above listing does not include the following agreements with other Government agencies:
November 30, 1958 7 contracts—$4,186,490.
November 30, 1959 8 contracts—$4,606,600.

Physical Research

Chemistry

Alabama, University of. D. F. Smith, Cryoscopic Determination of Fused Salt Systems.

Arizona, University of. D. S. Chapin, The Mechanism of the Heterogeneous Low Temperature Ortho Hydrogen Conversion.

Arizona, University of. P. E. Damon, Correlation and Chronology of Ore Deposits.

Arizona, University of. L. S. Forster, The Luminescence of Metal Complexes.

Arizona, University of. Henry Freiser, Development and Testing of Organic Reagents for use in Inorganic Analysis.

Arizona, University of. E. N. Wise, Coulometric Analysis of Rare-Earth Elements at Controlled Potential.

Arkansas, University of. E. S. Amis, Electron-Transfer Reactions.

Arkansas, University of. R. W. Fink and A. Fry, Nuclear Chemistry Research.

Arkansas, University of. 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.

Boston University. N. N. Lichtin, Radiation Chemistry of Organic Compounds.

Brandeis University. Henry Linschitz, Photochemical Reactions of Complex Molecules in Condensed Phase.

Brigham Young University. R. M. Izatt and J. J. Christensen, Jr., A Thermodynamic Study of the Reaction of Aquated Mercury (II) Ion with Selected Anions over the Range 0°–90° C.

Brooklyn, Polytechnic Institute of. R. A. Marcus, Chemical Reactions of Atomic Beams and Related Problems

Brooklyn, Polytechnic Institute of. Herbert Morawetz, Study of Radiation Induced Solid State Polymerization.

Brown University. J. O. Edwards, Mechanisms of Peroxide Reactions.

Brown University. E. F. Greene and John Ross, Chemical Reaction Cross Sections—A Study of Chemical Reactions by means of Molecular Beam Techniques.

Buffalo, University of. G. M. Harris, Applications of Isotopes in Chemical Kinetics.

Buffalo, University of. J. A. Marinsky, Inorganic and Nuclear Chemistry Research.

California Institute of Technology. Harrison Brown, Study of the Fundamental Geochemistry of Critical Materials and the Development of Economic Processes for their Isolation.

California Institute of Technology. Norman Davidson, Complex Ions and Reaction Mechanisms in Solution.

California Institute of Technology. G. S. Hammond, The Chemistry of Metal Chelates in Nonhydroxylic, Organic Solvents.

California, University of. C. S. Garner, Isotopic Exchange Reactions.

California, University of. J. H. Hildebrand, Intermolecular Forces and Solubility.

California, University of. D. T. Sawyer, Study of Metal Chelates.

California, University of. R. L. Scott, Fluorocarbon Solutions.

California, University of. H. C. Urey, Study of the Natural Abundances of the Elements and Isotopes and the Properties of Meteorites and Other Astronomical Bodies.

Carnegie Institute of Technology. T. P. Kohman, Nuclear Chemistry Research.

Carnegie Institute of Technology. G. J. Mains, High Intensity X-Radiolysis.

Carnegie Institute of Technology. G. M. Pound, Electrochemical Separations in Non-Aqueous Melts.

Case Institute of Technology. Louis Gordon, Coprecipitation from Homogeneous Solution.

Chicago, University of. Edward Anders, Radiochemical and Geochemical Studies.

Chicago, University of. W. G. Brown. Applications of Fission Product Sources in Organic Radiation Chemistry.

Chicago, University of. Robert Gomer, Corrosion Research with Field and Ion Microscopy.

Chicago, University of. C. A. Hutchison, Jr., Paramagnetic Resonance Absorption.

Chicago, University of. J. E. Mayer, Statistical and Quantum Mechanisms of Interacting Atoms.

Chicago, University of. Henry Taube, Reactions of Solvated Ions.

Chicago, University of. A. Turkevich and N. Sugarman, Nuclear Chemistry Research.

Chicago, University of. A. Turkevich and N. Sugarman, Synchrocyclotron Operation.

Clark University. A. E. Martell, Reactions of Partially-Chelated Metal Ions.

Clark University. T. T. Sugihara, Nuclear Chemistry and Radiochemistry.

Clarkson College of Technology. Milton Kerker, A Study of 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, Scintillation Properties of Coordination Compounds.

Colorado, University of. J. R. Lacher and J. D. Park, The Photochemical and Thermal Nitrating Properties of $UO_2(NO_3)2.H_2O.N_2O_4$.

Colorado, University of. H. F. Walton, Specific Attractions in Ion Exchange.

Columbia University. E. L. Gaden, Jr., Foam Separation of Metallic Ions from Solution.

Columbia University. P. F. Kerr, Alteration and Mineralization of Primary Uranium Deposits.

Columbia University. J. L. Kulp, Helium and Argon in Rocks and Minerals.

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Columbia University. V. K. LaMer, Colloidal Properties of Thorium Oxide Slurries.

Columbia University. J. M. Miller, Research in the Field of Radiochemistry.

Columbia University. T. I. Taylor, Separation of Isotopes by Chemical Exchange.

Connecticut, University of. J. T. Stock, Analytical Chemistry at Low Concentrations.

Cornell University. S. H. Bauer, The Rates of Gas Phase Isotope Exchange Reactions, Studied in a Single-Pulse Shock Tube.

Cornell University. F. A. Long, Mechanism of Acid Catalysis and Studies in Deuterium Oxide as Solvent.

Dartmouth College. J. B. Hyne, Utilization of Gas Flow Radioactivity Counter in Kinetic Studies.

Delaware, University of. R. L. Pigford, Thermal Diffusion in Liquids.

Duke University. D. G. Hill, Spectrometry in Fused Salts.

Duke University. H. A. Strobel, Ion Exchange in Polar Non-Aqueous Solvents.

Duquesne University. N. C. Li, Solution Chemistry of Metal Complexes.

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Florida State University. G. R. Choppin, Chemistry of the Actinide and Lanthanide Elements, and Heavy Ion Nuclear Chemistry.

Florida State University. R. H. Johnsen, Radiation Induced Effects in Heterogeneous Organic Systems.

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Florida State University. J. V. Quagliano, Structural Studies of Metal Coordination Compounds.

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Florida, University of. W. S. Brey, Jr., Physical Characteristics and Catalytic Activity of Thorium Oxide.

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Georgia Institute of Technology. Jack Hine, The Effect of Structure on the Reactivity of Polyfluoro Organic Compounds.

Georgia Institute of Technology. J. A. Knight, Jr., R. C. Palmer and Fred Sicilio, Radiation Chemistry of Organic Systems.

Georgia Institute of Technology. H. M. Neumann, Solvent Extraction of Halo-Complexes.

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Rochester, University of. E. O. Wiig, Studies of Spallation Reactions.

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Rutgers University. William Rieman, III, Analytical Chemistry of the Polyphosphates.

Rutgers University. William Spindel, Separation and Exchange of Isotopes.

South Carolina, University of. O. D. Bonner, Fundamental Studies of Ion Exchange Equilibria.

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Southern California, University of. S. W. Benson, Free Radical Studies with HI and I_2.

Southern California, University of. R. F. Brown, The Action of Fenton's Reagent Upon Amides.

Southern California, University of. W. K. Wilmarth, Aqueous Chemistry of Inorganic Free Radicals.

Southern Research Institute. R. B. Ellis, Surface Tension of Fused Salts.

Stanford Research Institute. Daniel Cubicciotti, Fundamental Study of Fused Metal-Salt Systems.

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Washington, University of. A. L. Babb, Separation Efficiency of Pulsed Extraction Columns.

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Wisconsin, University of. Robert West, Isotope Exchange and Isotope Effects in the Reactions of Organolithium Compounds.

Wisconsin, University of. J. E. Willard, Application of Radioisotopes to Chemical Problems.

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Yale University. M. L. Jensen, Sulfur Isotopes and the Origin of Sandstone-Type Uranium Deposits.

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Brown University. R. A. Peck, Jr., Reaction Studies with Fast Neutrons.

California Institute of Technology. R. F. Bacher, Research in High Energy Physics.

California Institute of Technology. J. W. M. DuMond, Nuclear Spectroscopy and X-Ray Studies.

California, University of. K. A. Brueckner, Problems in the Theory of Many Body Systems.

California, University of. C. D. Jeffries, Study of Nuclear Moments.

California, University of. J. A. Jungerman, Low Energy Nuclear Physics.

California, University of. J. H. Reynolds, Mass Spectroscopy Research.

California, University of. J. R. Richardson, Research in High Energy Physics.

Carnegie Institute of Technology. R. B. Sutton, 400 Mev Synchrocyclotron and Associated Research.

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Case Institute of Technology. E. F. Shrader, Low Energy Nuclear Physics.

Chicago, University of. S. K. Allison, Reactions of Light Nuclei and the Penetration of Charged Particles through Matter.

Chicago, University of. N. C. Metropolis, Computer Research and Development.

Chicago, University of. Gregor Wentzel, Theoretical Research in Elementary Particle Physics.

Colorado, University of. J. J. Kraushaar, Research Program in Nuclear Spectroscopy.

Colorado, University of. D. A. Lind, Variable Energy Cyclotron.

Columbia University. W. W. Havens, Jr., Nuclear Physics Research.

Columbia University. Robert Serber, Theoretical Physics.

Columbia University. Jack Steinberger and Leon Lederman, Research in High Energy Particle Physics.

Concordia College. C. L. Bailey, Transfer of AEC Equipment from Iowa State College to Concordia College.

Duke University. M. M. Block, Development and Application of a Helium Bubble Chamber.

Duke University. H. W. Newson, Fast Neutron Cross Sections and Shell Structure.

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Florida State University. Alex E. S. Green, Analysis of Nuclear Forces.

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Louisiana State University. R. C. Mobley, Neutron Scattering.

Maryland, University of. W. F. Hornyak and R. A. Ferrell, The Structure of Light Nuclei.

Maryland, University of. G. A. Snow, The Properties of K Mesons and Hyperons and Related Topics.

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Michigan State University. H. G. Blosser, Magnet Design for a 45 Mev Multi-Particle Cyclotron.

Michigan, University of. H. R. Crane, G-Factor Experiment.

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Michigan, University of. P. V. C. Hough, Machine Scanning of Emulsions and Chamber Photographs.

Michigan, University of. D. I. Meyer, Time of Flight Counters.

Michigan, University of. W. C. Parkinson, 42'' Cyclotron Program.

Michigan, University of. G. H. Trilling, Study of High Energy Nuclear Interactions.

Michigan, University of. M. Wiedenbeck, Nuclear Spectroscopy.

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Notre Dame, University of. J. W. Mihelich, Nuclear Spectroscopy of Rare Earth Nuclides.

Notre Dame, University of. C. J. Mullin, Interaction of Photons and Particles with Nuclei.

Ohio State University. J. C. Harris, Nuclear Physics with a Van de Graaff Accelerator.

Ohio State University. H. J. Hausman, Scattering Studies with the Ohio State University Cyclotron.

Ohio State University. P. S. Jastram, A Program for Research in Low Energy Nuclear Physics.

Oregon State College. Larry Schecter, Nuclear Physics Research with the 37-Inch Cyclotron.

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Pennsylvania State University. F. G. Brickwedde and R. R. Roy, Low Energy Nuclear Physics.

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Princeton University. M. G. White, 18 Mev Cyclotron and Associated Nuclear Physics Research.

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Rice Institute. T. W. Bonner, Nuclear Physics Research.

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Washington, University of. G. W. Farwell, 60-inch Cyclotron Development and Research Program.

Wisconsin, University of. H. H. Barschall, Installation of a High Voltage Engineering Model EN Tandem-Style Van de Graaff Accelerator.

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Houston, University of. H. K. Reynolds and J. C. Allred, Sputtering by Ion Bombardment.

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Illinois, University of. G. M. Sinclair, Fatigue Behavior of Dilute Alloys of Niobium.

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Notre Dame, University of. G. C. Kuczynski, Optical and Mechanical Properties of Alkali Halide Crystals.

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Oregon, University of. W. M. Graven, Photo- and Electrochemical Studies on the Corrosion of Nuclear Reactor Metals.

Pennsylvania State University. C. R. Kinney and P. L. Walker, Jr., Research on Graphite.

Pennsylvania State University. Raymond Pepinsky, Neutron Single Crystal Structure Analysis.

Pennsylvania State University. J. A. Sauer, Effect of Radiation on Dynamic Properties of High Polymers.

Pennsylvania, University of. Norman Brown, The Effect of Stress on Recovery.

Pennsylvania, University of. Elias Burstein, Optical Investigations of Solids.

Pennsylvania, University of. N. A. Gokcen, Thermodynamic Properties of Carbides at High Temperatures.

Pennsylvania, University of. J. N. Hobstetter, Dislocation Pipe Effect in Diffusion Through Solids.

Pennsylvania, University of. Doris Kuhlmann-Wilsdorf, Origin of Dislocations.

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Pittsburgh, University of. R. S. Craig, Calorimetric, Structural, and Magnetic Studies of Metals and Intermetallic Compounds.

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Purdue University. R. E. Grace, Diffusion in Liquid Alloys.

Purdue University. R. E. Grace, Effect of Oxygen Pressure on the Oxidation of Chromium.

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Rensselaer Polytechnic Institute. A. A. Burr, Mechanism of the Effect of Rare Earth Solutes on the Allotropic Temperature of Zirconium.

Rensselaer Polytechnic Institute. H. B. Huntington, Anisotropic Self-Diffusion in Metals.

Rensselaer Polytechnic Institute. F. V. Lenel, Mechanism of Sintering Loose and Pressed Metal Powder Compacts.

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Stanford University. V. F. Macres and R. A. Huggins, Kinetics in Solid State Systems.

Stanford University. O. D. Sherby, Effect of Lattice Vacancies on Mechanical Behavior of Crystalline Materials.

Stanford University. D. A. Stevenson, Thermodynamic and Transport Properties in Liquid Metal Solutions.

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Tennessee, University of. E. E. Stansbury, Application of Adiabatic Calorimetry to Metal Systems.

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Union Carbide Metals Co. W. W. Webb, Metallic Solid Solutions.

Utah, University of. I. B. Cutler, Recrystallization and Sintering of Oxides.

Virginia Institute for Scientific Research. Henry Leidheiser, Jr., Corrosion of Metals in Boiling Acids.

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Virginia, University of. J. W. Mitchell and N. Cabrera, Physical Studies of the Surface State.

Wake Forest College. T. J. Turner, A Study of Atomic Movements in Solids Employing Anelastic Measurements.

Western Reserve University, Stefan Machlup, Point Imperfections in Metals.

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Controlled Thermonuclear

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Delaware, University of. W. M. Gottschalk, Review of Literature on Oscillations and Wave Motion in Plasma.

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Georgia Institute of Technology. E. W. McDaniel, Ionization and Charge Transfer Cross Sections in the Range 0.15–1.1 Mev.

Illinois, University of. R. C. Becker, Development of a Production Prototype Line of Two Millimeter Wave Equipment.

Illinois, University of. P. D. Coleman, Research and Investigation Leading to Methods of Generating and Detecting Radiation in the 100–1000 Micron Range of the Spectrum.

Massachusetts Institute of Technology. J. B. Wiesner, Basic Research on High Temperature Gas Plasmas.

Miami, University of. H. S. Robertson, A Study of Plasma Oscillations.

Michigan, University of. H. J. Gomberg, Study Program Related to Project Sherwood.

New York University. Leon Fisher, Low Density Plasma Probing by Atomic Beams.

New York University. Harold Grad, Theoretical Investigations in Plasma Fluid Dynamics.

Northwestern University. R. L. Hines, Radiation Effect of Positive Ion Bombardment.

Physics Engineering Chemistry Corporation. W. E. Brittin, An Investigation of the Equilibrium Properties of a Fully Ionized Gas.

Space Technology Laboratories, Inc. Milton Clauser, Theoretical Studies of Plasma Turbulence.

Stanford University. Marvin Chodorow, Plasma Oscillations.

Stevens Institute of Technology. W. H. Bostick, Development of High Velocity Deuterium Plasma Gun.

Tennessee, University of. E. G. Harris, Instabilities Due to Anisotropic Velocity Distributions.

Westinghouse Electric Corp. R. E. Fox, Ultrahigh Vacuum Techniques.

DIVISION OF BIOLOGY AND MEDICINE

	As of November 1958			As of November 1959		
	Number	Amount	Scientific man-years	Number	Amount	Scientific man-years
Biology:						
New contracts	38	$478,332		50	$803,248	
Renewal contracts	192	2,817,683		195	3,265,082	
Subtotal	230	3,296,015	323.1	245	4,068,330	445.1
Environmental sciences:						
New contracts	23	520,797		19	469,250	
Renewal contracts	42	1,492,431		39	1,425,475	
Subtotal	65	2,013,228	149.0	58	1,894,725	156.9
Fallout studies:						
New contracts	[a]			10	171,072	
Renewal contracts				17	1,783,258	
Subtotal				27	1,954,330	120.9
Medicine:						
New contracts	43	872,089		33	754,816	
Renewal contracts	138	4,286,371		150	4,872,757	
Subtotal	181	5,158,460	333.0	183	5,627,573	383.7
Radiation instruments:						
New contracts	9	271,572		3	66,039	
Renewal contracts	27	697,889		25	851,499	
Subtotal	36	969,461	36.0	28	917,538	50.1
Education, training and information:						
New contracts	7	146,970		8	165,298	
Renewal contracts	5	96,311		12	201,379	
Subtotal	12	243,281		20	366,677	
New contracts	120	2,289,760		123	2,429,723	
Renewal contracts	404	9,390,685		438	12,399,450	
Total	524	11,680,445	841.1	561	14,829,173	1,156.7
Total contract terminations	59			86		

[a] Included as part of Environmental Sciences.

Biology Branch

Irradiation Effects—Molecular Level

Agnes Scott College, Decatur, Ga. Josephine Bridgman, A Comparison of Irradiation Effects on Wet and Dry Ciliate Cysts in Nitrogen, Oxygen, and Air.

Albany Medical College of Union University, N.Y. Charles Hurwitz and R. A. Peabody, Studies of Nuclear Acid and Protein Synthesis with Spheroplast Lysates of *Escherichia Coli.*

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ganese, Chromium, and Nickel) in the Viscera of Rats Before and After Total Body X-Irradiation.

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Arkansas, University of. Jacob Sacks, Studies on the Phosphorylation Cycle in the Intact Animal Using Radioactive Phosphorus.

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California, University of, Davis. A. S. Crafts, The Uptake, Distribution and Fate of Labeled Compounds Used as Tracers in Plants.

California, University of, Berkeley. A. D. McLaren, investigation of the Mechanism of the Effect of Ultraviolet Light on Enzymes and Viruses.

California, University of, San Francisco. Harold Tarver, Metabolism of Protein Studied with Tritium as a Tracer.

Chicago, University of. Hans Gaffron, Photochemical Reactions of Chlorophyll and of Related Photoactive Pigments.

Chicago, University of. J. O. Hutchens, The Entropy of Amino Acids and Proteins.

Chicago, University of. R. E. Zirkle, Investigations of Cellular Biology, with Special Reference to Cell Division, by Means of Microbeams of Ultraviolet Radiation.

Christian Brothers College, Memphis, Tenn. Edward Doody, Uranium Complexes with Amino Acids and Peptides.

Clemson Agricultural College. J. B. Whitney, Jr., Overwintering of *Xanthomonas pruni*, The Casual Organism of Bacterial Spotof Peaches.

Colorado, University of. B. M. Tolbert, Radiation Effects in Biochemistry and Organic Chemistry.

Columbia University. R. F. Dawson, Pathways of Alkaloid Biosynthesis.

Columbia University. C. G. King, To Identify Precursors and End-Products Containing Radio-Carbon, in Studies of the Role of Glucose, Ascorbic Acid, etc., in Metabolism.

Columbia University. T. D. Price, Study of the Condensing Units in Nucleic Acid Biosynthesis.

Columbia University. David Rittenberg, The Activation of Hydrogen by Biological Catalysts.

Columbia University. J. H. Taylor, Nucleic Acid and Protein Synthesis in Individual Cells and Chromosomes Studied by Radioactive Tracers and Autoradiographs.

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Howard University, Washington, D.C. W. M. Booker, The Relation of Ascorbic Acid to Cholesterol.

Howard University, Washington, D.C. Herman Branson, Kinetic and Mass Spectrometric Studies of Biophysical Systems with Radioactive and Stable Isotopes.

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Institute for Cancer Research, Philadelphia, Pa. Jack Schultz, Studies on the Effects of Ultraviolet Radiation on Cell Structure and Behavior.

The Institute of Living, Hartford, Conn. M. W. Gordon, Metabolic Studies on Nervous Tissue.

Johns Hopkins University. Robert Ballentine, Cell Membrane Permeability and Accumulation of Ions.

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Johns Hopkins University. Theodore Enns and Francis Chinard, A Study of the Relative Diffusion Rates of Isotopes from Capillaries.

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Massachusetts Institute of Technology. S. A. Goldblith, Fundamental Studies on the Effects of Ionizing Radiations on Bacteria.

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North Dakota, University of. W. E. Cornatzer, A Study of Methionine as a Source of Methyl and Sulfur in Intermediary Metabolism.

Northwestern University. Chiadao Chen, Synthesis and Metabolic Studies of Rings A and/or B Labeled Estradiol and Related Compounds.

Northwestern University. J. A. D. Cooper, Studies on the Direct Oxidation of Galactose by Galactose Oxidase.

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Smithsonian Institution, Washington, D.C. W. H. Klein, A Study of the Biochemical Effects of Ionizing and Nonionizing Radiation on Plant Metabolism During Development.

Southern California, University of. P. D. Saltman and E. M. Butt, The Use of Radioiron to Determine the Mechanisms of Utilization and Transport of Iron in the Mammalian Organism.

Southern Research Institute, Birmingham, Ala. H. E. Skipper, Body Retention of Carbon 14.

Syracuse University. Trevor Robinson, The Use of Ionizing Radiation for Studying Enzyme Complexes.

Syracuse University. B. S. Strauss, The Genetic Effect of Incorporated Isotopes: The Transmutation Effect.

Tennessee, University of. J. G. Carlson, Studies *in vitro* of the Immediate Effects of X-Radiation on Chromosome Morphology and Mitotic Activity.

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Texas Agricultural Experiment Station. Raymond Reiser, The Biosynthesis of Polyunsaturated Fatty Acids by the Laying Hen.

Texas, A & M College of. N. P. Wood, The Formate-Pyruvate Exchange Reaction in *Streptococcus faecalis.*

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Tufts College. David Rapport, Study of the Effects of Radiation on Growth.

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Utah, University of. S. R. Dickman, Pancreas Metabolism as Studied with Radioactive Tracers.

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Washington University, St. Louis, Mo. David Lipkin, Synthesis of Nucleotides and Related Compounds.

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Wistar Institute of Anatomy and Biology, Philadelphia, Pa. David Kritchevsky, Effects of Deuterium on Normal and Virus Infected Tissue Culture Cells.

Worcester Foundation for Experimental Biology, Shrewsbury, Mass. Yutaka Kobayashi, Metabolism of Biologically Active Amines.

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Michigan, University of. H. J. Gomberg, Resonance in Radiation Effects.

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California, University of, Berkeley. Louis Jacobson and Roy Overstreet, Study of the Internal or Metabolic Factors and the External or Environmental Factors Affecting Ion Absorption by Plants.

California, University of, Berkeley. Hans Jenny, Modes of Entry of Strontium and Other Polyvalent Ions into Plant Roots.

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California, University of, Berkeley. A. D. McLaren, An Investigation into the Utility of Radiation Sterilized Soil as a Medium for Growth of Plants and Microorganisms.

California, University of, Berkeley. Roy Overstreet, Study of Decontamination of Soils Containing Radioactive Elements and Salts.

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Connecticut, University of. F. H. Emmert, Ion Interactions in Plant Tissues.

Connecticut, University of. A. E. Schwarting, A Study of Alkaloidal Synthesis in *Claviceps purpurea* (Ergot).

Cornell University. C. L. Comar, Fission Product Metabolism and Response in Laboratory and Domestic Animals.

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Longwood College, Farmville, Va. R. T. Brumfield, Effects of Radiation on Root Growth of Higher Plants.

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Nebraska, University of. F. A. Haskins, Effects of X-Rays and Thermal Neutrons on Plant Metabolism.

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North Carolina State College of Agriculture and Engineering. N. T. Coleman, The Mineral Composition of Plants Grown on Southeastern Soils as Related to Soil Characteristics, Lime, and Fertilizer Additions and Root Distribution, with Particular Emphasis on Sr–90.

Northwestern University. E. I. Pentz, The Effect of X-Irradiation on Certain Aspects of Salt and Sulfur Metabolism in Adrenalectomized Rats.

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Purdue Research Foundation. Harry Beevers, Carbohydrate Catabolism in Plants.

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South Dakota State College. E. I. Whitehead, Metabolism of Selenium and Sulphur in Plants.

Texas Agricultural Experiment Station. J. R. Brazzel, Ecological, Physiological, and Toxicological Investigation with the Boll Weevil.

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Amherst College. P. T. Ives, Genetic and Direct Effects of Gamma Radiation on Drosophila.

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Arkansas, University of. F. E. Clayton, Developmental-Genetic Study of the Effects of X-Ray Irradiation in *Drosophila virilis* and *Bufo valliceps.*

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Brown University. Walter Kenworthy, Radiation Effects on the Cytoplasm of Habrobracon Eggs.

California Institute of Technology. G. W. Beadle, The Genetic and Cytological Effects of High Energy Radiation.

Chicago, University of. W. K. Baker, The Genetic Functioning of Heterochromatin.

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Columbia University. Ernest Borek, A Study of the Mechanism of Induction in a Lysogenic Organism which Converts the Latent Bacterial Virus to Virulence.

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New Hampshire, University of. W. R. Lee, Radiation Induced Viability Mutations in the Honey Bee.

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Pittsburgh, University of. E. B. Spiess, Genetic Potential of Certain Populations of *Drosophila persimilis* from the Sierra Nevada of California.

Purdue Research Foundation. A. B. Burdick, Genetic Effects of Thermal Neutron Irradiation in Homozygous Tomatoes.

R. B. Jackson Memorial Laboratory, Bar Harbor, Maine. E. L. Green, Quantitative Population Genetics of Mice Under Irradiation.

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Washington State University. R. A. Nilan, A Study of Factors that Govern Radiosensitivity in Plants.

Wisconsin, University of. A. B. Chapman, Genetic Effects of Cumulative Irradiation in Rats.

Wisconsin, University of. N. E. Morton, Lethal and Detrimental Equivalents in Drosophila and Man.

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California, University of, Davis. A. C. Andersen, The Effect of Radiation on Work Capacity and Longevity of the Dog.

Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica. P. H. Emmett, R. H. Allee, Atomic Energy Applied to Agriculture in Latin America; (a) Use of Isotopes; (b) Gamma Field.

Iowa State University of Science and Technology. J. W. Gowen and Janice Stadler, Quantitative Study of Lifetime Sickness and Mortality and Progeny Effects Resulting From Exposure of Animals to Penetrating Irradiation.

Service Contracts

Health, Education, and Welfare, U.S. Department of, National Institutes of Health. W. G. Baylis, Interdepartmental Committee on Nutrition for National Defense.

Environmental Sciences Branch

Ecology

Alaska, University of, College, Alaska. Brina Kessel, An Ecological Study of the Flora and Fauna of the Cape Thompson-Ogotoruk Creek Region, Alaska.

Bowling Green State University Foundation, Inc., Bowling Green, Ohio. Jacob Verduin, A Study of Productivity of Aquatic Habitats Near Bowling Green, Ohio.

Brigham Young University. D. M. Allred, Comparative Ecological Studies of Animals.

Brigham Young University. W. W. Tanner, Comparative Population Studies of Vertebrates in the Uranium Areas of the Upper Colorado River Basin, With Specific Reference to the Natural Effects on the Animals Inhabiting the Areas of Heavy Radiation.

Central Michigan College of Education. L. L. Curry, A Study of the Ecology and Taxonomy of Fresh-Water Midges (Tendipedidae: Diptera) of Michigan with Special Reference to Their Role in the "Turnover" of Radioactive Substances in the Hydrosol.

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Connecticut, University of. J. S. Rankin, Proposal to Inventory the Macroscopic Benthic Fauna of Various Locations Off the New England Coast.

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Iowa State University of Science and Technology. K. D. Carlander, A Study of the C–14 Method of Evaluating Primary Production in Iowa Lakes.

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Louisville, University of, Louisville, Ky. L. A. Krumholz, A Radioecological Study of the Biota of Doe Run, Meade County, Kentucky.

Maryland, University of. R. C. Stross, A Study of Plankton Nutrition and Antibiosis Using Radioisotopes Under Varying Ecological Conditions.

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Michigan, University of. G. H. Lauff, Uptake, Transport, and Effects of Radioactive Materials in Aquatic Ecosystems.

Minnesota, University of. J. J. Christensen, Physiological Crop Ecology Using Radioisotopes.

Morehead State College, Morehead, Ky. M. B. Heaslip, Germination and Seedling Growth of Irradiated Seeds of Several Dominant Species of the United States Deciduous Forest Region.

New Mexico Highlands University. L. M. Shields, Selective Denuding Action of Atomic Radiation on Vegetation of Some Nevada Sites and Gross Changes in the Surviving Flora.

North Carolina State College. L. A. Whitford, Studies in the Ecology of Fresh-Water Algae in North Carolina.

Northwestern State College, Natchitoches, La. J. E. Sublette, The Geographic Distribution and Habitat Preference of Midges (Family Tendipedidae: Order Diptera, Insecta) in the Streams of the Principal Water-Sheds Lying Between the Red River in Louisiana and the Rio Grande in Texas.

Ohio Agricultural Experiment Station. G. E. Gilbert, Bioclimatic and Soils Investigations in Forest Environments.

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Tennessee, University of. R. E. Shanks, Vegetation Studies Related to Disposal of Radioactive Wastes.

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Tulane University. N. C. Negus, Dynamics of Mammal Populations.

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Wisconsin, University of. A. D. Hasler, Radioisotope Exchange Studies in Lakes.

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The Bermuda Biological Station for Research, Inc. J. H. Ryther, The Plankton Ecology and Related Chemistry and Hydrography of the Sargasso Sea.

California, University of, Scripps Institute of Oceanography, La Jolla, Calif. Gustaf Arrhenius and E. D. Goldberg, A Study of the Transfer of Heavy Metals from Seawater to Sediments, with Emphasis on Members of the Natural Radioactive Series.

Columbia University, Lamont Geological Observatory. W. S. Broecker, Age Determination Studies on Deep Sea Cores.

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Florida, University of. J. B. Lackey, Rates, Amounts, Nuclide Origin and Effects of Radiation Acquired by Fresh Water Micro-organisms Under Experimental Control.

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Smithsonian Institution, Washington, D.C. F. A. Chace, Harold Rehder and L. P. Schultz, Systematic Zoological Research on the Marine Fauna of the Tropical Pacific Area.

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Fallout Studies Branch

Environmental Radiation

Agriculture, U.S. Department of, Soil Conservation Service. L. T. Alexander, Collection and Preparation of Samples of Soils, Plants, and Animals for Calcium and Strontium Analyses.

Agriculture, U.S. Department of, Forest Service. N. T. Mirov, Obtaining Accurately Dated and Located Turpentine Samples for the Contemporary Natural C–14 Survey.

Air Force, U.S. Department of, Air Research and Development Command, Air Force Cambridge Research Center, Bedford, Mass. E. A. Martell, VHA Tracer and Strontium-90 Studies.

Air Force, U.S. Department of. L. J. Pardue, Project "Ash Can".

Arkansas, University of. P. K. Kuroda, Radioactive Fallout.

Armour Research Foundation of the Illinois Institute of Technology. John Rosinski, Some Studies Related to Radioactive Fallout.

Atlantic Research Corporation, Alexandria, Virginia. Michael Markels, Jr., Sampling of the Upper Atmosphere for Particulate Matter.

California, University of, Scripps Institution of Oceanography, La Jolla, Calif. H. E. Suess and Harmon Craig, Investigation of Mixing Processes in the Atmosphere and Sea Utilizing Stable and Radioactive Isotopes.

Chicago, University of. E. W. Barrett, Research on Tritium in the Atmosphere.

Columbia University. A. R. Schulert, Distribution of Nuclear Fallout.

Commerce, U.S. Department of, Weather Bureau. Lester Machta, Transport, Deposition and Meteorological Effects of Atomic Test Debris in the Atmosphere.

Del Electronics Corporation, Mount Vernon, N.Y. H. J. DiGiovanni, Research and Development on an Electrostatic Stratospheric Dust Sampler.

General Mills, Inc., Minneapolis, Minn. Sidney Stern, Stratospheric Particle Collection Studies.

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Michigan, University of. A. N. Dingle, Rain Scavenging of Particulate Matter from the Atmosphere.

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Stockholm, University of, Stockholm, Sweden. Bert Bolin, An Investigation of Tritium in Atmospheric Moisture, Rainwater, Rivers, and the Sea in the European Area.

Weizmann Institute of Science, Rehovoth, Israel. Aharon Nir, Tritium Concentrations in Natural Water Sources in Eastern Mediterranean Area.

Medical Research Branch

Irradiation Effects—Organ Systems

Albert Einstein Medical Center, Philadelphia, Pa. D. M. Sklaroff, Study of the Uptake of Radioactive Phosphorus (P–32) by the Prostate Gland.

Boston University. G. P. Fulton, Research on Permeability Changes in the Microcirculation Resulting from X-Irradiation.

Boston University. Fabian Lionetti, Enzymology of the Formed Elements of Human Blood. Dynamics and Biosynthesis of Carbon Labelled Substrates by Human Leucocytes *in vitro.*

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Boston University. L. C. Wyman, The Effect of Irradiation on the Growth and Functioning of Transplanted or Regenerated Adrenocortical Tissue in the Rat.

California, University of, Davis, Calif. L. M. Julian, R. W. Brauer, J. S. Krebs, Distribution Studies of the Reticuloendothelial System at Various Stages of Development in Relation to the Problem of the Dissociation of Liver Functions.

Chicago, University of. F. C. McLean, Skeletal Distribution of Estrone–16C–14 in Mice.

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Chicago, University of. W. J. Visek, The Biological Effects of Stressful Agents as Related to Diet.

Children's Hospital Society of Los Angeles. Phillip Sturgeon, Iron Storage and Reutilization.

Creighton University School of Medicine. R. P. Heaney, Ca–45 and Sr–85 Metabolism in Man.

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Columbia University. C. V. Harding, Studies on Transport and Metabolism of Isotopically Labelled Materials in the Eye.

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Florida, University of. D. S. Anthony, A Study of the Biochemical Results of Certain Treatments Given Patients Suffering from Phenylpyruvic Acid Oligophrenia.

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Illinois, University of. S. R. Rosenthal, A Reevaluation of Radiation Injury (B-Rays) of the Skin by a Direct Method Approach.

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Johns Hopkins University. C. L. Conley, Blood Coagulation, Hemorrhagic Disease.

Johns Hopkins University. J. E. Rose, Studies on Forebrain After Its Irradiation by a Monoenergetic Beam of High Energy Deuterons.

Kansas, University of. F. E. Hoecker, Investigation of Organic Substances Tagged with I–131 by Human Thyroid Gland *in vivo.*

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Kresge Eye Institute, Detroit, Mich. V. E. Kinsey, Effects of Neutrons and Other Radiations on the Ocular Lens.

Marquette University. Peter Abramoff, A Study of the Effects of X-Irradiation of Exclusively the Circulating Blood on the Antibody Producing Mechanism of the Rabbit.

Massachusetts Eye and Ear Infirmary. 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 Radioactive Isotopes with Special Reference to the Plastic Artificial Cornea.

Massachusetts General Hospital. Humberto Fernandez-Moran, Studies of the Effects of Ionizing Radiation on the Ultrastructure of Developing Nervous Tissue as Revealed by Electron Microscopy.

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Montefiore Hospital Association of Western Pennsylvania. Richard Abrams, Synthesis of Nucleic Acid Purines in Bone Marrow.

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New England Center Hospital. William Dameshek, Bone Marrow Research Project.

New England Deaconess Hospital. S. P. Hicks, The Effects of Ionizing Radiation on the Developing Mammalian Nervous System.

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New York Medical College. H. B. Eiber, Preparation of Radioactive Heparin.

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Notre Dame, University of. C. S. Bachofer, Mechanisms Involved in the Actions of Radiations on Living Cells.

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Oregon, University of. C. V. Hodges, Intracellular Pickup of Radioactive Phosphorus by Prostatic Epithelial Cells.

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Tennessee, University of. Lester Van Middlesworth, Studies in Iodide Metabolism.

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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.

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Bjorksten Research Foundation, Madison, Wis. Johan Bjorksten, Fundamentals of Aging—Insolubilization of Protein as a Function of Aging.

Buffalo, University of. Ernest Witebsky and M. L. Bloom, Immunological Factors in Bone Marrow Transplants.

California, University of, San Francisco. W. O. Reinhardt, An Immunocytological Study of Developmental Abnormalities in Mouse Embryos Irradiated Prior to Implantation.

California, University of, San Francisco. D. A. Wood, Age and Vulnerability to X-Rays.

Cedars of Lebanon Hospital, Los Angeles, Calif. Harry Sobel, Chemical Studies on Connective Tissues of Animals Aged Prematurely by Irradiation (Assessment of Biochemical Age).

Chicago, University of. C. P. Miller, Bacteriological Aspects of Radiation Sickness.

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Colorado, University of. J. K. Aikawa, Immunophysiologic Studies with Electrolytes, Including Mg-28, in Patients.

Harvard University. Brian MacMahon, Prenatal X-Ray and Childhood Neoplasia: A Cohort Study.

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Medical Evangelists, College of, Los Angeles County Hospital. J. J. Quilligan, Jr., Irradiation and Influenza Infections in Mice: Consequences of the Dual Action.

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Tennessee, University of. N. R. DiLuzio, The Response of the Reticulo-Endothelial System to X-Irradiation.

Tennessee, University of. W. M. Hale, A Study of the Effects of Cobalt-60 Gamma Irradiation on Infection and Immunity.

Tennessee, University of. A. W. Jones, A Survey of the Effects of Radiation on Host-Parasite Relations.

Texas A & M College. S. O. Brown, Study of the Influence of Pre- and Post-Natal Low Intensity Chronic Radiation on the Structure and Function of the Germinal Epithelium in the Albino Mouse.

Texas Technological College. S. J. Kaplan, The Effects on Rat Behavior of Developmental Aberrations Induced by Ionizing Radiation *in utero.*

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Wayne State University, Detroit, Mich. Jack Werboff, The Effect of Prenatal X-Irradiation on the Behavioral Development of the Albino Rat.

Worcester Foundation for Experimental Biology, Shrewsbury, Mass. M. C. Chang, Effects of Co-60 Irradiation on Rabbit Eggs *in vitro*.

Yerkes Laboratory of Primate Biology, Inc., Orange Park, Fla. A. J. Riopelle, Behavioral Effects of Ionizing Radiation on Chimpanzees of Various Ages.

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Albert Einstein Medical Center, Philadelphia, Pa. E. E. Schwartz, Studies on Chemical Protection Against Radiation-Induced Intestinal Injury.

The Children's Medical Center, Boston, Mass. Sidney Farber, The Nature of Bleeding in Pancytopenia with Special Regard for Thrombocytopenia and the Vascular Defect.

Jefferson Medical College of Philadelphia. L. M. Tocantins, Transplantation of Preserved Marrow Between Animals and From One Human to Another.

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New England Center Hospital. William Dameshek, Physiopathology of Platelets and Development of Platelet Substitutes.

North Carolina, The Agricultural and Technical College of. G. C. Royal, Jr., Biochemical and Immunological Comparisons of Irradiated Mice and Rats Treated with Bone Marrow Transplants.

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Yale University. J. W. Hollingsworth, Biologic Implications of Isologous and Heterologous Bone Marrow Repopulation in Irradiated Animals.

Burns and Blast

Lovelace Foundation for Medical Education and Research, Albuquerque, N. Mex. W. R. Lovelace II, *et al.*, Indirect Blast Injuries.

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Catholic University of America, Washington, D.C. C. L. Cowan, Jr., Detector Development.

Cincinnati, University of. E. L. Saenger, Preparation of a Handbook of Medical Procedures for Radiation Accidents and Hazards.

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Harvard University. Leslie Silverman, Research and Development of Protective Respiratory Equipment.

Ionics, Inc., Cambridge, Mass. H. G. Petrow, The Determination of Low Level Concentrations of Thorium and Radium in Water.

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Baltimore City Hospitals. J. D. McQueen, The Use of Positron Emitting Isotopes in the Localization of Intracranial Lesions.

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California, University of, Berkeley. I. L. Chaikoff, Studies on the Induction of Thyroid Cancer and on the Nature of Metabolic Blocks Following Irradiation.

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Colorado, University of. R. W. Whitehead and Dimitry Morkovin, Studies on Radiation Protective Agents.

Columbia University. H. H. Zinsser, Use of Radioactive Silver III on Indwelling Balloon Catheters for the Treatment of Gastric Hyperacidity and Bladder Papillomatosis.

Florida, University of. F. E. Ray and M. F. Argus, Effect of Radiation on the Uptake of Large Organic Molecules by the Liver and Spleen of the Mouse.

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Illinois, University of. Armand Littman, Study on the Effects of Intragastric Irradiation with Beta Rays from Ruthenium^{106} -Rhodium^{106} in Patients with Malignant Disease.

Illinois, University of. S. R. Rosenthal, The Effects of Phenol Ethers on Lesions of the Skin Produced by Beta Radiation (Strontium 90).

Illinois, University of. H. R. Snyder, Experimental Research on Synthesis of Boron-Containing Dyes.

International Atomic Energy Agency, Vienna, Austria. Development of Methods for the Enrichment of Calcium 46 for the Production of Calcium 47.

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. W. H. Sweet, The Use of Thermal and Epithermal Neutrons in the Treatment of Neoplasms.

Massachusetts General Hospital. W. H. Sweet and Gordon Brownell, External Localization of Brain Tumors Employing Position-Emitting Isotopes.

Meharry Medical College, Nashville, Tenn. Horace Goldie, Effect of Beta Rays and X-Irradiation on Growth and Spread of Free Tumor Cells.

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Methodist Hospital, The Texas Medical Center. H. C. Allen, Jr., Further Investigation of the Preoperative External Localization of Intracranial Lesions, Using Sodium Iodide Gamma–Ray Spectrometry Techniques in Conjunction with a Graphic Recording Automatic Scanning Device.

Michigan, University of. F. J. Hodges and Isodore Lampe, Clinical Evaluation of Teletherapy.

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Oregon, University of. E. E. Osgood and A. J. Seaman, Studies of Hemic Effects of Radioisotopes, X-Rays and of Adrenocortical Hormones.

Palo Alto Medical Research Foundation, Palo Alto, Calif. S. F. Thomas, Radioactive Colloids for Medical Research.

Stanford University. H. S. Kaplan, Biological and Medical Investigations with the 70 MEV Linear Electron Accelerator.

Texas, University of, Southwestern Medical School. F. J. Bonte, Changes in Radiation Quality with Depth, Measured by a Biological System.

Texas, University of, M. D. Anderson Hospital and Tumor Institute. W. K. Sinclair, Physical and Radiobiological Investigations with 22 MEV X-Rays and Electrons, as Compared with Cobalt 60 and 250 Kv X-Rays.

Washington Hospital Center, Washington, D.C. J. C. Bateman, Investigation of Distribution, Localization and Excretion of Tagged Triethylene Thiophosphoramide Following Injection by Various Routes.

Washington University, St. Louis, Mo. Michel Ter-Pogossian, Radiosensitivity of Tissues and Oxygen Tension.

Wayne State University, Detroit, Mich. J. E. Lofstrom, Evaluation of Radioactive Isotope Gamma Ray Source for Medical Teletherapy.

Multiple Projects

California, University of, Davis. A. C. Andersen, Effects of Sr^{90} Administered During the Growth Period of the Dog.

Columbia University. Gioacchino Failla, Biological Action of Ionizing Radiation. Instrumentation for Research.

Massachusetts General Hospital. P. C. Zamecnik and J. W. Gardella, Mechanisms of Protein and Nucleic Acid Synthesis, and Their Possible Relationship to Radiation Damage.

Massachusetts Institute of Technology. R. D. Evans, Radium, and Mesothorium Poisoning and Dosimetry and Instrumentation Techniques in Applied Radioactivity.

New England Deaconess Hospital. Shields Warren, Acute and Chronic Radiation Injury.

Sloan Kettering Institute for Cancer Research. Arthur Denues, Biological Effects of Radiation and Related Biochemical and Physical Studies.

Utah, University of. T. F. Dougherty, Toxicity Studies of Plutonium and Other Radioactive Substances in Animals.

Western Reserve University. H. L. Friedell, Investigations of the Biological Effects of Internally Deposited Radioisotopes and Related Radiobiology Studies.

Service Contracts

American Institute of Biological Sciences, Washington, D.C. H. T. Cox, Management Service Contract.

Health Education and Welfare, U.S. Dept. of, Bureau of State Services, Public Health Service. F. J. Weber, Expansion of the Biological Sampling Program Initiated in Nevada.

Smithsonian Institution, Washington, D.C. S. L. Deignan, Bio Sciences Information Exchange.

Radiation Instruments Branch

Radiation Detection and Measurement

Allen B. DuMont Laboratories, Inc., Clifton, N. J. A. E. Becker, Photomultiplier Tube Development.

Allen B. DuMont Laboratories, Inc., Passaic, N.J.. Bernard Linden, The Construction of a Nuclear Track Viewing Device.

Anton Electronic Laboratories, Inc., Brooklyn, N.Y. N. G. Anton, Proposal to Develop Low Background Level Detection Tube.

Armour Research Foundation of the Illinois Institute of Technology. C. A. Stone, Magnetic Recorder for Nuclear Pulse Application.

Army, U.S. Department of, Corps of Engineers. R. W. Beadle, Program of Research and Development on Scintillation Crystals.

Chicago, University of—Chicago Midway Laboratories. F. F. Rieke, Development of an Image Amplifier.

Columbia University. C. B. Braestrup, Development of Instruments and Procedures for the More Accurate Evaluation of the Cumulative Occupational Dose in Radiology.

Commerce, U.S. Department of—National Bureau of Standards. L. S. Taylor, Assistance to the National Committee on Radiation Protection and Measurement.

Commerce, U.S. Department of—National Bureau of Standards. L. B. Leder, Electron Scattering.

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Commerce, U.S. Department of—National Bureau of Standards. L. Costrell, Instrumentation for Nuclear Applications.

Commerce, U.S. Department of—National Bureau of Standards. S. W. Smith, Evaluation and Testing of Radiation Instruments.

Commerce, U.S. Department of—National Bureau of Standards. E. C. Lloyd, High Temperature Strain Gages.

Commerce, U.S. Department of—National Bureau of Standards. W. A. Wildhack, Miscellaneous Investigations in Basic Instrumentation.

Levinthal Electronic Products, Inc., Palo Alto, Calif. W. J. Van Sciver, Study of Scintillation and Other Related Properties of NaI Crystals.

New England Center Hospital. C. V. Robinson, Development of Small *in vivo* Detectors.

New Mexico, University of. G. H. Daub, The Synthesis and Properties of Compounds Which may be Used as Scintillation Solutes in Liquid Scintillators.

New York University. M. H. Shamos and S. Z. Lewin, Measurement of Environmental Radiation.

Notre Dame, University of. D. W. Juenker, Fundamental Research on Photoemission.

Polytechnic Institute of Brooklyn. Gerald Oster, Color Forming Dosimeters for Ionizing Radiation.

Radio Corporation of America, Princeton, N.J. G. A. Morton, Photomultiplier Tube Research and Development.

Sloan Kettering Institute for Cancer Research. J. S. Laughlin, Equivalence of Absorbed Radiation Energy and Cavity Ionization.

St. Procopius College, Lisle, Ill. F. R. Shonka and W. P. Jesse, I—Special Problems in Nuclear Instrumentation; II—Ionization of Gases.

Westinghouse Electric Corporation, Pittsburgh, Pa. A. E. Anderson, Proposal for Research on Development of a High Gain Image Intensifier for Use with Scintillation Track Chambers.

Education, Training and Information

Adelphi College, Garden City, N.Y. H. A. Robinson, Support for an Institute in Chemistry and Radiation Biology for High School Science Teachers.

Baylor University, Waco, Tex. B. C. Brown, Radiation Biology Course—Summer Institute for High School Science Teachers.

Brigham Young University. L. A. Compton, Summer Institute of Radiobiology for High School Science Teachers.

California, University of, Los Angeles. R. L. Libby, Summer Institute in Radiation Biology for High School Science Teachers.

Duke University. H. S. Roberts, Jr., Radiation Biology Course for High School Teachers.

Harvard University. A. K. Solomon and Fletcher Watson, Intensive Summer Program Devoted to Furthering the Scientific Education of High School Teachers with Particular Emphasis on the Use of Radioactive Materials.

Howard University, Washington, D.C. M. C. Taylor, Summer Institute on Radiobiology for High School Science Teachers.

Kansas, University of. E. I. Shaw, Summer Institute in Radiation Biology for High School Science Teachers.

Michigan, University of. Melvin Levine, Summer Institute in Radiation Biology for College Science Teachers.

Montana State University. L. H. Harvey, Summer Institute in Radiation Biology for High School Science Teachers.

New Mexico, University of. H. O. Ried, Radiation Biology Course for High School Teachers.

Ohio State University. J. S. Richardson, Summer Institute in Radiation Biology for High School Science Teachers.

Puerto Rico, University of. J. A. Ramos, Summer Institute in Radiation Biology for High School Science Teachers.

Purdue University. J. E. Christian, Summer Institute in Biology and Radiation Biology for High School Science Teachers.

Syracuse University. M. W. Jennison, Summer Institute in Radiation Biology for High School Science Teachers.

Tuskegee Institute, Alabama. J. H. M. Henderson, Summer Institute in Radiation Biology for High School Science Teachers.

Washington, University of. A. D. Welander, Summer Institute in Radiation Biology for High School and College Science Teachers.

Wayne State University, Detroit, Mich. A. J. Vorwald, Summer Institute on Radiobiology for High School Science Teachers.

Wyoming, University of. C. A. Cinnamon, Summer Institute in Biology and Radiobiology for High School Science Teachers.

Washington, University of. N. B. Everett. Basic Training Program for Medical Students in the Use of Radioactive Isotopes in Biology and Medicine.

DIVISION OF RAW MATERIALS CONTRACTS

	As of November 1958			As of November 1959		
	Number of contracts	Amount	Scientific man-years	Number of contracts	Amount	Scientific man-years
New contracts				1		0.1
Renewal contracts	6	$1,171,639	87	4	$365,805	30.2
Contract terminations	3	42,653		2	[a] 35,553	

[a] $29,496 of the total amount represents final payment for contracts which were terminated in 1958.

NOTE: Above table for 1958 corrects information as given in the 25th Semiannual Report to Congress (July–December 1958).

RAW MATERIALS

Columbia University. H. D. Hassialis, Recovery of Uranium from the Chattanooga Shale.

Denver, University of. Lee Brogan, Mathematical Consulting in the Field of Mathematic Measurements and Radiation Relative to Logging.

National Lead Co., Inc., C. E. Crompton, Process Development Studies on Control of Radioactivity in Uranium Mill Effluents.

Pennsylvania State University. Harold Wright, Research on Trace Quantities of Uranium in Sulfides of Veins.

U.S. Bureau of Mines. Ballard H. Clemmons, Amenability Testing and Assaying of Uranium Ores and Unit Process Studies.

REACTOR DEVELOPMENT RESEARCH CONTRACTS

Acoustica Associates. Study Program and Development of High Temperature Liquid Level Sensor.

Aeroprojects, Inc. Application of Ultrasonic Energy to Problems of Interest to AEC.

Alco Products, Inc. Analysis, Design and Fabrication of APPR–1 Core II.

Arcos Corp. Development of Alloys for Welding Stainless Steel Reactor Pressure Vessels.

Babcock and Wilcox. Comparative Critical Experiment and Preparation of NS Savannah Safeguards Report; Design and Development of a Nuclear Reactor and Components of the Propulsion Plant Suitable for the Propulsion of a Merchant Ship.

Carnegie Institute of Technology. Thermal and Hydraulic Studies at High Reynolds Numbers.

Columbia University. Research and Development in Heat Transfer.

Combustion Engineering. Study of Solid State Bonding; High Conversion in an Uranium-Plutonium Fuel Cycle; Development and Testing of UO_2 Fuel Element System; Development and Testing of Homogeneous Ceramic Fuels; Ultrasonic Roll Bonding of Fuel Plates.

Franklin Institute. Investigation of Stresses and Deflection in NS Savannah Reactor Vessel Model and Nozzle Attachments.

General Dynamics. Study of Hazards Associated with Processing Enriched Uranium by Commission Licensees; Engineering Studies for Servicing Facilities to Maintain, Refuel and Provide Waste Disposal for Nuclear Merchant Ships; Maritime Gas-Cooled Reactor Programs; Research and Conceptual Design of a High Temperature Gas-Cooled Reactor.

Harvard College. Air Cleaning Research and Development; Mechanisms of Dilution of Radiocontaminants in Surface Waterways.

Johns Hopkins University. Dispersal of Fission Products in Estuarine and Coastal Environments.

Henry J. Kaiser Co. Study of the Economic Application of Nuclear Power to Remote Military Installations.

The Martin Co. Research and Development for the SNAP Program.

Massachusetts Institute of Technology. Decontamination of Radioactive Liquid Wastes; Research in Nuclear Science and Engineering; Research on the Cost of Nuclear Fuel Cycles; Research on Thermal Conductance of Metallic Surfaces in Contact; Reactor Lattice Research Utilizing Heavy Water as a Moderator and Slightly Enriched Uranium and Uranium Oxide as Fuel.

Materials Research Corp. Permeability of Cladding Materials to Inert Gases.

Metal Hydrides, Inc. Rate of Hydrogen Permeation Through Materials.

National Academy of Sciences. Disposal of High-Level Radioactive Waste into the Ground.

New York University. Research on Chemical Aspects of Nuclear Engineering.

Nuclear Development Corp. of America. Investigation of Sintered Uranium Powders; Sponge Fuel Element; Uranium-Plutonium Carbide Fuel Cycle Development Program; Range of Validity of Multi-Group Methods for Shielding; Penetration of Neutrons; Light-Water Steam Mixtures as Reactor Coolants.

Nuclear Materials and Equipment Corp. Preparation of Corrosion-Resistant and Radiation Damage-Resistant Compacts of Coated Particles for Use as a Nuclear Fuel; Research and Development Work Pertaining to the Development of Plutonium Bearing Fuel Materials.

Nuclear Metals, Inc. Clad Massive UO_2 Fuel Elements by Hot Extrusion; General Fuel Cycle Development Research Program.

Olin Mathieson Corp. Low Cost Fabrication Process for Uranium Oxide Fuel; Development of Uranium Carbides as a Nuclear Fuel.

Pennsylvania State University. Studies of the Structure of Materials by Neutron Diffraction Techniques; Stresses at Nozzle Connections of Pressure Vessels.

Radiation Applications, Inc. Research and Development on Removal and Concentration of Strontium 90 and Cesium 137 from Radioactive Waste by Foam Separation Techniques.

Rensselaer Polytechnic Institute. Research to Determine Feasibility of Using Glass Fibers as part of Fuel Elements of a Nuclear Reactor; Definitive Design of Linear Electron Accelerator and Betatron Operations.

Sanderson and Porter. Design and Feasibility Study of a High Temperature Pebble Bed Reactor; Uranium-Graphite Spherical Fuel Elements for a Pebble Bed Reactor.

Southwest Research Institute. Design of Pressure Vessels; Research on Properties of Materials Employed in Pressure Equipment; Fatigue Damage in Materials Employed in Pressure Equipment.

Stevens Institute of Technology. Research for the Development of Optimum Slip Casting Fabrication Procedures for the Production of Uranium Oxide Fuel Elements.

Sylvania-Corning Nuclear Corp. Research in Powder Metallurgy.

Syracuse University. Research on the Problem of Fractures Produced in Various Alloys by Plastic Strain Cycling at Ambient and Elevated Temperatures.

TRG, Inc. Practical Application of Small Source Reactor Physics Calculations to the Development of Fuel Element Materials and Designs.

Vitro Laboratories Division of VCA. Research and Development on Electrophoretic Techniques.

Westinghouse Electric Corp. Multi-Region Reactor Lattice Studies; Research and Development on Thermoelectric Materials in the Presence of Irradiation.

Yale University. Initiation of Chemical Reactions by Gamma Irradiations.

M. W. Kellogg. Studies on the Fixation of Radioactive Materials by Thermite Techniques.

Arthur D. Little, Inc. Survey of Information Aspects of Commission's Materials Research Program.

The Martin Co. Nuclear Calculation Code Development and Supporting Experimental Core Physics; Research on Flux Measurement Techniques; Aqueous Fluidized Bed Reactor Study.

Owens-Corning Fiberglass. Glass Fiber Fuel Development.

University of North Carolina. Disposal of Radioactive By-products of Nuclear Fission.

University of Virginia. Research and Development Activities Using Pool-Type Reactor.

Georgia Institute of Technology. Fused Ceramics for Nuclear Applications and Fused Silica Heat Exchanger Development.

Puerto Rico Water Resources Authority. Power Reactor Design Study.

Clevite Corp. Mechanical Research Division. Development of Fuel Bearing Fiber Glass Fuel Elements.

The Carborundum Co. Synthesis of Refractory Uranium Compound.

Union Carbide Corp. (Union Carbide Metals Co.) Development of a Uranium Carbide Clad Fuel Element.

Union Carbide Corp. (National Carbon Co.) Development of Graphite Matrix Fuel Elements.

Henry J. Kaiser Co., Kaiser Engineers Division. Research and Development for the Experimental Gas Cooled Reactor Project.

University of Texas. Disposal of Radioactive Wastes.

North Carolina State College. Study of Phase Relationships in the U-C-O System under US-Euratom Joint Research and Development Program.

Allis-Chalmers Manufacturing Co. Design and Development of a Closed-Cycle Boiling Water Reactor.

Alco Products, Inc. Design of Prototype Steam Generator and Prototype Heat Exchanger.

Armour Research Foundation. Study of Reactor Containment; Scavenging of Particulate Matter in Connection with Nuclear-Powered Ships.

Atomic Power Development Association, Inc. Conceptual Design Study of a Sodium Components Test Facility.

Babcock and Wilcox Co. Experimental Physics Program for Light Water Reactors.

Battelle Memorial Institute. Research and Development and Experimentation in AEC Nuclear Reactor Programs.

Bureau of Mines (U.S. Dept. of Interior). Investigation of the Application of Fused Salt Electrolysis Technique to the Recovery of Zirconium and Hafnium from scrap; Research and Development on Yttrium, Zirconium, Hafnium, Uranium and other Materials.

Combustion Engineering, Inc. Nuclear Superheat Development Project.

Denver Research Institute. Study to Determine Optimum Alloy Additions and Heat Treatment Conditions to Promote Highest Ductilities of Iron-Aluminum Alloys; Systematic study on the Complete Niobium-Zirconium Phase Diagram and on ARC Melted Alloys.

Dow Chemical Co. Development of a Pyrometallurgical Process Applicable to Closed Reactor Fuel Cycles and Recovery of Uranium from Uranium Zirconium Fuel Materials.

University of Illinois. Aerosol Research and Development.

Internuclear Co. Development of an Advanced Engineering Test Reactor.

University of Minnesota. Two Phase Heat Transfer Studies.

Monsanto Chemical Co. Research and Development on the Reclamation of Organic Coolants.

MSA Research Corp. Materials Testing.

North American Aviation, Inc. Research and Development in Reactor Development Programs, including SRE, OMRE, HNPF, Piqua.

Northern States Power Co. Design and Development of a Nuclear Power Plant.

Ohio Injector Co. Development of Less Expensive and more Reliable Flow Control Mechanisms of Advanced Design.

Oklahoma State University. Study in Use of Furnace Calorimetry for Rapid Determination of Specific Heat of Solids at High Temperatures.

Griscom-Russell Co. Design of an Offset Tube Type Steam Generator.

Aerojet General Corp. Research and Development involving the Gas-Cooled Experimental Reactor and the Development of Gas-Cooled Systems.

Aerojet-General Nucleonics. Sulfur Cooled Power Reactor Study.

Advanced Technology Laboratories, American-Standard Corp. Thorium Alloys Program; Zirconium Thermal Stress Study; Mercury-Cooled Fast Breeder

Reactor Feasibility Study; Neutron-Flux Sensitive Devices; Metallic Uranium Fuel Elements of Improved Irradiation Stability.

Advanced Technology Laboratorines, American-Standard Corp. Variable Moderator Reactor Development Program; Development of Clad Ceramic Plate Fuel Elements by Spray-Coating Techniques (US-Euratom).

General Electric Co. Metal Water Reactions; Research and Development on Nuclear Fuel Assemblies for NS Savannah; Control Rod Materials Research and Development Program; Boiling Water Reactor System for a Large Tanker; Sodium Modular Reactor Study; UO_2 High Burn-Up Program; Development of a Fast Reactor using Plutonium Oxide-Uranium Oxide Fuel; Nuclear Superheat Research and Development Program; Investigation of Mass Transfer in Liquid Metal Systems at Moderately High Temperatures. Fuel Cycle Development Program for Boiling Water Reactors.

Gladding, McBean and Co. Develop Flat-Plate Ceramic Fuel Elements.

Stanford Research Institute. Fission Product Utilization; Study of Spontaneous Ignition of Metals.

Thompson Ramo Wooldridge Inc. Void Growth in Water-Cooled Reactors; Thermal Neutron Detection using Electromagnetic Waveguides.

University of California. Disposal of Radioactive Wastes into the Ground; Calculation of Heat Flux Liquids; High Speed Heat Flux Transient; Study of Behavior and Significance of Radioactive Substances Found in Hyperion Sewage Treatment Plant in Los Angeles, California.

Stanford Research Institute. Containment of Fragments from Runaway Reactors.

California Research Corp. Investigation of Irradiation Stability of Organic Fluids useful as Coolant Moderators for Nuclear Reactors; Investigation and Interpretation of Effects of Irradiation upon Gross Changes in Chemical and Physical Properties in various Organic Fluids.

APPENDIX 13

White House Statement on "A Proposed Federal Program in Support of High Energy Accelerator Physics"

1. High energy physics is one of the most active fields in contemporary science, and one which has attracted many of the best experimental and theoretical scientists throughout the world. In a sense, it is the most fundamental branch of physics, since its aim is to discover and investigate the elementary particles from which all matter is made. Many of these particles are now known, and the majority of them are unstable; in order to investigate their properties, the experimenter must have means for creating these unstable particles in the laboratory, which is done by converting the kinetic energy of accelerated protons or electrons into the equivalent mass of the new particles. Hence the need for high energy.

The exact energy needed depends on the particle to be produced, as well as the bombarding particle. The better-known class of pions and muons can be made at energies as low as 200 Mev (million electron volts), while the still very mysterious "strange particles" require energies starting at about 1 Bev (billion electron volts), for electron bombardment and about 2 Bev for proton bombardment. To produce some types of strange particles in pairs (in order to get the anti-particles, in analogy to the anti-protons) requires many Bev. The importance of this field in understanding the basic nature of matter and its behavior cannot be overestimated.

2. Experimentation in high energy physics requires expensive devices to accelerate particles to the desired energy, expensive instruments to measure and control particles traveling at speeds approaching the velocity of light and large numbers of scientific and technical personnel. Thus, not only the construction of these high energy physics accelerators, but also their utilization require the expenditure of large sums of money.

3. Immediately after the war, the Federal Government encouraged and supported the construction of high energy accelerators in several universities and national laboratories and, at the completion of these accelerators, funds were provided for the operation of these machines to perform the necessary and desirable experiments. In addition to providing important research results, these accelerators also have provided the training ground for the group of young scientists who are now carrying the responsibility for the future of this field and for many who have since made contributions in other fields.

4. Later requirements were recognized for more and more powerful, and thus more expensive, accelerators. The Federal Government supplied support for these new accelerators, some of which are now operating, others still under construction. Funds for the construction and operation of all new high energy accelerators initiated since 1953 have been provided by the Atomic Energy Commission. Other countries throughout the world—Western Europe and Russia—also have development programs for construction and utilization of particle accelerators for the study of high energy physics.

5. There is now need to review the high energy accelerator program and needs at the Presidential level. This stems from: (*a*) the extraordinarily high cost of the construction and utilization of high energy accelerators; (*b*) the fact that all

support in this scientific area comes from the Federal Government; (*c*) the interest of a number of Government agencies in the science and technology associated with both the construction and the experimental results; and (*d*) the desire to have an orderly national program taking full account of the activities abroad.

6. A number of groups within the Federal Government have studied this problem. The most detailed examinations have been made by the Advisory Panel on High Energy Accelerators of the National Science Foundation.[1] Other advisory groups which have also been concerned with this general area are the President's Science Advisory Committee, the General Advisory Committee to the Atomic Energy Commission, and the Defense Science Board of the Department of Defense. There is general agreement on the recommendations contained herein among the several groups listed above.

7. An adequate approach to high energy physics research requires well rounded coverage of the basic accelerator parameters—most importantly, the type of accelerated particle (protons and electrons), the energy, the intensity and the beam geometry. Progress in the field will require, in addition to full exploitation of existing accelerators, extensions of certain of these important parameters.

8. *Current Situation.*

The United States has 15 high energy accelerators in operation with energies above 200 Mev (Table I); four of these have energies in excess of 1 Bev and are capable of producing "strange" particles. The highest energy particles now available are 6.2 Bev protons and 1.2 Bev electrons. Four additional accelerators are under construction by the Atomic Energy Commission: a 6 Bev electron synchrotron at Cambridge, Mass. (Harvard-MIT); a 25-30 Bev proton synchrotron at the Brookhaven National Laboratory; a 12.5 Bev proton synchrotron at the Argonne National Laboratory; and a 3 Bev proton synchrotron at Princeton University that will greatly increase the intensity available at that energy. The Argonne and Brookhaven accelerators will be capable of producing all known types of particles.

9. *Needed Extensions of Parameters.*

The most urgent additional needs at present are to extend electron energies, to improve both electron and proton intensities at the higher energies and, where feasible, to improve the beam geometries.

(*a*) *Electrons.* The important electron experiments requiring extended parameters are (1) electron-nucleon scattering at higher energies and especially at better beam geometries than the Cambridge accelerator will provide; (2) electron-and photo-production of hyperon pairs. Fortunately, significant extensions of the energy with moderately high intensity and excellent beam geometry are feasible by the linear accelerator method.

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[1] The following National Science Foundation Panel reports have been issued:

Report of the NSF Advisory Panel on Ultra High Energy Nuclear Accelerators, MPE Study S–5, May 2, 1954.

Report of the Advisory Panel on High Energy Accelerators to the NSF, October 25, 1956.

Supplement to the Report of the Advisory Panel on High Energy Accelerators to the NSF, NSF–58–29, August 7–8, 1958.

(*b*) *Protons.* Although there appears to be no immediately compelling requirement for extending the proton energy parameter beyond the 25–30 Bev to be available at Brookhaven National Laboratory (and at CERN, the European Center in Geneva, Switzerland), there is an urgent need for higher proton intensities. Although accelerators now in operation produce strange particles in sufficient numbers to study their production processes, their intensity limitations make very slow and difficult—and in some cases impossible—adequate study of the interactions of these particles with other particles. These limitations will be only partly remedied by the accelerators under construction. Interaction studies are indispensible to a determination of the properties of these strange particles and hence to an understanding of their nature and of the role they play in the structure of matter. Hence there is a need for a multi-Bev proton accelerator of much higher intensity than any in the present programs, to produce adequate beams of strange particles, including anti-nucleons. Its energy should be at least 8 Bev.

10. In addition to the need for extending the ultimate energy and intensity limits, the problem of understanding in a quantitative way the detailed processes involved in high energy interactions requires multiple beams of different energies and intensities and floor space to accommodate a large variety of experimental setups. Although present accelerators are properly operated as national assets and are made available to any qualified scientist to the fullest extent practical, the capacities of these instruments are limited both for research and for training even though operated on an around-the-clock basis.

The disruption of the teaching and other academic activities of university scientists makes it difficult for them to conduct experimental research programs on remote accelerators. The need for additional research space, experimental beams and accelerators accessible to university scientists justifies the construction of additional regional or university accelerators, not necessarily of the most advanced design.

11. *Needs.*

The Committee has carefully reviewed the present high energy accelerator program (Table I) in the light of the above factors and finds that the future United States requirements fall into four major categories.

(*a*) *Presently operating accelerators.* It i snecessary to continue and to expand the support of presently operating accelerators to assure maximum exploitation. This requires continuous updating of facilities, expansion of research space, and the support of major efforts aimed at the augmentation of existing techniques for beam analysis, particle detection and data reduction and analysis.

(*b*) *Accelerators presently under construction.* It is necessary that the accelerators now under construction be finished without undue delay and that adequate funds be provided to equip and operate them. It is necessary to give particular attention to providing early support to plans for initial experimental facilities in order that these facilities be efficient, flexible, and available once an accelerator is operating.

It is clear that the Federal Government is committed to provide adequate support to those accelerators which are now in operation or under construction in order to fully exploit the capabilities of the instruments. Thus, regardless of decisions which may be made with respect to the construction of additional

accelerators, high energy accelerator physics can be expected to be costing the Government about $75 to $80 million annually by 1963. This figure must be considered as a base cost upon which any future forward steps must be built. The projected costs shown in Table II have been jointly developed by the Atomic Energy Commission, Department of Defense and National Science Foundation and reflect the present degree of diversity of support.

(*c*) *New construction.* There is a clear need for the construction and operation of additional accelerators both to increase the energy and intensity parameters and to increase the U.S. capacity for experimentation in this field.

(1) *Extension of energy, intensity, and geometry parameters.* There does not now appear to be a clear need for extension of the energy parameter for *protons* beyond the 30 Bev now in sight at the Brookhaven National Laboratory and CERN. (Paragraph 9(b).) As stated in Paragraph 9(a) there is an immediate need for a moderately high intensity *electron* accelerator in the energy region of 10–15 Bev. There is also a need for a high intensity *proton* accelerator at an energy of 8 Bev or above. Accelerators to meet these needs will cost approximately $15–$20 million each per year to build and operate. Thus, these two needs can be expected to increase the costs of high energy accelerator physics from $75–$80 million to about $120 million per year in the course of the next five years.

(2) *Increased United States capacity for experimentation.* As explained in Paragraph 10, the faculties and students of the nation's universities must have increased access to high energy accelerators. The additional accelerators need not necessarily be unique or extreme in their energy or intensity characteristics in order to fully justify their construction at a site where they may exploit the unique capabilities of a single university or group of institutions. It is our best judgment that by FY 1963 an additional $15 million per year will be required to meet these needs, thus raising the total cost of high energy accelerator physics to between $120 and $130 million per year by 1963.

(*d*) *New accelerator concepts.* Research and exploratory development of new accelerator concepts must be strongly supported without prejudice to a later determination of need for full-scale construction. In addition, in order to make optimum use of the accelerators, strong support will be required for advancing the techniques of particle detection, data reduction, and data anaylsis.

12. Policy Considerations and Conclusions.

(*a*) *Need for expanded support.* The basic importance of research in the field of high energy physics and its high cost, well beyond private resources, requires the Federal Government to continue to expand its support of this field consistent with valid scientific needs and the availability of qualified research personnel. Consequently, government planning must be based on the need for an increasing level of support from some $59 million in fiscal year 1959 to approximately $135 million in fiscal year 1963, in accordance with the needs outlined in Paragraph 11 (See fig. 1).

(*b*) *Effect on other areas of basic science.* Concern has been expressed that increased financial support for high energy physics may have an adverse effect on the support of other areas of science. In our judgment it should not.

It is not possible to assign relative priorities to various fields of basic science nor should they be placed in competition. Each science, at any given time, faces a set of critical problems that require solutions for continued growth. Sometimes these solutions can be acquired at little cost; sometimes large expenditures

of funds are needed. Hence, the cost may not reflect the relative value but rather the need.

Each area must be funded according to these needs. The peculiarly high cost of high energy accelerator physics is due to the size and complexity of the research tools required to attack the fundamental problems of the field. The tools required are proposed by active leaders in the field anxious to devote their talent and energy to developing those tools. Hence, in high energy physics the necessary combination of qualified people with sound ideas for meeting widely recognized scientific needs does exist and the field should be supported.

(*c*) *Priorities.* Within the field of high energy accelerator physics, first priority should be given to fullest utilization of existing accelerators including their modification and the continuing provision of new instrumentation. Next priority should be given to adequate facilities for effective use of the accelerators now under construction. Next in importance is the construction of new accelerators required for the exploration of new scientific phenomena beyond the capabilities of existing accelerators and the provision of university facilities.

(*d*) *Guidelines for implementing priorities.* The following guidelines should apply in order to assure that the needs outlined in Paragraph 11 are met:

(1) *New accelerator construction to extend energy and intensity parameters.* Construction should be recommended only when the accelerator is designed to meet a clear research need in physics and after the technical feasibility has been firmly established.

(2) *University Accelerators.* A university accelerator need not necessarily extend either the energy or the intensity parameter; the accelerator and associated laboratories should be within the administrative and technical capabilities of the university.

(3) *Regional Accelerators.* Regional accelerators need not necessarily extend either the energy or intensity parameters. The construction of conventional accelerators or accelerators of advanced design and established technical feasibility may be justifiable on the basis of an expressed regional need and a regional capability.

(*e*) *Diversity of support within the Executive Branch.* It is important that the Atomic Energy Commission, the National Science Foundation and the Department of Defense each support research in high energy physics because of their separate responsibilities for the support of basic research, because of the fundamental nature and significance of high energy physics and the corresponding need for each of these agencies to keep in direct and intimate contact with the scientists in this field and their research. Accordingly, the construction and operation of future high energy accelerators should not be considered the responsibility of any single Federal agency.

The Atomic Energy Commission, Department of Defense and National Science Foundation should each maintain strong interests and contacts in the field of high energy accelerator physics. This can be achieved only through direct financial responsibility and participation in the construction of high energy accelerators. The budgeting for the total cost of construction and operation of a particular accelerator should be the responsibility of a single Federal agency, as sole agent on behalf of all, supplemented by appropriate coordination with the other agencies active in this field.

These large particle accelerators constitute a national asset and should be made available to competent scientists elsewhere in this country and abroad to the fullest extent practicable. The support of any given accelerator project by a particular Federal agency should not be construed to prevent or limit the

financial support of outside groups using the accelerator by other agencies, public or private.

(*f*) *Coordination.* The parallel interest of several Federal agencies in the support of high energy physics and the impact of this support on national budget planning and programing require a coordinating mechanism to assure effective planning and review at the national level. An interdepartmental council on high energy accelerators should be established to assure coordination of budget and technical planning. The membership of the council should consist of policy level representatives from the Atomic Energy Commission, Department of Defense and National Science Foundation. Technical assistance to the council should be provided by the scientific staff of the three agencies (AEC, DOD and NSF) directly concerned with the administration of high energy physics research programs. The council should be responsible for continuing reformulation of national policies on high energy accelerator physics and the implementation of this policy. This should include the review and coordination of agency programs and plans in the field of high energy accelerator physics and the review of agency proposals for new accelerators.

(*g*) *Review of contracting practices and prefinancing.* There should be a review of contracting procedures by the Atomic Energy Commission, Department of Defense and National Science Foundation to assure that such procedures properly support scientific undertakings of this magnitude and character. Present procedures should be revised where necessary so that agencies can provide funds in the contract, for a period of 1 to 3 years in advance, for the support of research operations connected with high energy accelerators.

(*h*) *International collaboration.* The world-wide scientific significance of research in high energy physics, the extensive, high quality of scientific activity abroad in this field, and the limited number and costliness of high energy accelerators present a unique opportunity for a high degree of international collaboration and cooperation in the planning for and design of future accelerators and in the increased use of facilities. As a first step in the direction of international collaboration looking toward the development of new high energy accelerators, representative scientific groups from other countries, including the USSR, should be encouraged to meet with us in order to lay plans for cooperative research on new accelerator concepts. The National Academy of Sciences should be requested to advise on the best means for accomplishing this objective.

13. *Specific Proposals on Hand.*

Consistent with the needs and guidelines outlined in Paragraphs 11 and 12 (d) above, the following comments apply to the three major proposals before the Federal Government:

(*a*) *Stanford University.* The Stanford proposal for an electron linear accelerator adequately meets the requirement discussed above (Par. 12(d)(1)) of a research need for a new electron accelerator and its technical feasibility has been adequately demonstrated. It should be supported fully with the ultimate objective as described in the proposal and with an initial energy of at least 10 Bev. It is desirable that this accelerator project be initiated in fiscal year 1959 in order to avoid an undue delay in high energy research. Because of its dependence on advanced microwave technology, this proposal should be of particular relevance to the interests of the Department of Defense.

(*b*) *Midwestern Universities Research Association (MURA).* Although the technical feasibility and research utility of the specific accelerator recently proposed by MURA have not been established, many of the important new accelera-

tor concepts of recent years have come from the ideas and work of the MURA group. Continued progress in these developments is strongly dependent on the continuation and intensification of the MURA program. The group should be supported on a continuing basis with the funds and facilities necessary for its participating intensively in the development, construction and operation of high energy accelerators.

(*c*) *Oak Ridge National Laboratory.* The research need for a high energy accelerator at the Oak Ridge National Laboratory should be further explored with the Laboratory and the southern universities concerned. The Oak Ridge group should be supported in continuing design and development activities. The technical feasibility of the accelerator proposed by Oak Ridge has not been established.

RECOMMENDATIONS

14. It is recommended that the Federal Government:

(*a*) Expand its support of high energy accelerator physics in a manner consistent with valid scientific needs (Par. 11) and the availability of qualified research personnel;

(*b*) Plan for an increasing level of support for construction and operation of high energy accelerators to a level of approximately $135 million by fiscal year 1963 with the priorities and guidelines outlined in Paragraph 12 (*c*) and (*d*);

(*c*) Note that the increased funds for high energy accelerator physics should be provided without affecting the support of other areas of basic science;

(*d*) Note that specific needs exist for an electron linear accelerator of at least 10 Bev and a high intensity proton accelerator of at least 8 Bev;

(*e*) Approve the initiation in fiscal year 1959 of the proposed accelerator project at Stanford University as modified in Paragraph 13(a);

(*f*) Note that construction of the Stanford accelerator can be expected to cost approximately $100 million;

(*g*) Note that initial operating costs of the Stanford accelerator will be approximately $15 million per year once the accelerator comes into operation and that instrumentation and initial experimentation should be undertaken several years in advance of the completion of the accelerator;

(*h*) Continue to provide adequate support and encouragement to the development group of the Midwestern Universities Research Association;

(*i*) Encourage the further exploration of the research needs of the Oak Ridge region and the design of accelerators capable of meeting those needs;

(*j*) Note that the interests of the Federal Government and the scientific community are best served by the direct financing of the projects in this field by the Atomic Energy Commission, Department of Defense and National Science Foundation with the contract authority and budget responsibility for a given project being vested in a single agency;

(*k*) Approve the establishment of an interagency council at the policy level to assure coordination of budget and technical planning, this council to be assisted by the scientific staff of the agencies concerned;

(*l*) Approve the provision of contract funds for periods between one and three years for the support of research operations connected with high energy accelerators;

(*m*) Encourage international collaboration and cooperation in the planning for and design of future machines and the increased use of facilities; and

(*n*) Request the National Academy of Science to study and advise the Government on the best method for proceeding with international cooperative

research on new accelerator concepts, such cooperative activity including the Soviet Union.

TABLE I

U.S. HIGH ENERGY ACCELERATORS PRESENTLY IN OPERATION

Machine	Particle	Energy	Location
		Bev	
Synchrocyclotron	Proton	0.240	Univ. of Rochester.
Synchrotron	Electron	.300	Univ. of California.
Synchrotron	Electron	.300	General Electric Co.
Synchrotron	Electron	.300	Mass. Institute of Tech.
Synchrotron	Electron	.300	Purdue University.
Betatron	Electron	.300	Univ. of Illinois.
Synchrocyclotron	Proton	.400	Columbia University.
Synchrocyclotron	Proton	.440	Carnegie Inst. of Tech.
Synchrocyclotron	Proton	.450	Univ. of Chicago.
Synchrocyclotron	Proton	.740	Univ. of California.
Linear Accelerator	Electron	.7	Stanford University.
Synchrotron	Electron	1.2	Cornell University.
Synchrotron	Electron	1.2	Calif. Inst. of Tech.
Synchrotron	Proton	3.2	Brookhaven Natl. Lab.
Synchrotron	Proton	6.2	Univ. of California.

U.S. HIGH ENERGY ACCELERATORS PRESENTLY UNDER CONSTRUCTION

Machine	Particle	Energy	Location	Completion expected
		Bev		
Synchrotron	Proton	3	Princeton-Penn (N.J.)	1960
Synchrotron	Proton	12.5	Argonne Natl. Lab	1962
Alternating-gradient synchrotron.	Proton	25–30	Brookhaven Natl. Lab	1960
Synchrotron	Electron	6	Harvard-MIT, Camb	1960

TABLE II

ANNNUAL HIGH ENERGY PHYSICS SUPPORT BY VARIOUS GOVERNMENT AGENCIES BASED ON EXISTING OR AUTHORIZED ACCELERATORS

(In thousands)

Fiscal year	AEC		ONR	OSR	NSF	Total
	Operating	Construction				
1946			3,900			3,900
1947		500	4,000			4,500
1948	3,400	600	2,400			6,400
1949	4,800	1,600	2,200			8,600
1950	3,400	7,500	1,600			12,500
1951	5,900	4,100	3,300			13,300
1952	6,300	1,700	1,600			9,600
1953	7,600	2,300	2,400			12,300
1954	7,400	1,900	1,800	270	80	11,400
1955	8,300	1,600	1,500	320	280	12,000
1956	10,200	3,200	1,600	610	220	15,800
1957	16,000	7,000	2,000	930	180	26,100
1958	19,100	12,900	3,300	1,000	210	36,500
1959*	27,700	26,300	3,300	865	400	58,600
1960*	36,600	20,500	3,600	950	700	62,400
1961*	45,900	19,000	4,000	1,150	1,000	71,100
1962*	53,700	18,800	4,400	1,250	1,500	79,700
1963*	60,500	9,000	4,800	1,550	2,000	77,900

* Estimated.

APPENDIX 14

Nuclear Reactors Built, Building or Planned in the United States, as of December 31, 1959

The following tabulation is a compilation of facilities built, building or planned in the United States as of December 31, which are capable of sustaining a nuclear chain reaction. Certain experiments relating to military systems are included but are not listed in detail because of their classified nature.

This issue of the table is presented in the following sequence:

A. CIVILIAN POWER AND PROPULSION REACTORS
  - A.1. Stationary power, U.S. locations
  - A.2. Propulsion (Maritime)

B. OTHER CIVILIAN REACTORS
  - B.1. Reactor experiments
  - B.2. General test
  - B.3. Research and training
  - B.4. Specialized test

C. MILITARY PROPULSION, POWER AND TEST REACTORS
  - C.1. Naval propulsion
  - C.2. Prototypes, experiments and field plants
  - C.3. Research and test

D. PRODUCTION REACTORS
  - D.1. Materials production
  - D.2. Test

E. REACTORS FOR EXPORT
  - E.1. Stationary power
  - E.2. Test
  - E.3. Critical experiment facilities

F. CRITICAL ASSEMBLY FACILITY ABBREVIATIONS
  - F.1. Critical assembly facilities

Reactors are tabulated in categories according to definitions based primarily on the function or purpose of the reactor. Distinctions among the major categories of the tabulation—civilian, military, production, export, power and propulsion—are self explanatory. Distinctions among other principal categories are presented in the following tentative definitions.

Reactor experiment. A reactor in the research and development program, usually producing less than 10 Mwt, designed for the limited purpose of testing the technical feasibility of a reactor concept or some unique reactor feature or piece of equipment. (Section B.1.)

Experimental reactor. A relatively complete reactor plant designed engineered, constructed and operated to provide the technical basis for the design of a large-scale nuclear power plant. Design flexibility permits changes to prove-out different aspects of reactor technology. Electrical or power generation may or may not be included as part of the plant. (Section B.1.)

Prototype reactor plant. A nuclear power plant of any size designed, constructed and operated principally for the purpose of proving-out economical and technical aspects of a future commercial nuclear power plant of the same

type. The generation of significant quantities of electricity, mechanical power or process heat is usually a function of such a plant. (Section A.1 and A.2.)

Commercial reactor plant. A nuclear facility constructed and operated under a license issued under Section 103 of the Atomic Energy Act of 1954 and capable of producing steam for the generation of electricity, propulsion and space or process heat applications at costs as low as a non-nuclear plant built at the same site. (No reactors presently in the category.)

General test reactor. The general test reactor category includes only those reactors having (1) a thermal output of 10,000 kilowatts or more, (2) test loops or experimental facilities within or in close proximity to the core and (3) the use of nuclear radiation for testing the life or performance of reactor components as its major function. (Section B.2.)

Special test reactors. A reactor which is in general an integral part of a test performance which has kinetic or short duration high power excursion or which is designed for special testing purposes. (Section B.4.)

Research reactor. Any reactor whose nuclear radiations are used primarily as a research tool for basic or applied research regardless of operating power level. May include facilities for testing reactor materials. (Section B.3.)

Training reactor. Any reactor operated for the primary purpose of training in the operation and utilization of reactors and for instruction in reactor theory and performance. Thermal power level is arbitrarily limited to 10 kw. (Section B.3.)

Critical facility. A reactor capable of sustaining a nuclear chain reaction and designed to test at extremely low power (a few watts) a critical mass, neutron flux distribution and other characteristics of flexible arrangement of nuclear fuel, materials of construction, coolant and other reactor components. Fluid critical facilities are used to explore the critical masses of various concentrations of solutions in differing geometries. Metal critical assemblies are used to investigate the variation in heterogeneous cores. (Section F.)

Listings in the "principal contractor" column refer to the nuclear industry technical organization assigned primary responsibility for design and/or fabrication of the reactor system. Contractors' names, abbreviated in the column listing, are given in full in the listing on pages 539 and 540. Also listed are the names of designers, shipbuilders, and facility operators; these are abbreviated in the column listings.

Startup dates refer to the year of first criticality. Startup dates shown for projects not yet in service are estimates based on the best available information. The dates for non-Commission projects are estimates announced by the sponsoring organizations.

Reactors are listed as being "operable" under the following circumstances:

(*a*) Federal Government reactors—when criticality is achieved.

(*b*) Non-Federal Government reactors in the United States—when an operating license is issued by the Commission.

(*c*) Reactors for foreign locations—when criticality is achieved.

Reactors are listed as "being built" under the following circumstances:

(*a*) Federal Government reactors—when ground is broken, components ordered, or contract awarded, whichever is first.

(*b*) Non-Federal Government reactors in the United States—when construction permit is issued by the Commission.

(*c*) Reactors for foreign locations—when an application for an export license is received by the Commission or when reliable information is received relating to the fabrication of reactor components.

Reactors are listed in the "planned" category under the following circumstances:

(*a*) Federal Government reactors—when publicly announced or when development work is started.

(*b*) Non-Federal Government reactors in the United States—when license application is received by the Commission, or a public announcement which includes principal contractor and reactor type is made, whichever is first.

(*c*) Reactors for foreign locations—when public announcement which includes principal contractor and reactor type is made or when the Commission receives information that a U.S. reactor manufacturer is proceeding with pre-construction design and development on the basis of a "letter of intent."

LIST OF CONTRACTORS, DESIGNERS, SHIPBUILDERS, AND FACILITY OPERATORS FOR WHICH ABBREVIATIONS APPEAR IN TABLES

Abbreviation	*Name of Organization*
AC	Allis-Chalmers Manufacturing Co.
ACF	ACF Industries, Inc. (Absorbed by AC).
AG	Aerojet-General Corp.
AGN	Aerojet-General Nucleonics, Subsidiary of Aerojet-General Corp.
Alco	Alco Products, Inc.
AMF	AMF Atomics, a Division of American Machine & Foundry Co.
ANL	Argonne National Laboratory, operated by the University of Chicago.
ARSS	American Radiator and Standard Sanitary Corp.
B&W	Babcock & Wilcox Co., The.
BAC	Bendix Aviation Corp.
Bethlehem	Bethlehem Shipbuilding Corp., Quincy, Mass.
BNL	Brookhaven National Laboratory, operated by Associated Universities, Inc.
CE	Combustion Engineering, Inc.
CW	Curtiss-Wright Corp.
CL	Clinton Laboratory of Manhattan Engineering District.
Cook	Nucledyne Corp. of Chicago, Div. of Cook Electric Co.
Convair	Convair Division of General Dynamics Corp.
Daystrom	Daystrom, Inc.
duPont	E. I. duPont de Nemours & Co.
FW	Foster Wheeler Corp.
Fluor	Fluor Corp., Limited.
GDC	General Atomic Division of General Dynamics Corp.
GE	General Electric Co.
GNE	General Nuclear Engineering Co., a subsidiary of Combustion.
Elec. Boat	Electric Boat Division of General Dynamics Corp. Eng., Inc.
HKF	H. K. Ferguson Co., The.
Ingalls	Ingalls Shipbuilding Corp.
KE	Kaiser Engineers, Division of Henry J. Kaiser Co.
LASL	Los Alamos Scientific Laboratory, operated by University of California.
Lockheed	Lockheed Aircraft Corp.
MA	Maritime Administration, Department of Commerce.
Mare Island	Mare Island Naval Shipyard.

Abbreviation	*Name of Organization*
Martin	Martin Co., The.
Maxon	Maxon Construction Co., Inc.
Met. Lab	Metallurgical Laboratory of Manhattan Engineering District.
NAA	Atomics International, a Division of North American Aviation, Inc.
NASA	National Aeronautics and Space Administration.
Newport News	Newport News Shipbuilding and Dry Dock Co.
NRL	Naval Research Laboratory.
NDA	Nuclear Development Corp. of America.
NYSBC	New York Shipbuilding Corp.
ORNL	Oak Ridge National Laboratory, operated by Union Carbide Nuclear Co., a Division of Union Carbide Corp.
Portsmouth	Portsmouth Naval Shipyard.
PPC	Phillips Petroleum Co.
P&W	Pratt and Whitney Aircraft Division, United Aircraft Corp.
Sandia	Sandia Laboratory, operated by Sandia Corporation, a subsidiary of Western Electric, Inc.
SL	Sargent and Lundy.
West	Westinghouse Electric Corp.
Vitro	Vitro Engineering Co., a Division of Vitro Corp. of America.

NUCLEAR REACTORS BUILT, BUILDING OR PLANNED IN THE UNITED STATES AS OF DECEMBER 31, 1959

A. Civilian Power and Propulsion Reactors

A.1. Stationary power, U.S. locations

Name and/or owner	Location	Principal nuclear contractor	Type	Power (kilowatts)[1]		Startup
				Electrical Net	Thermal	
Operable:						
Shippingport Atomic Power Station (AEC & Duquesne Light Co.).[2]	Shippingport, Pa.	West	Pressurized water	60,000	231,000	1957
Dresden Nuclear Power Station (Commonwealth Edison Co.).	Morris, Ill.	GE	Boiling water	180,000	626,000	1959
Being Built:						
Consolidated Edison Thorium Reactor.[3]	Indian Point, N.Y.	B&W	Pressurized water	255,000	795,000	1961
Enrico Fermi Atomic Power Plant (Power Reactor Development Co.).[4]	Lagoona Beach, Mich.	Owner	Fast breeder	94,000	304,000	1960
Yankee Atomic Electric Co.[5 6]	Rowe, Mass.	West	Pressurized water	110,000	392,000	1960
AEC & Rural Cooperative Power Association.[5 7]	Elk River, Minn.	AC	Boiling water	22,000	73,000	1961
Hallam Nuclear Power Facility, Sheldon Station (AEC and Consumers Public Power District).[5]	Hallam, Nebr.	AI	Sodium graphite	75,000	254,000	1962
AEC and City of Piqua, Ohio [5]	Piqua, Ohio	AI	Organic moderated	11,400	45,500	1961
Planned:						
Northern States Power Co. Pathfinder Plant [5 8]	Sioux Falls, S. Dak.	AC	Boiling water	62,000	203,000	1962
Carolinas-Virginia Nuclear Power Associates, Inc.[5]	Parr, S.C.	West	Pressure tube heavy water	17,000	60,500	1962
Humboldt Bay Powerplant, Unit No. 3 (Pacific Gas and Electric Co.).	Humboldt Bay, Calif.	GE	Boiling water	47,500	163,000	1962
Consumers Power Co.[9]	Big Rock Point, Mich.	GE	Boiling water	50,000		1962
Small Size Nuclear Powerplant (AEC and undetermined utility organization).			Pressurized water	22,000	63,000	1962
East Central and Florida West Coast Nuclear Groups.[5]	Florida	GNE	Gas cooled, heavy water moderated.	50,000	153,000	1963
Philadelphia Electric Co.[5 10]	Peach Bottom, Pa.	GDC	Gas cooled, graphite moderated.	28,500	92,000	1963
Improved Cycle Prototype Boiling Water Reactor (AEC and undetermined utility organization).			Boiling water	50,000		
Boiling Reactor Nuclear Superheat Project (AEC and PRWBA).				16,300		
Organic Cooled Reactor Prototype (AEC and undetermined utility).			Organic cooled	50,000		

See footnotes at end of table.

A.2. Propulsion (Maritime)

Name and/or owner	Nuclear designer	Shipbuilder	Type	Shaft horsepower max.[1]	Thermal power (kilowatts)	Startup
Being built:						
NS *Savannah* (AEC and Maritime Administration)	B&W	New York Shipbuilding Corp.	Pressurized water	22,000	69,000	1960
Planned:						
Tanker (AEC and Maritime Administration)			Light water	30,000	89,000	1964
Maritime Gas Cooled Reactor (AEC and Maritime Administration).	GDC		Gas cooled	22,000	54,000	1964

B. Other Civilian Reactors

B.1. Reactor experiments, U.S. locations

Name (all owned by AEC except as noted)	Designation	Location	Principal nuclear contractor	Type	Power (kilowatts)[1]		Start-up	Dismantled
					Electrical (net)	Thermal		
Operated, later dismantled:								
Boiling Reactor Experiment No. 1.	BORAX-1	NRTS, Idaho	ANL	Boiling water	No electricity	1,400	1953	1954
Homogeneous Reactor Experiment No. 1.	HRE-1	Oak Ridge, Tenn.	ORNL	Aqueous homogeneous solution (UO_2SO_4).	140	1,000	1952	1954
Los Alamos Power Reactor Experiment No. 1.[11]	LAPRE-1	Los Alamos, N. Mex.	LASL	Aqueous homogeneous (Phosphoric acid).	No electricity	2,000	1956	1957
Boiling Reactor Experiments [12]	BORAX-2, 3, 4.	NRTS, Idaho	ANL	Boiling water	2,000	15,500	1954	1958
Los Alamos Power Reactor Experiment No. 2.	LAPRE-2	Los Alamos, N. Mex.	LASL	Aqueous homogeneous (Phosphoric acid).	No electricity	1,000	1959	
Operable:								
Experimental Breeder Reactor No. 1 [13]	EBR-1	NRTS, Idaho	ANL	Fast Breeder	150	1,400	1951	
Experimental Boiling Water Reactor [14]	EBWR	Lemont, Ill.	ANL	Boiling water	4,500	100,000	1956	
Vallecitos Boiling Water Reactor (General Elec. Co.* and Pacific Gas and Elec. Co.)[15]	VBWR	Pleasanton, Calif.	GE	Boiling water	5,000	30,000	1957	

Sodium Reactor Experiment (AEC and Southern Calif. Edison Co.).	SRE	Santa Susana, Calif.	AI	Sodium graphite	6,000	20,000	1957	
Organic Moderated Reactor Experiment.	OMRE	NRTS, Idaho	AI	Organic moderated	No electricity.	5,000–15,000	1957	
Homogeneous Reactor Experiment No. 2.	HRE-2	Oak Ridge, Tenn	ORNL	Aqueous homogeneous solution (UO_2SO_4).	Negligible	5,220	1957	
Being Built:								
Experimental Breeder Reactor No. 2	EBR-2	NRTS, Idaho	ANL	Fast breeder	16,500	62,500	1961	
Los Alamos Molten Plutonium Reactor Experiment.	LAMPRE	Los Alamos, N. Mex.	LASL	Fast molten plutonium fueled, sodium cooled.	No electricity.	1,000	1959	
Boiling Reactor Experiment No. 5	BORAX-5	NRTS. Idaho	ANL	Light water	2,000	20,000	1961	
Planned:								
Saxton Nuclear Experimental Reactor Project.*		Saxton, Pa	West	Pressurized water	5,000		1961	
High Temperature Gas Cooled Reactor Experiment.[16]	TURRET	Los Alamos, N. Mex.	LASL	Gas cooled	No electricity.	3,000	1962	
Experimental Prototype Gas Cooled Reactor (AEC and TVA)[17].	EGCR	Oak Ridge, Tenn	KE-ACF	Gas cooled graphite moderated.	22,300	84,300	1962	
Experimental Organic Cooled Reactor	EOCR	NRTS. Idaho		Organic	No electricity.	40,000		
Experimental Low Temperature Process Heat.	ELPHR	Point Loma, San Diego, Calif.		Pressurized water	SL	40,000	1962	

*Privately owned.

B.2. General Test

Name and/or owner	Designation	Location	Principal nuclear contractor	Type	Thermal power (kilowatts)	Startup
Operable:						
Materials Testing Reactor (AEC)	MTR	NRTS. Idaho	Fluor	Tank	40,000	1952
Engineering Test Reactor (AEC)	ETR	NRTS, Idaho	KE	Tank	175,000	1957
General Electric Co. Materials Testing Reactor	GETR	Pleasanton, Calif.	Owner	Tank	20,000	1958
Westinghouse Testing Reactor	WTR	Waltz Mill, Pa	Owner	Tank	60,000	1959
Being built:						
National Aeronautics and Space Agency	NASA-TR	Sandusky, Ohio	NASA	Tank	60,000	1959
Planned:						
Babcock & Wilcox Test Reactor		Lynchburg, Va	B&W	Tank		

See footnotes at end of table.

B.3. Research and training

Name and/or owner	Designation	Location	Princ. nuclear contractor	Type	Thermal power (kilowatts)	Start-up	Dismantled
Operated, later dismantled:							
Los Alamos Water Boiler	HYPO	Los Alamos, N. Mex.	LASL	Homogeneous	5.5	1944	1950
Chicago Pile 1, rebuilt as CP-2 (MED-AEC)[19]	CP-1	Chicago, Ill.	Met. Lab.	Graphite	.2	1942	1954
Argonne CP-3, rebuilt as CP-3' (MED-AEC)	CP-3'	Palos Park, Ill.	Met. Lab.	Heavy water	300	1944	1955
Los Alamos Fast Reactor (AEC)	Clementine	Los Alamos, N. Mex.	LASL	Fast, plutonium fuel, mercury cooled.	25	1946	1953
Atomics International [18]	L-47	Canoga Park, Calif.	AI	Homogeneous	Negligible	1957	1958
Operable:							
Oak Ridge Graphite Reactor (AEC)	X-10	Oak Ridge, Tenn.	CL	Graphite	3,800	1943	
Los Alamos Water Boiler (AEC)	SUPO	Los Alamos, N. Mex.	LASL	Homogeneous	25	1950	
Brookhaven Research Reactor (AEC)	BGRR	Upton, N.Y.	HKF	Graphite	20,000	1950	
Low Intensity Test Reactor (AEC)[20]	LITR	Oak Ridge, Tenn.	ORNL	Tank	3,000	1950	
North American Aviation Water Boiler Neutron Source (AEC)[21].	AE-6	Santa Susana, Calif.	AI	Homogeneous	2	1952	
Livermore Water Boiler (AEC)	LIWB (WBNS)	Livermore, Calif.	AI	Homogeneous	.5	1953	
Livermore Reactor (AEC)		Livermore, Calif.	AI	Solution	.5	1953	
North Carolina State College (Raleigh Research Reactor).[22]	RRR	Raleigh, N.C.	Owner	Homogeneous	.5	1957	
Argonne Research Reactor (AEC) [23]	CP-5	Lemont, Ill.	ANL	Heavy water	2,000	1954	
Pennsylvania State University		Univ. Park, Pa.	Owner	Pool	100	1955	
Armour Research Foundation	ARR	Chicago, Ill.	AI	Homogeneous	100	1956	
Battelle Memorial Institute	BRR	West Jeff., Ohio	AMF	Pool	2,000	1956	
Omega West Reactor (AEC)	OWR	Los Alamos, N. Mex.	LASL	Tank	5,000	1956	
Argonne Naught Power Reactor (AEC)	Argonaut (CP-11)	Lemont, Ill.	ANL	Graphite/water	10	1957	
University of Michigan (Ford Nuclear Reactor)		Ann Arbor, Mich.	B&W	Pool	1,000	1957	
Livermore Pool Type Reactor (AEC)	LPTR	Livermore, Calif.	FW	Tank	1,000	1957	
U.S. Naval Post Graduate Sch.[18]	AGN-201-100	Monterey, Calif.	AGN	Homogeneous solid	Negligible	1956	
Catholic Univ. of America[18]	AGN-201-101	Wash., D.C.	AGN	Homogeneous solid	Negligible	1957	
Oklahoma State University of Agri. & Appl. Science.[18]	AGN-201-102	Stillwater, Okla.	AGN	Homogeneous solid	Negligible	1957	
Aerojet-General Nucleonics [18]	AGN-201P-103	San Ramon, Calif.	AGN	Homogeneous solid	Negligible	1957	
University of Akron [18]	AGN-201-104	Akron, Ohio	AGN	Homogeneous solid	Negligible	1957	
National Naval Medical Center USN [18]	AGN-201M-105	Bethesda, Md.	AGN	Homogeneous solid	Negligible	1957	
Texas A&M College [18]	AGN-201-106	College Station, Tex.	AGN	Homogeneous solid	Negligible	1957	
University of Utah [18]	AGN-201-107	Salt Lake City, Utah.	AGN	Homogeneous solid	Negligible	1957	
Aerojet-General Nucleonics [18]	AGN-201-108	Lemont, Ill.	AGN	Homogeneous solid	Negligible	1957	
Colorado State University [18]	AGN-201-109	Ft. Collins, Colo.	AGN	Homogeneous solid	Negligible	1957	
University of California [18]	AGN-201-112	Berkeley, Calif.	AGN	Homogeneous solid	Negligible	1957	
University of Delaware [18]	AGN-201-113	Newark, Del.	AGN	Homogeneous solid	Negligible	1958	
Oregon State College [18]	AGN-201-114	Corvallis, Oreg.	AGN	Homogeneous solid	Negligible	1958	
Curtiss-Wright Corp.		Quehanna, Pa.	Owner	Pool	4,000	1958	

General Dynamics Corp.	TRIGA	La Jolla, Calif.	GDC	Homogeneous solid	30	1958	
Neutron Source Reactor (AEC)		Upton, N.Y.	BNL	Tank	1,000	1958	
Atomics International [18]	L–77	Canoga Park, Calif.	AI	Homogeneous	Negligible	1958	
American Radiator and Stand. Sanitary Corp. [18]	UTR–1	Mountain View, Calif.	Owner	Graphite/water	Negligible	1958	
Pawling Research Reactor [18]	PRR	Pawling, N.Y.	NDA	Heavy water	Negligible	1958	
Massachusetts Institute of Technology	MITR	Cambridge, Mass.	ACF	Heavy water	1,000	1958	
Industrial Reactor Labs., Inc.		Plainsboro, N.J.	AMF	Pool	5,000	1958	
Babcock & Wilcox Lynchburg Pool Reactor		Lynchburg, Va.	Owner	Pool	10	1958	
Rice Institute [18]	AGN–211–101	Houston, Tex.	AGN	Homogeneous solid pool.	Negligible	1959	
University of Oklahoma [18]	AGN–211–102	Norman, Okla.	AGN	Homogeneous solid pool.	Negligible	1958	
West Virginia University College of Engineering [18]	AGN–211–103	Morgantown, W. Va.	AGN	Homogeneous solid pool.	Negligible	1959	
University of Arizona	TRIGA	Tucson, Ariz.	GDC	Heterogeneous tank	10	1958	
Oak Ridge Research Reactor (AEC)	ORR	Oak Ridge, Tenn.	ORNL	Tank	30,000	1958	
Brookhaven Medical Research Reactor	MRR	Upton, N.Y.	Daystrom	Tank	3,000	1959	
University of Wyoming [18]	L–77	Laramie, Wyo.	AI	Homogeneous	Negligible	1959	
University of Florida		Gainesville, Fla.	GNE	Graphite/water	10	1959	
Omaha Veterans Administration Hospital	TRIGA	Omaha, Nebr.	GDC	Heterogeneous solid tank.	10	1959	
Puerto Rico Nuclear Center (AEC) [18]	L–77	Mayaguez, West, P.R.	AI	Homogeneous	Negligible	1959	
Iowa State University	UTR–10	Ames, Iowa	ARSS	Graphite/water	10	1959	
Stanford University		Palo Alto, Calif.	GE	Pool	10	1959	
State College of Washington		Pullman, Wash.	GE	Pool	100	1960	
Worcester Polytechnical Institute		Worcester, Mass.	GE	Pool	1	1959	
Virginia Polytechnic Institute	UTR–10	Blacksburg, Va.	ARSS	Graphite/water	10	1959	
Being Built:							
University of Virginia		Charlottesville, Va.	Owner	Pool	1,000	1960	
Union Carbide Nuclear Co.		Sterling Forest, N.Y.	AMF	Pool	5,000	1961	
Aerojet-General Nucleonics (25 reactors) [18]	AGN–201–(111, 115–117–120, 126–131, 133–140) AGN–201P–(122–125).	San Ramon, Calif.	AGN	Homogeneous solid	Negligible	1960–62	
Aerojet-General Nucleonics (7 reactors) [18]	AGN–211–104–110	San Ramon, Calif.	AGN	Homogeneous solid pool.	Negligible	1960	
Cornell University Dual Core Reactor		Ithaca, N.Y.	Vitro	Pool	10	1960	
North Carolina State College		Raleigh, N.C.	Cook	Pool	10	1960	
Puerto Rico Nuclear (AEC)		Mayaguez, West, P.R.	AMF	Pool	1,000	1960	
University of Washington	Educator	Seattle, Wash.	AMF	Graphite/water	10	1960	
University of Buffalo		Buffalo, N.Y.	AMF	Pool	1,000	1960	
Walter Reed Army Institute of Research	L–54	Washington, D.C.	AI	Homogeneous	50	1960	
Nuclear Science Center Reactor, Texas A & M College System.	NSCR	College Station, Tex.	Convair	Pool	100	1961	
Brookhaven High Flux Beam Research Reactor		Upton, N.Y.	BNL	Heavy water	20,000	1962	
University of Missouri, School of Mines and Metallurgy.		Rolla, Mo.	CW	Pool	10	1960	
Argonne Nat'l. Lab. (AEC) [24]	Juggernaut	Lemont, Ill.	ANL	Graphite/water	100	1960	
University of California at Los Angeles, College of Engineering.	Educator	Los Angeles, Calif.	AMF	Graphite/water	10	1959	

See footnotes at end of table.

B.3. Research and Training—Continued

Name and/or owner	Designation	Location	Princ. nuclear contractor	Type	Thermal power (kilowatts)	Start-up	Dis-mantled
Planned:							
University of Tennessee		Knoxville, Tenn	NDA	Heavy water	10	1960	
University of Maine	AGN-201-132	Orne, Maine	AGN	Homogeneous solid	Negligible	1960	
University of Kansas	Model 4180	Lawrence, Kans	BAC	Tank	10	1960	
Ohio State University		Columbus, Ohio	Lockheed	Pool	10	1960	
Georgia Institute of Technology		Atlanta, Ga	GNE	Heavy water	5,000	1961	
University of Illinois	TRIGA-Mk2	Urbana-Champaign, Ill.	GDC	Homogeneous solid tank.	100	1960	
High Flux Isotope Reactor	HFIR	Oak Ridge, Tenn	ORNL	Pool	100,000		
Argonne High Flux Reactor	AHFR	Lemont, Ill		Flux trap	100,000		
University of Maryland		College Park, Md	AC	Pool	10	1961	
Bethesda Medical Reactor		Bethesda, Md				1961	

B.4. Specialized test

Name (all owned by AEC)	Designation	Location	Principal nuclear contractor	Type	Thermal power (kilowatts)	Startup	Dis-mantled
Operable:							
Bulk Shielding Reactor No. 1 [25]	BSR-1	Oak Ridge, Tenn	ORNL	Pool	1,000	1950	
Process Development Pile	PDP	Savannah River, S.C.	duPont	Heavy water	1	1953	
Thermal Test Reactor	SP	Savannah River, S.C.	duPont	Graphite	1 to 10	1953	
Special Power Excursion Reactor Test No. 1 [26]	SPERT-1	NRTS, Idaho	PPC	Open tank		1955	
Kinetic Experiment on Water Boilers	KEWB	Santa Susana, Calif	AI	Homogeneous	50	1956	
General Electric Nuclear Test Reactor	NTR	Pleasanton, Calif	GE	Light water	30	1957	
Special Power Excursion Reactor Test No. 3 [76]	SPERT-3	NRTS, Idaho	PPC	Pressurized water	60,000	1958	
Special Power Excursion Reactor Test No. 2 [26]	SPERT-2	NRTS, Idaho	PPC	Pressurized heavy water.		1959	
Transient Test Reactor Facility	TREAT	NRTS, Idaho	ANL	Graphite	100	1959	
Fast Source Reactor	FSR	NRTS, Idaho	ANL	Fast	1	1959	
Being Built:							
Plutonium Recycle Test Reactor	PRTR	Hanford, Wash	GE	Heavy water moderated and cooled pressure tube.	70,000	1960	
Heavy Water Components Test Reactor	HWCTR	Savannah River, S.C. (TC-1 Area).	duPont	Pressurized heavy water.	60,000	1961	
Planned:							
Biological Research Reactor	JANUS	Lemont, Ill	ANL	Tank	200	1961	
Special Power Excursion Reactor Test No. 4	SPERT-4	NRTS, Idaho	PPC	Tank			

C. Military Propulsion, Power and Test Reactors

C.1. Naval Propulsion

Name (all owned by U.S. Navy)	Designation	Nuclear designer	Shipbuilder	Type [27]	Startup	Dismantled
Operated, later dismantled:						
Seawolf S2G Sodium Reactor		GE		Sodium	1956	1959
Operable:						
USS Nautilus	SSN571	West	Electric Boat	S2W	1955	
USS Skate	SSN578	West	Electric Boat	S3W	1957	
USS Swordfish	SSN579	West	*Portsmouth*	S4W	1958	
USS Sargo	SSN583	West	Mare Island	S3W	1958	
USS Skipjack	SSN585	West	Electric Boat	S5W	1958	
USS Seadragon	SSN584	West	Portsmouth	S4W	1959	
USS Triton (2 reactors)	SS(R)N586	GE	Electric Boat	S4G	1959	
USS Halibut	SS(G)N587	West	Mare Island	S3W	1959	
USS George Washington	SSB(N)598	West	Electric Boat	S5W		
Being built:						
USS Seawolf	SSN575	West	Electric Boat	S2Wa		
Submarine Scamp	SSN588	West	Mare Island	S5W		
Submarine Scorpion	SSN589	West	Electric Boat	S5W		
Submarine Sculpin	SSN590	West	Ingalls	S5W		
Submarine Shark	SSN591	West	Newport News	S5W		
Submarine Snook	SSN592	West	Ingalls	S5W		
Submarine Thresher	SSN593	West	Portsmouth	S5W		
Submarine Permit	SSN594	West	Mare Island	S5W		
Submarine Plunger	SSN595	West	Mare Island	S5W		
Submarine Pollack	SSN596	West	Ingalls	S5W		
Submarine Tullibee	SSN597	CE	Electric Boat	S2C		
Submarine Patrick Henry	SSB(N)599	West	Electric Boat	S5W		
Submarine Theodore Roosevelt	SSB(N)600	West	Mare Island	S5W		
Submarine Robert E. Lee	SSB(N)601	West	Newport News	S5W		
Submarine Abraham Lincoln	SSB(N)602	West	Portsmouth	S5W		
Submarine Barb	SSN603	West	NYSHBC	S5W		
Submarine Haddo	SSN604	West	NYSHBC	S5W		
Submarine Jack	SSN605	West	Portsmouth	S5W		
Submarine Tinosa	SSN606	West	Portsmouth	S5W		
Submarine Dace	SSN607	West	Ingalls	S5W		
Submarine Ethan Allen	SSB(N)608	West	Electric Boat	S5W		
Submarine Sam Houston	SSB(N)609	West	Newport News	S5W		
Submarine Thomas A. Edison	SSB(N)610	West	Electric Boat	S5W		
Submarine John Marshall	SSB(N)611	West	Newport News	S5W		
Guided Missile Cruiser Long Beach (2 reactors)	CG(N)9	West	Bethlehem	C1W		
Aircraft Carrier Enterprise (8 reactors)	CVA(N)65	West	Newport News	A2W		
Guided Missile Destroyer Bainbridge (2 reactors)	DLG(N)25	GE	Bethlehem	D2G		
S5W reactor for HMS Dreadnaught		West		S5W		
Authorized:						
Submarine	SSN612	West	Not assigned	S5W		
Submarine	SSN613	West	Not assigned	S5W		
Submarine	SSN614	West	Not assigned	S5W		
Submarine	SSN	West	Not assigned	S5W		

See footnotes at end of table.

C.2. Prototypes, experiments and field plants

Name (all owned by AEC except as noted)	Designation	Location	Principal contractor	Type	Power (net electric kilowatts) [1]	Start-up	Dismantled
Operated, later dismantled:							
Aircraft Reactor Experiment	ARE	Oak Ridge, Tenn	ORNL	Molten salt		1954	1954
Heat Transfer Reactor Experiment No. 1 [28]	HTRE-1	NRTS, Idaho	GE-ANPO	Air-cooled		1956	1959
Submarine Intermediate Reactor Mark A	SIG	West Milton, N.Y	GE	Sodium		1955	1957
Operable:							
S1W Reactor Facility	S1W	NRTS, Idaho	West	Pressurized water		1953	
Stationary Medium Power Plant No. 1 (Formerly APPR-1).	SM-1	Ft. Belvoir, Va	Alco	Pressurized water	1,855	1957	
Large Ship Reactor Prototype (2 reactors)	A1W	NRTS, Idaho	West	Pressurized water		1958	
Submarine Advanced Reactor Prototype	S3G	West Milton, N.Y	GE	Pressurized water		1958	
Stationary Low Power Plant No. 1 (Formerly ALPR). [29]	SL-1	NRTS, Idaho	ANL	Boiling water	200	1958	
Small Scale Nuclear Rocket Propulsion Experiment (Project Rover).	KIWI-A	NTS Nevada	LASL	Open cycle gas		1959	
Heat Transfer Reactor Experiment No. 2	HTRE-1&2	NRTS, Idaho	GE				
Heat Transfer Reactor Experiment No. 3	HTRE-3	NRTS, Idaho	GE				
Small Submarine Reactor Prototype	S1C	Windsor, Conn	CE	Pressurized water		1959	
SNAP Experimental Reactor Test	SER	Santa Susana, Calif	AI				
Being built:							
Gas Cooled Reactor Experiment	GCRE-1	NRTS, Idaho	AG	Gas cooled	No electricity	1959	
Destroyer Reactor Prototype	D1G	West Milton, N.Y	GE	Pressurized water			
Stationary Medium Power Plant No. 1A (USA) [30]	SM-1A	Fort Greely, Alaska	Alco	Pressurized water	1,700	1960	
Portable Medium Power Plant No. 1 (USAF-AEC). [31]	PM-1	Sundance, Wyo	Martin	Pressurized water	1,000	1961	
Portable Medium Power Plant No. 2A (USA) [32]	PM-2A	Arctic location	Alco	Pressurized water	1,500	1961	
Planned:							
Mobile Low Power Plant No. 1	ML-1	NRTS, Idaho	AG	Gas cooled	400	1961	
Natural Circulation Test Plant	NCTP						
Intermediate Scale Nuclear Rocket Propulsion Experiment (Project ROVER).	KIWI-A1	NTS, Nevada	LASL				
Intermediate Scale Nuclear Rocket Propulsion Experiment (Project ROVER).	KIWI-A3	NTS, Nevada	LASL				
Experimental Reactor	PWAC-II	Middletown, Conn	P&W				
Experimental Power Reactor Test (Project PLUTO)	Tory-II	NTS, Nevada	UCRL				
Intermediate Scale Nuclear Rocket Propulsion Experiment (Project ROVER).	KIWI-B1	NTS, Nevada	LASL				
Intermediate Scale Nuclear Rocket Propulsion Experiment (Project ROVER).	KIWI-B2	NTS, Nevada	LASL				
Intermediate Scale Nuclear Rocket Propulsion Experiment (Project ROVER).	KIWI-C	NTS, Nevada	LASL				
SNAP Developmental System	SDA	Santa Susana, Calif	AI				
SNAP Prototype System	SPS	Santa Susana, Calif	AI				
SNAP Flight System	SFS	Santa Susana, Calif	AI				
Advanced Core Test	ACT	NRTS, Idaho	GE-ANPO				

C.3. Research and test reactors

Name and/or owner	Designation	Location	Principal contractor	Type	Thermal power (kilowatts)	Startup	Dismantled
Operable:							
Thermal Test Reactor No. 1 (AEC)	TTR-1	Schenectady, N.Y.	GE	Graphite	10	1951	
Ground Test Reactor (USAF)	GTR	Ft. Worth, Tex	Convair	Pool	500	1953	
Tower Shielding Reactor No. 1 (AEC)	TSR-1	Oak Ridge, Tenn	ORNL	Tank	500	1954	1958
Operated, later dismantled:							
Aircraft Shield Test Reactor (USAF)	ASTR	Ft. Worth, Tex	Convair	Light water	1,000	1954	
Naval Research Reactor (USN)	NRR	Wash., D.C.	NRL	Pool	100	1956	
Radiation Effects Reactor (USAF)	RER	Dawsonville, Ga	Lockheed	Tank	10,000	1958	
Shield Test Pool Facility	Susie	NRTS, Idaho	GE-ANP	Pool	100	1959	
Being Built:							
Tower Shielding Reactor No. 2 (AEC)	TSR-2	Oak Ridge, Tenn	ORNL	Light water	5,000	1959	
Nuclear Engineering Test Reactor (USAF) [33]	NETR	Dayton, Ohio	ACF	Pool	10,000		
Ordnance Materials Research Office (USA)		Watertown, Mass	Owner	Pool	1,000	1959	
Sandia Engineering Reactor Facility (AEC)	SERF	Sandia Base, N. Mex	Sandia	Tank	5,000	1960	
Planned:							
Nuclear Test Plant (AEC)	NTP	NRTS, Idaho		Pressurized water	60,000	1961	
Shield Test Air Facility (AEC)	STAR	NRTS, Idaho	GE-ANP				
Sandia Pulsed Reactor Facility (AEC)	SPRF	Sandia Base, N. Mex	Sandia	Prompt burst		1961	

D. Production Reactors

D.1. Materials production

Designation	Nuclear designer	Type	Location
Operable:			
B Reactor	duPont	Graphite	Hanford, Wash.
D Reactor	duPont	Graphite	Hanford, Wash.
F Reactor	duPont	Graphite	Hanford, Wash.
C Reactor	GE	Graphite	Hanford, Wash.
DR Reactor	GE	Graphite	Hanford, Wash.
H Reactor	GE	Graphite	Hanford, Wash.
KE Reactor	GE	Graphite	Hanford, Wash.
KW Reactor	GE	Graphite	Hanford, Wash.
R Reactor	duPont	Heavy water	Savannah River, S.C.
P Reactor	duPont	Heavy water	Savannah River, S.C.
K Reactor	duPont	Heavy water	Savannah River, S.C.
L Reactor	duPont	Heavy water	Savannah River, S.C.
C Reactor	duPont	Heavy water	Savannah River, S.C.
Being built:			
New Production Reactor [34]	GE	Graphite	Hanford, Wash.

See footnotes at end of table.

D.2. Test

Name (all owned by AEC)	Designation	Location	Nuclear designer	Type	Thermal power (kilowatts)[1]	Start-up
Operable:						
Hanford 305 Test Reactor	HEW-305	Hanford, Wash	duPont	Graphite	0.03	1944
Savannah River Test Pile 305	SR-305	Savannah River, S.C.	duPont	Graphite	1	1953
Physical Constants Test Reactor	PCTR	Hanford, Wash	GE	Graphite	.1	1955
Thermal Test Reactor No. 2	TTR-2	Hanford, Wash	GE	Graphite	.1	1955

E. Reactors for Export

E.1. Stationary power

Name and/or owner	Location	Principal contractor	Type	Power (kilowatts)[1]		Start-up
				Electrical (net)	Thermal	
Being built:						
Belgium (Center for the Study of Nuclear Energy—CEN).	Mol	West	Pressurized water	11,500	43,000	1959
Germany (Rhine—Westphalia Power Co.—RWE)	Kahl-am-Main	GE	Boiling water	15,000	62,000	1960
Italy (Project Enrico Fermi of SELNI—Edisonvolta).[36]	Milan	West	Pressurized water	160,000	615,000	1963
Planned:						
Cuba, Gov't of (National Bank for Social and Economic Development—BANDES).[35]	Santa Lucia	AMF	Boiling water	20,500	75,000	
Italy (Project ENSI of SENN Ponta Fiume Plant)	Punta Fiume	GE	Boiling water	150,000	615,000	1962
Japan, Gov't of (JAERI)	Tokai-Mura	GE	Boiling water	10,000	40,000	1962

E.2. Research, training and testing

Owner	Location	Principal contractor	Type	Thermal power (kilowatts)	Startup
Operable:					
Belgium Congo, Gov't of (Univ. of Lovanium) [37]	Leopoldville	GDC	TRIGA	10	1958
Brazil, Gov't of (Univ. of Sao Paulo)	Sao Paulo	B&W	Pool	5,000	1957
Canada (McMaster University)	Hamilton, Ont	AMF	Pool	1,000	1959

Denmark, Gov't of (Atomic Energy Commission)	Risoe	AI	L-55	2	1957
Denmark, Gov't of (Atomic Energy Commission)	Risoe	FW	Tank	5,000	1959
Germany, Fed. Rep. of (Munich Tech. Univ.)	Munich	AMF	Pool	1,000	1957
Germany, Fed. Rep. of (Hoeshst Dyeworks Inc.)	Frankfurt	AI	L-54	50	1958
Germany, (Interatom, Inc.) [18 38]	Duisberg	AI	L-77	Negligible	1958
Germany, Fed. Rep. of (Society for the Utilization of Nuclear Energy in Shipbuilding and Navigation, Inc.).	Hamburg	B&W	Pool	5,000	1958
India (First World Agricultural Fair—U.S. Exhibit)	New Delhi	GDC	TRIGA Mk II	100	1959
Italy (Univ. of Palermo) [18]	Palermo	AGN	201-110	Negligible	1958
Italy, Gov't of (National Committee for Nuclear Research)	Ispra	AC	Heavy-water tank	5,000	1959
Italy (SORIN Nuclear Center)	Chivasso	AMF	Pool	1,000	1959
Italy (Milan Technical University)	Milan	AI	L-54	50	1959
Japan, Gov't of (Atomic Energy Research Inst.)	Tokai-Mura	AI	L-54	50	1957
Netherlands, Gov't of (Delft Tech. Univ.) [39]	Delft	AMF	Pool	10	1957
Spain, Gov't of (Nuclear Energy Board)	Madrid	GE	Pool	3,000	1958
Switzerland, Gov't of (Reactor, Inc.) [40]	Wuerenlingen	ORNL	Pool	100	1955
Switzerland (Univ. of Geneva) [18 41]	Geneva	AGN	201-111	Negligible	1958
Switzerland (Univ. of Basel) [18 42]	Basel	AGN	211-100	Negligible	1958
West Berlin, City of (Hahm-Meitner Inst. for Nuclear Research)	West Berlin	AI	L-54	50	1958
Being built:					
Austria, Gov't of (Austrian Study Co. for Atomic Energy)	Vienna	AMF	Pool	5,000	1959
Austria, Gov't of (Ministry of Education)	Vienna	GDC	TRIGA	100	1959
Brazil (University of Minas Gerais)	Belo Horizonte	GDC	TRIGA	30	1959
China, Republic of (National Tsing-Hau Univ.)	Hainchu	GE	Pool	1,000	1959
Greece, Gov't of (Atomic Energy Commission)	Athens	AMF	Pool	1,000	1959
Israel, Gov't of (Atomic Energy Commission)	Tel-Aviv	AMF	Pool	1,000	1959
Italy, Gov't of (Nat'l Committee for Nuclear Research)	Rome	GDC	TRIGA Mk II	100	1959
Italy (Naval Academy & University of Pisa (C.A.M.E.N.)	Livorno	B&W	Pool	5,000	1961
Iran, Gov't of (University of Tehran)	Tehran	AMF	Pool	5,000	1961
Japan, Gov't of (Atomic Energy Research Inst.)	Tokai-Mura	AMF	Heavy water	10,000	1960
Japan (Kinki University)	Osaka	ARRS		Negligible	1960
Netherlands, Gov't of (Reactor Center)	Petten	AC	Tank (MTR)	20,000	1961
Philippines, Gov't of (National Science Development Board)	Quezon City	GE	Pool	1,000	1961
Portugal, Gov't of (Nuclear Energy Board)	Lisbon	AMF	Pool	1,000	1960
Sweden, Gov't of (Atomic Energy Company)	Studsvik	AC	Tank (MTR)	30,000	1960
Thailand (Chulalongkhorn University)	Bangkok	CW	Pool	1,000	1961
Turkey, Gov't of (Atomic Energy Commission) [43]	Istanbul	AMF	Pool	1,000	1960
Venezuela, Gov't of (Inst. of Neurology and Brain Research)	Caracas	GE	Pool	3,000	1960
Viet-nam, Gov't of [43]	Dalat	GDC	TRIGA Mk II	100	1961
Planned:					
Japan (St. Pauls University)	Tokyo	GDC	TRIGA Mk II	100	
Korea, Gov't of (Atomic Energy Commission)	Seoul	GDC	TRIGA Mk II	100	1960
Finland, Gov't of (Institute of Technology)	Helsinki	GDC	TRIGA Mk II	100	
Germany (University of Mainz)	Mainz	GDC	TRIGA Mk II	100	
Japan (Rikkyo University)	Yokosuka City	GDC	TRIGA Mk II	100	1961
Japan (Musashi Institute of Technology)	Kawasaki City	GDC	TRIGA Mk II	100	
Pakistan, Gov't of (Atomic Energy Commission)	Taxila	AMF	Pool	1,000	

See footnotes at end of table.

E.3. Critical Assembly Facilities

Name and/or owner	Location	Subject of experiment or study	Designation	Startup
Planned: Japan, Gov't of (JAERI)	Tokai-Mura			

F. Critical Assembly Facility Abbreviations

Abbreviation	Name and location of facility	Operator	Number of cells	Number of control panels
AC	Allis Chalmers Critical Experiment Facility, Greendale, Wis	Owner	1	1
AI	Atomics International Critical Experiment Laboratory, (AEC), Santa Susana, Calif	AI	3	3
Alco	Alco Products, Inc., Schenectady, N.Y	Owner	1	1
ANL	Argonne National Laboratory (AEC), Lemont, Ill	ANL	3	3
ANL-ID	Argonne National Laboratory, Idaho Div., (AEC), NRTS, Idaho	ANL	1	1
ARMF	Advanced Reactivity Measurement Facility, (AEC), NRTS, Idaho	PPC	1	1
Bettis	Bettis Plant (AEC), Pittsburgh, Pa	West	8	8
B&W	The Babcock & Wilcox Co., Lynchburg, Va	Owner	3	2
BMI	Battelle Memorial Institute, West Jefferson, Ohio	Owner	1	1
BNL	Brookhaven National Laboratory (AEC), Upton, N.Y	BNL	2	2
CANEL	Connecticut Aircraft Nuclear Engine Laboratory, (AEC), Middletown, Conn	P&W	2	2
CE	Nuclear Engine Laboratory of Combustion Engineering, Inc., Windsor, Conn	Owner	3	2
ETRC	Engineering Test Reactor Critical Facility (AEC), NRTS, Idaho	PPC	1	1
GE	General Electric Co., Vallecitos Laboratory Experimental Physics Facility, Pleasanton, Calif.	Owner	1	1
GEANP	Evendale Critical Experiment Facility (AEC), Evendale, Ohio	GE	2	2
GDC	General Dynamics Corp., San Diego, Calif	Owner	2	2
KAPL	Knolls Atomic Power Laboratory (AEC), Schenectady, N.Y	GE	7	7
LAC	Lockheed Aircraft Corporation, Dawsonville, Ga., (USAF)	Owner	1	1
LASL	Los Alamos Scientific Laboratory, Los Alamos, N. Mex	LASL		
Livermore	University of California Lawrence Radiation Laboratory Critical Assembly Area, (AEC), SAGA Building, Livermore, Calif.	UCLRL		
LPTF	Low Power Test Facility (AEC), NRTS, Idaho	GE	2	2
Martin	The Martin Co., Middle River, Md	Owner	2	2
NASA	Lewis Flight Propulsion Laboratory, Sandusky, Ohio	Owner	1	1
NDA	Nuclear Development Corporation of America, Pawling, N.Y	Owner	1	1
UCLRL-NTS	University of California Lawrence Radiation Laboratory, (AEC), NTS, Nev	UCLRL		
ORNL-CF	Oak Ridge National Laboratory Critical Facility (AEC) Oak Ridge, Tenn	ORNL	3	5
ORNL-PCA	Pool Critical Assembly, BSF Pool (AEC), Oak Ridge, Tenn	ORNL	1	1
RMF	Reactivity Measurement Facility, MTR Canal (AEC), NRTS, Idaho	PPC	1	1
West	Westinghouse Reactor Evaluation Center Critical Experiment Station (CES) (LRX) and (YCF), Waltz Mill, Pa.	Owner	3	3

F.1. Critical Assembly Facilities

Abbreviation of facility and location within facility	Subject of experiment or study	Designation of experiment	Startup of experiment	Experiment dismantled
Operated, later dismantled:				
LASL	Los Alamos Water Boiler Critical Experiment	LOPO-CX	1943	1944
LASL, Kiva I	Studies of core configuration in thick natural U or Ni reflectors	Topsy (Popsy) (Scripto)	1948	1957
LASL, Kiva I and II	Bare metal prompt burst neutronics studies	Godiva I	1951	1957
LASL, Kiva I	Flooding tests	Aquarium		
LASL, Kiva I	Studies of D_2O moderated and reflected spheres	Pot	1952	1953
LASL, Kiva I	Studies of bare D_2O moderated cylinders	Can	1953	1955
LASL, Kiva II	Solid-fuel mockup of LAMPRE	LCX		1959
LASL, Kiva I	Critical Experiment for Kiwi A (Rover)	ZEPO	1958	1959
LASL	Classified			
LASL	Classified			
Livermore, SAGA Bldg	Nuclear data	Puppy I & II, Snoopy	1956	1957
ORNL, Bldg. 205	Nuclear safety and reactor design studies	X-10-200	1945	1948
ORNL, Bldg. K-25	Nuclear physics and nuclear safety with uranium solutions	K-25	1946	1950
ORNL—Y12 area	Test reactor assembly No. 1	TRA-1	1954	1954
Bettis	Spare Plate Critical Assembly	SPCA	1952	1955
Bettis	Danger Coefficient Test Facility	DCTF	1953	1957
Bettis	Production Test Facility	PTF	1956	
Bettis	S5W core design	S5W-FA	1956	1958
Bettis	Reactivity physics measurements	RPF	1958	1959
Operable:				
AC	Northern States Power Reactor Critical Experiments	CRBR-CX	1959	
AI-OMCA	Nuclear properties of organic moderated systems		1959	
AI—SCGA	Nuclear properties of sodium graphite systems		1959	
Alco	APPR-1A core design	APPR-s	1956	
ANL—ID	Fast critical mass determinations	ZPR-3	1955	
ANL—Bldg. 316, Cell A [44]	Nuclear constants with fast exponential source	ZPR-4'	1957	
ANL—Bldg. 316, Cell B	Interactions between two basic systems	ZPR-5	1956	
ANL—Bldg. 316, Cell C	Boiling water concept nuclear design information	ZPR-7	1957	
Bettis	Two region physics	TRX	1953	1959
Bettis	Surface ship physics [45]	SS-CFA	1956	
Bettis	Surface ship physics [45]	SS-CFB	1957	
Bettis	PWR core 1 physics	PWR-FA-1	1954	
Bettis	PWR core 2 physics	PWR-FA-2	1957	
Bettis	S5W core 4 physics [45]	Sub-FA and FC	1954	
B&W—Cell 1	*Consolidated Edison reactor*		1957	
B&W—Cell 2	Critical experiment with NS *Savannah* Production Fuel		1958	
B&W—Cell 3 [46]	LMFRE physics data		1958	
BMI-Cell 1 [47]	Reflector control critical	BMI-CX	1957	
BNL—Bldg. T-523	Exponential and critical assembly		1956	
CE—Bldg. 1, Cell 1, Pot 1 [48]	SIC physics and mockup	SIC-FC	1956	
CE—Bldg. 2, Cell 1, Pot 1	Vacant			
CE—Bldg. 2, Cell 2, Pot 1 [48]	SIC advanced mockup	SIC-AC	1956	

See footnotes at end of table.

F.1. Critical Assembly Facilities—Continued

Abbreviation of facility and location within facility	Subject of experiment or study	Designation of experiment	Startup of experiment	Experiment dismantled
Operable—Continued				
Canel—Physics Bldg., Cell 1	Sodium stainless steel criticals		1958	
Canel—Physics Bldg., Cell 2	Sodium stainless steel criticals		1959	
ETRC—ETR-MTR Area	ETR physics, core loading and core design		1957	
GDC—Cell 1	Zirconium—uranium hydride fuel for TRIGA	CIRGA	1957	
CE—Cell 1	Commonwealth Edison reactor		1957	
GEANP—1 [49]	Criticals for direct cycle reactors	SMR	1955	
GEANP—2	Criticals for direct cycle reactors	TSM & CERA	1956	
KAPL	Physical data [50, 51]	PPA	1948	
KAPL	Reactor physics studies with plastic moderator and mockup [51]	PMA	1954	
KAPL	Submarine advanced reactor mockup	ATR	1954	
KAPL	SAR physics and mockup	FPR	1956	
KAPL	D1G cold water mockup	CWA	1958	
KAPL	SAR high temperature and pressure physics and mockup	PTR	1958	
LAC	RER core configurations	CERF	1958	
LASL	Enriched metal in 3 inch thick U reflector	Little Eva	1951	
LASL, Kiva I	Plated bare Pu (to be replaced by U-233) sphere studies	Jezebel	1954	
LASL, Kiva I	Cold criticals for Rover reactors	Honeycomb	1956	
LASL	Cold criticals for Rover reactors	Aunt Polly		
LASL, Outside Kiva II	Jacketed enriched core lateral and base reflector of water studies, used as neutron sources for exponential column.	Hydro	1956	
LASL, Kiva II	Super prompt critical bursts with plated bare enriched core	Godiva II	1957	
LASL, Kiva II	Spherical metal cores in thick metal reflector	Flattop	1957	
LASL, Kiva I	Critical configuration safety tests	Comet		
LASL, Kiva II	Critical configuration safety tests	Planet		
LASL	Critical configuration safety tests	Planet II		
LASL, Kiva II	Physics measurements of thin enriched uranium foils in thick D_2O reflector	Cavity Reactor		
LASL	Classified			
Livermore, SAGA Bldg	Critical measurements with different geometrics		1953	
Livermore, SAGA Bldg	Project Pluto cold critical experiments		1957	
NAA-AI	Critical Experiments for SNAP reactors	Powder Compact	1957	
NTS—Nevada	Hot criticals for Tory II (Project Pluto)	Hot Box	1959	
LPTF—Cell 1	Hot critical experiments	HOTCE	1959	
LPTF—Cell 2	Critical experiment tank for advanced reactor design testing	CET	1958	
Martin—Cell 1	Martin power reactor experiments		1957	
Martin—Cell 2	Engineer Research and Development Laboratory experiments		1958	
NASA—Materials and Stresses Bldg.	NASA Test Reactor critical experiments		1959	
RMF—MTR Canal	Reactor physics constants and reactivity changes caused by test reactor irradiation		1954	
West—YCF	Loose lattice critical experiments			
West—CES	Reactor fuel measurement facility design		1958	
NDA—Cell 1 [52]	Development of research reactor	NDA—CX	1957	
ORNL—CF-Bldg. 9213, Cell E	Uranium-paraffin experiments related to physics and safety of homogeneous reactors.	CA-28	1950	

ORNL—CF-Bldg. 9213, Cell W	Reactor physics and nuclear safety studies with homogeneous uranium solutions; lattices slightly enriched uranium in water; TSR–2 tests; investigations of neutron absorbers as poisons in chemical processing equipment.		1950	
ORNL—CF-Bldg. 9213, Cell S	Comparison of nuclear properties of U–235 and U–233			
ORNL—PCA-Bldg. 3010	Physics research on reactivity effects	PCA	1958	
Being Built:				
AI—ECEL	Nuclear properties of experimental reactor systems		1960	
ANL—Bldg. 315	Basic fast reactor theoretical studies	ZPR–6	1960	
ANL—Bldg. 315	Coupled fast core-thermal breeder blanket investigations	ZPR–9	1960	
BNL—Bldg. 526	Graphite-bismuth-uranium system physics data		1959	
Bettis	High temperature physics and mockup	HTTF	1959	
LASL	Kiva heated critical assembly		1960	
Planned:				
ARMF—ETR-MTR Area	Reactor physics constants and reactivity changes caused by test reactor irradiation		1960	
GDC	HTGR critical experiments	HTGR-CX	1960	
KAPL	NCR critical experiments		1960	
Livermore SAGA Bldg	Tory II critical experiments		1960	
West—LRX	Physical constants of critical assemblies moderated with D_2O and containing as fuel slightly enriched uranium in the form of UO_2.	CVTR-CRX	1960	

FOOTNOTES

[1] Capacity figures for power reactors are based on the best available information. In some cases, future modification in plans may cause changes.

[2] The Shippingport station is provided with a turbogenerator rated at 100,000 Ekw.

[3] Of total net output shown for the Consolidated Edison plant, 151,000 kw. will be nuclear and 104,000 kw. oil-fired superheat.

[4] The Enrico Fermi plant is to be provided with a turbogenerator rated at 150,000 Ekw. and may reach this gross output with later cores.

[5] Contract awarded by Commission under Power Demonstration Reactor Program.

[6] The net Ekw. for Yankee's second core is expected to be 134,000.

[7] Net output of Elk River plant includes about 16,000 kw. conventional superheat.

[8] Capacity of Northern States plant includes about 17,000 Ekw. nuclear superheat.

[9] Approved as basis for Commission contract negotiations under Power Demonstration Reactor Program.

[10] Net electric output with an all graphite core is expected to be 40,000 kw.

[11] LAPRE–1 was designated as a small reactor experiment which was to produce 2,000 kilowatts of heat power. It operated only very briefly and never succeeded in reaching full power.

[12] *Originally built and operated in 1954 as Boiling Reactor Experiment No. 2 (BORAX–2).* With the addition of a turbogenerator it operated during 1955 as BORAX–3. BORAX–4 was a further modification which operated from December 1956 until June 1958 when the experiment was shut down indefinitely.

[13] Gross Ekw. is shown for EBR–1 in the tabulation. In a trial run on December 21 and 22, 1951, EBR–1 generated the world's *first electric power from nuclear energy.* Criticality with the third core was achieved in November 1957.

[14] EBWR was successfully operated at a power level of 62,000 kilowatts of heat in experiments on March 20, 1958. It is now being converted to a 100,000 kw. thermal plant, but its electrical output is limited by turbogenerator capacity. Plant modification is scheduled for completion by June 1960.

[15] In January 1958, VBWR operated at a power level of 30,000 kilowatts of heat. Its electrical output is limited by turbogenerator capacity.

[16] Since it is provided with a very small turbogenerator, the HRE–2 produces only token amounts of electricity (about 300 kilowatts gross) as compared to a thermal output of 5,000 kilowatts, most of which is dumped to the atmosphere.

[17] The purpose of this reactor is to investigate problems associated with high temperature process heat reactors.

[18] Power output of EGCR will depend on operation of the eight experimental loops to be provided in the core.

[19] Reactors whose thermal power output is less than 50 watts are shown as having negligible power output. The thermal power of these reactors is as follows: AGN 201's, 100 milliwatts; AGN 201M's, 5 watts; AGN 201P's, 20 watts; AGN 211's, 15 watts; AI's L–77, 10 watts; ARSS' UTR–1, 1 watt; NDA's PRR, 5 watts; Hanford 305 Test Pile, 10 watts.

[20] In 1943, the Manhattan Engineering District disassembled Chicago Pile 1 and rebuilt it at Palos Park, Ill., as Chicago Pile 2. CP–2 had a thermal power level of 10 kw.

[21] LITR began as a mechanical model of the MTR. After MTR engineering aspects were proven, small amounts of nuclear fuel, control devices, shielding and instruments were added and the reactor called MTR critical experiment went critical for the first *time in the spring of 1950.* Research facilities were added and power increased to the present level; in the fall of 1951.

[22] AE–6 (also designated WBNS) was built and first operated at Downey, Calif. It was moved to Santa Susana in 1957.

Footnotes continued on next page.

FOOTNOTES—Continued

[23] Original 10 kw. research reactor at Raleigh, N.C., was started up in 1953 and dismantled in 1955. Reactor was reactivated with a 500 watt core in March 1957. Early in 1959, the reactor was moved to a new location in the Nuclear Science Laboratory and a new 10 kw. heterogeneous core, Argonaut type, reactor built in original RRR shield vacated by homogeneous core.

[24] CP-5 is undergoing modifications to permit operation at 10,000 thermal kilowatts.

[25] After assembly and operation of this reactor in the Government exhibit at Geneva in September 1958, it was dismantled and returned to ANL where it is being rebuilt as a 100 TKW Jugernaut.

[26] In 1959 BSR-1 began operating with a second core in which the fuel is clad in stainless steel rather than aluminum.

[27] Operated for reactor transient experiments only. The thermal power level shown for SPERT-3 is the maximum heat removal rate for a one-half hour period and is not a sustaining operating level.

[28] All reactors in the Naval propulsion program are of the pressurized water type except the sodium cooled system formerly installed in the *Seawolf*. Symbols in the type column indicate (1) the ship type for which reactor is designed, (2) sequence number of the plant design by prime contractor for each ship type, and (3) designator letter for name of the contractor responsible for design of the reactor plant. When appearing as the first letter of the symbol *S* indicates submarine, *D* for destroyer, and *A* for large surface ship. Prime contractor designation letters are *W* for Westinghouse, *G* for General Electric, and *C* for Combustion Engineering.

[29] This reactor was partially dismantled in 1957. It could be made operable again if desired but there are no present plans to do so.

[30] SL-1 can produce 1.3 million B.t.u. per hour of space heat, although this output is now being dissipated through a heat dump. The plant is now being operated by Combustion Engineering Co.

[31] SM-1A formerly known as APPR-1A will produce 38 million B.t.u. per hour of steam for space heating and about 1,700 kw. of electricity.

[32] PM-1, formerly known as APPR-2, will produce 7 million B.t.u. per hour of steam for space heating in addition to electricity.

[33] PM-2A is being built for the U.S. Army Corps of Engineers. The plant will produce 1,000 pounds of steam per hour (1 million B.t.u.) and 1,500 net Ekw. electricity.

[34] NETR was originally scheduled for operation in 1960. Present schedule is indefinite.

[35] The design of this reactor incorporates features making possible conversion to permit power take-off should this be desirable at a later date.

[36] Capacity of Cuban Plant (BANDES) includes about 17,000 Tkw. conventional superheat. Schedule is indefinite.

[37] Construction contract is subject to the following conditions: (a) obtaining favorable long term arrangements with AEC regarding fuel cycle, and (b) obtaining favorable long term loan from Export-Import Bank covering capital cost.

[38] This TRIGA reactor was operated at the 1958 International Conference in Geneva, Switzerland, prior to shipment to the University of Lovanium. The reactor began operating at the University of Lovanium in June 1959. It is the first reactor to be operated on the African continent.

[39] This L-77 reactor was operated in the Commercial exhibit of the 1958 International Conference at Geneva. It is presently in storage at Interatom, Inc.

[40] The Netherlands research reactor was originally operated at Amsterdam International Exhibition in June 1957. It is now in storage at Delft Technical University.

[41] This is the 1955 Geneva Conference Reactor rebuilt with increased power and now operating at Wuerenlingen, Switzerland.

[42] AGN201-111 was operated in the commercial exhibit of the 1958 International Conference at Geneva prior to transfer to the University of Geneva.

[43] This reactor was operated in the International Science Section of the Brussels International Exhibition, Apr. 15–Oct. 1, 1958, prior to transfer to the University of Basel.

[44] Bilateral agreement has not been executed.

[45] Zero power experiments of historical interest previously conducted in ANL facility cells include the Nautilus Core design (ZPR-1), the Savannah River reactor design (ZPR-2), and a series of fast neutron studies (ZPR-4) and interactions between two basic systems (ZPR-5).

[46] Cell has one control panel but two pots. Experiment may be operated in either pot but not simultaneously.

[47] B&W cells 2 and 3 share a control panel with only one cell capable of being operated at any one time.

[48] Solid fuel cold critical (PWAR-5) were conducted in BMI facility in 1957.

[49] Listed experiments completed in 1959.

[50] Test Reactor Assembly No. 1 and No. 2 were previously conducted in GEANP facility.

[51] PPA physics date experiment was formerly located at Sacondaga Site, West Glenville, N.Y.

[52] PMA at KAPL was modified from SIR Proof Test Reactor (PTR).

[53] The NDA facility is designed to accommodate two experiments but has a present capability of one.

List of Reactor Projects Under Construction or Development Included in Commission Statistical Survey

Civilian Power Experiments and Prototypes

Carolinas-Virginia Nuclear Power Associates, Inc.
East Central and Florida West Coast Nuclear Groups
Enrico Fermi Atomic Power Plant
Hallam Nuclear Power Facility
Northern States Power Co. Pathfinder Plant
City of Piqua, Ohio
Rural Cooperative Power Association
Yankee Atomic Electric Co.
Humboldt Bay Power Plant, Unit No. 3
Dresden Nuclear Power Station
Consolidated Edison Thorium Reactor
Philadelphia Electric Co.
Boiling Reactor Experiment No. 5
Experimental Breeder Reactor No. 2
Experimental Gas-Cooled Reactor
High Temperature Gas-Cooled Reactor Experiment
Los Alamos Power Reactor Experiment No. 2
Saxton Nuclear Experimental Reactor Project

Propulsion Plant for Merchant Ship

N.S. *Savannah*

Civilian Testing

National Aeronautics and Space Agency (NASA Test Reactor)
Westinghouse Testing Reactor
Fast Source Reactor
Biological Research Reactor
Heavy Water Components Test Reactor
Plutonium Recycle Test Reactor
Special Power Excursion Reactor Test No. 2 (SPERT-2)
Special Power Excursion Reactor Test No. 4

Civilian Research

Brookhaven High Flux Beam Research Reactor
Argonne National Laboratory (Jugernaut)
Puerto Rico Nuclear Center
Texas Agricultural and Mechanical College
Ohio State University
University of Virginia
Worcester Polytechnic Institute
North Carolina State College
University of California at Los Angeles
University of Kansas
University of Washington
Walter Reed Hospital Medical Research Reactor
Virginia Polytechnic Institute
State College of Washington
Georgia Institute of Technology
Union Carbide Nuclear Co.
Cornell University
Leland Stanford University
Iowa State University

Materials Production

New Production Reactor

Military Prototypes, Experiments and Field Plants

Destroyer Reactor Prototype
Mobile Low Powerplant No. 1
Portable Medium Powerplant No. 1
Portable Medium Powerplant No. 2A
Small Submarine Reactor Prototype
Stationary Medium Powerplant No. 1A
Gas-Cooled Reactor Experiment
Natural Circulation Test Plant
Stationary Medium Powerplant No. 2

Military Testing

Nuclear Test Plant
Sandia Engineering Reactor Facility
Tower Shielding Reactor No. 2
Nuclear Engineering Test Reactor
Ordnance Materials Research Office

Propulsion Plants for Naval Vessels

Submarines

Scamp
Scorpion
Sculpin
Shark
Snook
Thresher
Permit
Plunger
Barb
George Washington
Patrick Henry
Theodore Roosevelt
Tullibee
Robert E. Lee
Abraham Lincoln
Ethan Allen
Sam Houston
Thomas A. Edison
John Marshall
Pollock
Seawolf (Conversion)
Haddo
Jack
Tinosa
Dale
Four additional submarines

Surface Vessels

Long Beach (2 reactors)
Enterprise (8 reactors)
Bainbridge (2 reactors)

APPENDIX 15

Fallout From Nuclear Tests at Nevada Test Site

About 1 megaton of energy from fission has been released at the Nevada Test Site from nuclear test detonations. The total resultant fission product activity, if measured 1 hour after formation, would have been about 400 to 600 billion curies. The utmost care was taken to minimize the deposition of radioactivity outside the Nevada Test Site.

The following is a summary of the data on fallout from nuclear detonations at the Nevada Test Site.

External Gamma Exposures

The data on external gamma exposures in areas around the Nevada Test Site resulting from all past nuclear test detonations through the Hardtack II test series ending on October 30, 1958, has been summarized and combined into table 1. Since the estimates are based on potential exposures in areas if persons had lived continuously in the specific area mentioned, full use should be made of the notes at the end of the table. For example, the table shows 10.80 roentgens for Dodge Construction Camp, Nev., but the estimated exposure to persons was about 2.7 roentgens since no one was living in the area previous to Operation Plumbbob (spring-summer 1957). On the other hand, the table indicates a zero population for Riverside, Nev., which is correct for the present, but during the time of heaviest fallout (Operation Upshot-Knothole, spring 1953) some persons were in the area.

To summarize table 1:

(*a*) The highest estimated exposures were up to about 13.5 roentgens for one person and 10.5 roentgens for another at Butler Ranch, Nev.

(*b*) The highest estimated exposure at any "community" (Lincoln Mine) was about 6 roentgens.

(*c*) Between the above two radiation dose levels there might have been up to 30 persons so exposed.

Environmental Contamination

General. Relatively fresh fission product fallout, such as that originally placed into the troposphere from a nuclear detonation, contains a wide variety of isotopes. The composition (relative percentage of isotopes) varies with the time after formation. Also, fractionation may occur, i.e., there may be a deviation from the expected isotopic abundance due to the fact that some isotopes have gaseous precursors. However, the percentage of isotopes present may be estimated by reference to calculated data.[1]

The fallout that occurs around the Nevada Test Site from nuclear detonations does so within relatively short times after an explosion. This radioactive material contains a large percentage of short-lived radioisotopes which contribute significantly to total external gammas but little to the accumulated total accruing from those isotopes deposited internally. This is due to the short

[1] "Calculated Activities and Abundances of U^{235} Fission Products." Bolles, R. C. and Ballou, N. E. U.S. Naval Radiological Defense Laboratory. San Francisco 24, Calif., 30 Aug. 1956.

half-lives and to the relatively low uptake and deposition of most of these isotopes in the body.

The isotope of principal concern in terms of internal irradiation is strontium 90. It would be desirable to determine the strontium 90 content of fresh fission product activity found associated with foodstuffs and water. The isotopic analysis for this isotope, however, is not a simple and quick procedure. In an understandable desire to make conservative estimates of potential health hazards, all of the fission product activity found in foods and water has at times been ascribed to strontium 90. This can lead to erroneous evaluations. For example, if fresh fission product activity is measured 1 week after formation, as little as one part in 7,000 of this activity might be due to strontium 90 (assuming no fractionation). Such an approximation is not intended to be precise but it does estimate the strontium 90 content more accurately than does the method of ascribing all the fission product activity to the one isotope. This type of approximation may be more nearly correct for surface contamination on objects (including exposed foodstuffs) and in rain water, than in waters that have passed through or over soils, since some selective absorption would be expected in the latter case.

Many of the estimated exposures according to table 1 are higher than preliminary reports.[2] This has resulted from continuing studies of several factors, i.e., radiological decay rates, weathering effects, instrument cross-calibration, and the like. As with any such data there are associated uncertainty factors. In preparing the table the uncertainty factors were estimated as:

for doses less than 0.1 roentgen ±80%
for doses 0.1–1.0 roentgen±60%
for doses greater than 1.0 r ±40%

Some areas are included in the table that did not appear in the preliminary data. After all the monitoring data were collected, evaluated and plotted, interpolations between data points were made to include these areas.

As one of the monitoring programs, film badges were worn by persons in many localities around the Nevada Test Site. Assuming these were worn properly on the person, they represent one of the best estimates of actual exposures. Of interest is the ratio of these film badge readings to those badges placed out of doors in the same general area. These data are summarized in table 2, based on 87 locations. The lower ratios would be expected due in part to shielding effects when persons were indoors. Those with higher ratios are more difficult to explain. One factor is the normal movement of persons with some going to areas of higher contamination for longer periods of time.

The information from another study which analyzed data of dose rate readings inside and outside various type structures around the Nevada Test Site during Operation Plumbbob is summarized in table 3.

As a result of the fallout that occurred in Southern California in the fall of 1958, such foodstuffs as lettuce, spinach, and celery were found to contain gross beta activity (as counted about 2 weeks after the fallout occurred) ranging from a few to several tens of disintegrations per minute per gram. However, when five of these samples later were analyzed for strontium 90, the values ranged from 2.71 to 4.9 micromicrocuries per gram of calcium—values which are not significantly different from the foods grown elsewhere in the country and, in fact, on the low side of the average. Additional samples are

[2] See page 281–284, Twenty-third Semiannual Report (July–December 1957).

being analyzed and somewhat higher values will probably be found in some of these, but it would appear that whatever strontium 90 there may have been in the fresh fallout it was not a major addition to that already in the plants (strontium 90 originating from past tests).

Milk and Soils

Considerable data on contamination of soils, plants, and animals have been collected by the Offsite Rad-Safe Group of the Nevada Test Organization (U.S. Public Health Service, and several projects of the University of California at Los Angeles). The information given here is only a very small part of these data. They were chosen to illustrate the general levels of strontium 90 activity in the environment. More complete data may be found in the reports from these organizations.

Milk

Prior to Operation Plumbbob and again following the completion of that test series, sets of milk samples from around the Nevada Test Site were collected and analyzed by the University of California at Los Angeles. With one possible exception (Panguitch, Utah) the values are not significantly different from those found in most other localities in the United States. These data are summarized in table 4.

Milk collections have also been made in the Glendale, Nev., and the St. George-Cedar City, Utah, areas by the Offsite Rad-Safe Group and analyzed by the Division of Radiological Research, Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio. These data are summarized in table 5. These values are no higher than for most other areas sampled in the United States.

Soils

Soil samples from areas around the Nevada Test Site experienced some of the heaviest fallout following Operation Plumbbob (1957) and are being analyzed for their strontium 90 content. Values from cultivated lands are given in table 6. Some preliminary data from nontilled soils show, in general, higher values.

Concentration of Activity in the Air

An increase in small amounts of fallout debris in the air can be readily determined through standard air sampling techniques. Sensitivity of this method provides an excellent monitor to determine the time of the appearance and the relative amounts of fallout. At the same time, these data are subject to misinterpretations in terms of a "health hazard." For example, concentrations for short periods of fallout material in the air in amounts hundreds of times above background may not constitute a serious situation. This may be illustrated by the fallout that occurred in the Los Angeles, Calif., area in the fall of 1958.

Peak concentrations of radioactivity in the air over Los Angeles were due principally to nuclear detonations at the Nevada Test Site on October 29, 1958. Mixed with this was a smaller amount of longer-lived material originating

either from previous detonations in Nevada or from Soviet Union explosions, or both. The recurrence of higher than normal activities in the air the first week in November was undoubtedly due to meteorological conditions. In this case, the air masses passed seaward over Los Angeles, then returned and remained in the general area, accompanied by an inversion layer.

The highest concentration of fallout debris in the air was 700 micromicrocuries per cubic meter on October 30, 1958; it dropped to 38 of these units on November 1; and reached a second high of 370 units on November 3. Prior to this fallout, the "background values" were about 1 to 2 micromicrocuries per cubic meter.

Biological evaluation of such data is quite tenuous, yet some estimates can be made. For instance, it was estimated that the dose to the lungs from inhalation of air during the week of highest fallout activity amounted to a few millirems. During the same period, estimated exposure to the lungs from naturally occurring radiation substances in the air (radon and thoron, together with their daughter products) probably was several times this amount.

In addition to irradiation of the lungs there is the probability that some of the activity may find its way to other organs of the body. However, fallout around the Nevada Test Site has been found to be quite insoluble. Only rough estimates can be made, but these indicate that the strontium 90 that might be deposited in the body (other than the lungs) by the inhalation route, even on the day of peak air concentrations (700 micromicrocuries per cubic meter) would be only a very small quantity compared to the normal daily strontium 90 intake by ingestion of foodstuffs.

Concurrent with the fallout debris in the air over Los Angeles, there was a deposition of some of this material on the ground. Automatic gamma recorders in operation showed that the total external gamma exposure from this fallout was a few tenths of a milliroentgen at most—an amount received every day or two from naturally occurring radioactive substances in the environment.

The highest measured concentration of radioactive fallout in the air over populated areas of the United States was at St. George, Utah, on May 19–20, 1953. A recalculation of these data indicates a lung dose of about 230 millirems. The radiation exposure to the lungs from inhalation of naturally occurring radioactive substances varies from place to place and from time to time, but a value of about 25 millirems per week is a rough estimate. This is a lower estimate than was previously used.[3] Knowledge on radiation doses to the lungs from naturally occurring radioactive substances in the air still is meager and such estimates that have been made encompass a rather wide range. Using a conservative value of 25 millirems per week, the calculated exposure to the lungs from inhalation of fallout debris in the air at St. George might have been equivalent to that received in about 10 weeks from naturally occurring radioactive substances in the air.

Concentration in Water

Customarily, only gross beta counts have been made on fallout activity in water. Without further analyses only rough estimates can be made as to isotopic content, and thus potential radiation doses.

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[3] "Radiations From Fallout and Their Effects." The Nature of Radioactive Fallout and Its Effects on Man. *Hearings Before the Special Subcommittee on Atomic Energy, Congress of the United States.* May–June 1957, p. 170–258. Available from Government Printing Office, Superintendent of Documents, price $6.00.

The highest measured concentration of fallout activity in a potential drinking water supply (*this is not currently a known supply for humans*) was at upper Pahranagat Lake, Nev., during the 1955 test series at the Nevada Test Site. A concentration amounting to 1.4×10^{-4} microcuries per milliliter was measured 3 days after the detonation. If this water had been stored and used as a sole supply for 70 years, the resultant internal doses may be estimated as follows.

Bones	about 1.0 rad
Lower large intestine (with lesser doses to other parts of the GI tract).	about 0.25 rad
Thyroid	about 0.25 rad

TABLE 1.—[a] ESTIMATED RADIATION DOSES (ROENTGENS) NEAR NEVADA TEST SITE

Location	Population	Pre-Plumbbob	Plumbbob (1957)	Hardtack II (1958)	Cumulative
ARIZONA					
Beaver Dam	5	2.00	0.30	[b]	2.30
Big Bend Ranch	5	[c] (2.00)	.19	—	2.19
Bullhead	500	—	.02	—	.02
Catherine Ranger Station	[d]	—	—	—	—
Chloride	160	—	.02	—	.02
Davis Dam	15	—	—	—	—
Grasshopper Junction	2	—	.03	—	.03
Hackberry	100	—	.01	—	.01
Hughes Ranch	Transient	(2.00)	.30	—	2.30
Kingman	5,500	.03	.01	—	.04
Lake Mohave	2	—	.02	—	.02
Littlefield	44	1.60	.32	—	1.92
Mount Trumbull	100	.16	—	—	.16
Oatman	40	—	—	—	—
Peach Spring	600	—	—	—	—
Short Creek	90	1.60	—	—	1.60
Topock	80	—	—	—	—
Truxton	26	—	—	—	—
Valentine	50	—	.01	—	.01
Walapai	15	—	—	—	—
Warm Springs	[d]	—	—	—	—
Willow Beach	5	—	—	—	—
Wolf Hole	5	1.30	—	—	1.30
Yucca	150	—	—	—	—

[a] Prepared by a committee composed of the following members:
A. Vay Shelton, chairman, Lawrence Radiation Laboratory, University of California.
Roscoe H. Goeke, Albuquerque Operations Office, U.S. Atomic Energy Commission (on loan from the U.S. Public Health Service).
William R. Kennedy, Los Alamos Scientific Laboratory.
Kermit H. Larson, University of California, Los Angeles.
Kenneth M. Nagler, U.S. Weather Bureau.
Oliver R. Placak, Las Vegas Branch Office, U.S. Atomic Energy Commission (officer-in-charge U.S. Public Health Service).

[b] A dash implies no fallout or fallout not readily distinguishable from background radiation.

[c] Parentheses indicate that the community was not included in the October 1956, list of Pre-Plumbbob doses.

[d] Population figures not available.

NOTE: Footnotes concerning populations of communities are at end of this table.

Location	Population	Pre-Plumbbob	Plumbbob (1957)	Hardtack II (1958)	Cumulative
CALIFORNIA					
Amboy	1,004	—	—	—	—
Baker	726	—	.03	—	.03
Barstow	10,017	—	.01	—	.01
Benton Station	300	—	.07	—	.07
Big Pine	556	—	.03	—	.03
Bishop	2,891	—	.06	—	.06
Boron	592	—	—	—	—
Camp Irwin	Variable	—	—	—	—
Cantil	100	—	—	—	—
Cartago	126	—	.03	—	.03
Chalfant	25	—	.10	—	.10
China Lake	10,000	—	—	—	—
Crest View	25	—	—	—	—
Daggett	525	—	—	—	—
Death Valley Junction	20	—	—	.15	.15
Deep Springs	100	—	.03	—	.03
Emigrant Springs Ranger Station	2	—	.01	.08	.09
Essex	75	—	.02	—	.02
Four Corners	(d)	—	—	—	—
Furnace Creek	50	—	—	.15	.15
Hinkley	780	—	—	—	—
Independence	875	—	.02	—	.02
Inyokern	600	—	—	—	—
Johannesburg	300	—	.03	—	.03
Kalso	271	—	.03	—	.03
Laws	72	—	.07	—	.07
Lenwood	2,600	—	.01	—	.01
Littlelake	32	—	—	—	—
Lone Pine	1,415	—	.03	.05	.08
Ludlow	250	—	—	—	—
Manix	10	—	—	—	—
Mojave	2,055	—	—	—	—
Mountain Pass	10	—	—	—	—
Needles	5,480	—	—	—	—
Newberry	700	—	—	—	—
Oasis	12	—	.10	—	.10
Olancha	275	—	.03	—	.03
Randsburg	281	—	—	—	—
Red Mountain	320	—	.03	—	.03
Ridgecrest	4,000	—	.02	—	.02
Ryan Mine	1	—	.06	.15	.21
Shoshone	100	—	—	—	—
Silver Lake	10	—	.05	—	.05
South Haiwee	25	—	—	—	—
Stovepipe Wells	2	—	.01	.05	.06
Tecopa	25	—	—	—	—
Tom's Place	Variable	—	.02	—	.02
Troma	3,500	—	—	—	—
Wheaton Springs	(d)	—	—	—	—
Yermo	700	—	.01	—	.01
ZZYZX Springs	40	—	—	—	—
NEVADA					
A&B Mine	4-12	(0.50)	2.90	—	3.40
Acoma	10	3.00	—	—	3.00
Adam's Ranch	(d)	(1.00)	.37	0.80	2.17
Alamo	250	1.30	.04	.05	1.39
Apex	50 [2]	.10	.03	—	.13
Ash Meadows	8	.05	.01	.15	.21
Ash Springs	5	.60	.06	—	.66
Atlanta	2	(.30)	.26	—	.56
Austin	520	.05	.15	—	.20
Babbitt	2,464	—	.23	.05	.28
Baker	60	.80	.25	—	1.05
Barclay	10	2.00	.04	—	2.04
Bardoli Ranch	4 [3]	(1.70)	.26	.08	2.04
Basalt	8	—	.15	.05	.20
Beatty	550	.05	.11	.05	.21
Belew Ranch	3	(1.19)	.47	.08	1.74
Belmont	6	(.10)	1.10	.05	1.25
Blue Diamond	400	(.05)	—	—	.05
Blue Eagle School	11	(1.04)	.46	.05	1.55
Bonansa Boy Scout Camp	Variable [4]	(.12)	—	—	.12
Bond Ranch	(d)	(.05)	.70	—	.75

See footnotes at end of table.

Location	Population	Pre-Plumbbob	Plumbbob (1957)	Hardtack II (1958)	Cumulative
NEVADA—Continued					
Boulder City	4,000	.08	—	—	.08
Boyd	Variable [5]	(1.50)	.04	—	1.54
Bristol Silver Mine	25–50	(.64)	.06	.08	.78
Buckhorn Ranch (US 93)	12	.90	.08	—	.98
Buskerville	250	4.30	.17	.05	4.52
Butler Ranch	2 [6]	(8.40)	6.60	—	15.00
Cactus Springs	18	.03	.05	—	.08
Caliente	970	.70	.01	.05	.76
Carp	25	3.60	.30	—	3.90
Caselton Mine	40–147	(.70)	.02	—	.72
Charleston Lodge	60	.15	—	—	.15
Cherry Creek	112	(.26)	.24	—	.50
Clark's Station	0–5	.80	.81	—	1.61
Cloud	Variable [5]	(3.00)	.65	—	3.65
Coaldale	25	—	.88	.10	.98
Cole & Dolan Ranch	3	(.50)	.26	.05	.81
Corn Creek	11	(.40)	—	—	.40
Cove	20	(.55)	.30	—	.85
Crestline	22	.70	—	—	.70
Crystal	5 [7]	4.00	.06	—	4.06
Currant	75	.50	.33	—	.83
Delmue	7	(.60)	.01	—	.61
Desert Rock	Variable [8]	.05	.02	.08	.15
Dodge Construction Camp	175 [9]	(8.00)	2.70	.10	10.80
Donahue Ranch	4	(.25)	.05	.05	.35
Dry Lake	20	1.00	.03	—	1.03
Duckwater	50	.80	.21	—	1.01
D-X Ranch	(d)	(.85)	.20	—	1.05
Dyer	35	—	.13	.05	.18
East Ely	1,000	.60	.55	.05	1.20
El Dorado	3	(.45)	.60	—	1.05
Eldridge Ranch (N. of Eureka)	4	(.20)	.34	—	.54
Eldridge Ranch (Mt. Wheeler Inn).	(d)	(.85)	.13	—	.98
Elgin	30	3.50	.06	—	3.56
Ely	3,558	.60	.55	.05	1.20
Etna	Variable [5]	(.80)	.02	—	.82
Eureka	500	.20	.60	.05	.85
Fallini Ranch	15	.80	1.10	.08	1.98
Fallon	2,400	—	.14	—	.14
Fish Creek Ranch	(d)	(.50)	.60	.05	1.15
Gabbs	625	—	.38	—	.38
Galt	Variable [5]	(6.00)	4.90	—	10.90
Garnet	Variable [5]	(.85)	.05	—	.90
Geyser Maintenance Station	10	(1.00)	.42	—	1.42
Geyser Ranch	5	(1.05)	.50	—	1.55
Glendale	75	.70	.10	.05	.85
Goldfield	220	0	1.10	.10	1.20
Goldpoint	10	(.90)	.30	.10	1.30
Goodsprings	160	—	—	—	—
Groom Mine	0 [10]	2.00	2.80	.10	4.90
Gubler Ranch	(d)	(.90)	.44	.05	1.39
Hawthorne	1,861	—	.23	.05	.28
Henderson	14,000	.02	—	—	.02
Hiko	55	1.00	.08	—	1.08
Hollinger's Ranch	1	(.30)	.02	.05	.37
Hoover Dam	(d)	.05	—	—	.05
Hoya	Variable [5]	(3.70)	2.20	—	5.90
Indian Creek Ranch	(d)	(.80)	.18	—	.98
Indian Springs	2,650 [11]	.05	.10	—	.15
Ione	40	—	.24	—	.24
Johnnie	5	0	—	—	—
Kimberly	120	.50	.37	.05	.92
Kyle	Variable [5]	(3.20)	.26	—	3.46
Laboard Ranch	x	(.06)	.39	—	.45
Lake Mead Base	5	.05	.04	—	.09
Lane City	40	(.555	.38	.05	.98
Las Vegas	47,000	.20	.01	—	.21
Lathrop Wells	9–15	.05	.03	.08	.16
Lehman Caves	Variable [12]	(.95)	.25	—	1.20
Leith	Variable [5]	(3.00)	.32	—	3.32
Lida	25	(.50)	.32	.05	.87
Lida Junction	3	(.40)	.78	.10	1.28
Lincoln Mine	100–500	4.00	1.90	.05	5.95
Lockes	4	1.30	.31	—	1.61
Logandale	300	.40	.16	—	.56
Lund	250	.80	.44	.05	1.29
Luning	50	—	.44	.05	.49

See footnotes at end of table.

Location	Population	Pre-Plumbbob	Plumbbob (1957)	Hardtack II (1958)	Cumulative
NEVADA—Continued					
M&M Mine	2	(.50)	2.90	—	3.40
Manhattan	42	(.08)	.26	.05	.39
McGill	2,297	.40	.32	.05	.77
Mercury	300–3,500	.10	.02	.10	.22
Mesquite	590	1.80	.24	.05	2.09
Millett	5	(.04)	.40	—	.44
Mina	450	—	.50	.08	.58
Moapa	52	.80	.10	.05	.95
Moapa Indian Reservation	100–150	(.80)	.17	—	.97
Moon River Ranch	3	(1.48)	.52	.08	2.08
Mounts Ranch	(d)	(.85)	(.24)	—	1.09
Nellis Air Force Base	8,000	.05	—	—	.05
Nelson	100	—	—	—	—
Nivloc	250	—	.35	.08	.43
North Las Vegas	13,000	.20	—	—	.20
Nyala	6	1.70	.28	.08	2.06
Overton	750	.35	.08	—	.43
Pahrump	89	.20	—	—	.20
Pahrump Mining Co	(d)	(.09)	.01	—	.10
Panaca	500	.65	.01	—	.66
Parmon's Ranch	6–8	(.10)	.25	.10	.45
Pioche	1,392	.70	.04	—	.74
Pittman	(d)	(.10)	—	—	.10
Pony Springs	(d)	(.65)	.45	.08	1.18
Pop's Oasis	(d)	—	—	—	—
Potts	17	(.20)	.19	—	.39
Preston	60	.70	.48	.05	1.23
Rattlesnake Maintenance Station	4	(.75)	.80	.10	1.65
Reed	0 [13]	4.00	2.66	.08	6.74
Reveille Mill	6 [14]	(.70)	4.70	.10	5.50
Riverside	0 [15]	7.80	.10	.05	7.95
Rhyolite	7	—	.06	.05	.11
Rogers Ranch	10	(.76)	.21	.05	1.02
Rose Valley	10	(.65)	—	—	.65
Round Mountain	200	.05	.36	.08	.49
Rox	Variable [5]	3.00	.30	—	3.30
Ruby Hill Mine	50	(.18)	.65	.05	.88
Ruth	1,244	.50	.40	.05	.95
Sarcobatus	3	(.10)	.08	.05	.23
Schurz	100	—	.22	—	.22
Searchlight	150	—	.08	—	.08
Searls Ranch	16	(.70)	.23	.05	.98
Seven L. Ranch	1	(.40)	.02	—	.42
Sharps (Adaven)	25	1.20	.41	.08	1.69
Shoshone	250	.70	.24	—	.94
Silver Peak	7	—	.65	.10	.75
South Paw Mine	3	(1.00)	.79	.05	1.84
Springdale	15	.02	.04	.05	.11
State Line	90	—	—	—	—
Steward, R. Ranch	6	(.70)	.52	.08	1.30
Stine	Variable [5]	(1.10)	.06	—	1.16
Stone Cabin Ranch	8	(.60)	.37	.05	1.02
Sunnyside	26	1.20	.48	.05	1.73
Swallow Ranch	(d)	(.80)	.22	—	1.02
Tonopah	1,375	0	.98	.10	1.08
Tonopah Airport	4	—	.70	.10	.80
Uhaldi Ranch	5–8	(1.33)	.47	.08	1.88
Urretias Ranch	(d)	(1.10)	.63	.05	1.78
Ursine	25	.60	.01	—	.61
Vigo	Variable [5]	(3.00)	.52	—	3.52
Walch Pine Creek Ranch	4–6	(2.25)	.45	.08	2.78
Warm Springs	55	.50	.35	.08	.93
Warm Springs Ranch	58 [16]	1.00	.23	—	1.23
Watertown	300 [17]	(2.40)	(1.30)	.10	3.80
Whipple Ranch	10	(1.00)	.10	—	1.10
Whitney	78	0	—	—	—
Adamsville	98	(.23)	—	—	.23
Alton	154	.80	.03	—	.83
Anderson Junction	17	1.20	.68	—	1.88
Bear Valley Junction	10	.40	.55	—	.95
Beaver	1,685	.25	—	—	.25
Beryl	15	.50	.03	—	.53
Beryl Junction	8	1.00	.05	—	1.05
Black Rock	9	(.05)	—	—	.05
Bryce Canyon	Variable [18]	(.55)	.01	—	.56
Cedar City	6,106	.40	.24	—	.64
Central	49	(1.50)	.41	—	1.91
Cove Fort	8	.07	—	—	.07

See footnotes at end of table.

Location	Population	Pre-Plumbbob	Plumbbob (1957)	Hardtack II (1958)	Cumulative
NEVADA—Continued					
Desert Range Experimental Station.	5	(.10)	—	—	.10
Duck Creek Forest Camp	(d)	(.90)	.17	—	1.07
Enoch	250	(.50)	.04	—	.54
Enterprise	800	.70	.09	—	.79
Garrison	125	.70	.18	—	.88
Glendale	275	(.24)	—	—	.24
Greenville	173	(.24)	—	—	.24
Gunlock	127	2.60	.52	0	3.12
Hamilton Fort	26	.60	.20	—	.80
Hamlin Valley	Variable	(.50)	.01	—	.51
Hatch	24	(.50)	.14	—	.64
Hilldale	10	(.30)	.14	—	.44
Hurricane	1,375	4.20	.15	—	4.35
Kanab	1,900	1.60	.02	—	1.62
Kanarrville	263	1.20	.73	—	1.93
Kanosh	476	(.05)	—	—	.05
La Verkin	387	(3.50)	.16	—	3.66
Leeds	215	3.00	.70	—	3.70
Long Valley Junction	10	.80	.07	—	.87
Lund	75	.50	—	—	.50
Manderfield	62	(.20)	.03	—	.23
Milford	1,673	.10	—	—	.10
Minersville	593	.20	—	—	.20
Modena	100	.50	.04	—	.54
Mount Carmel	125	.85	.09	—	.94
Mount Carmel Junction	10	(.80)	.05	—	.85
New Castle	115	.60	.05	—	.65
New Harmony	126	1.20	.68	—	1.88
Orderville	371	1.50	.10	—	1.60
Paiute Indian Reservation	95	(.30)	—	—	.30
Panguitch	1,500	.20	.50	—	.70
Paragonah	404	.40	.02	—	.42
Parowan	1,455	.40	.02	—	.42
Pintura	50	1.20	1.00	—	2.20
Rockville	125	3.00	.10	—	3.10
Saint George	5,000	3.00	.70	—	3.70
Santa Clara	319	3.50	.77	—	4.27
Shivwits	95	2.80	.80	—	3.60
Springdale	209	2.60	.09	—	2.69
Summit	146	(.50)	.02	—	.52
Toquerville	219	2.00	.33	—	2.33
Uvada	15	(.70)	—	—	.70
Veyo	100	2.00	.82	—	2.82
Vic's Place	3	(1.20)	.68	—	1.88
Vic's Service Station	2	(3.00)	.90	—	3.90
Virgin	147	1.50	.12	—	1.62
Washington	435	3.00	.30	—	3.30
Zane	25	.30	—	—	.30
Zion Lodge	Variable [18]	(1.00)	.16	—	1.16

FOOTNOTES CONCERNING POPULATIONS OF COMMUNITIES

[1] Lake Mohave—also some transients.
[2] Apex—about 50 day workers; generally only a watchman at night.
[3] Bardoli Ranch—population only 1 after Plumbbob.
[4] Bonanza Boy Scout Camp—variable population, summer months only.
[5] Railroad maintenance stations (Boyd, Cloud, Etna, Galt, Garnet, Hoya, Kyle, Leith, Rox, Stine, Vigo)—population variable from 0 to about 15.
[6] Butler Ranch—Mrs. Butler was absent during the important fallout in Plumbbob (from the Smoky burst) and Mr. Butler was evacuated for a few hours shortly after the fallout arrived. Personnel film badges indicated that Mrs. Butler received less than 2 roentgens and that Mr. Butler received less than 5 roentgens.
[7] Crystal—unpopulated after Plumbbob.
[8] Desert Rock—*unpopulated except during major test series.*
[9] Dodge Construction Camp—unpopulated except Plumbobb series.
[10] Groom Mine—population variable 2–10 prior to Plumbbob, intermittent during Plumbbob but only trivial doses indicated by personnel film badges during Plumbbob.
[11] Indian Springs—population variable, about 250 plus 2,400 on military post during Plumbbob.
[12] Lehman Caves—tourists during summer season.
[13] Reed—population 3 during the Teapot series only, and these were evacuated for 7–10 days during the highest fallout activity.
[14] Reveille Mill—unpopulated prior to Plumbbob.
[15] Riverside—population 2–14 through Upshot-Knothole, 2 during Teapot and 0 after Teapot.
[16] Warm Springs Ranch—up to 500 people on weekends during the summer.
[17] Watertown—population 0 prior to Plumbbob; about 300 during first month of Plumbbob, and 2 thereafter.
[18] Bryce Canyon and Zion Lodge—many tourists during summer.

533136—60——37

TABLE 2.—COMPARISON OF FILM BADGE READINGS

Ratio, persons/area	*Percentage of total number of badges*
Film badge readings on persons not distinguishable above background	6
>0<.2	6
0.2–0.4	13
0.4–0.6	26
0.6–0.8	13
0.8–1.0	6
1.0–1.2	13
1.2–1.4	6
1.4–1.6	1
1.6–1.8	1
1.8–2.0	1
>2.0	5
Area film badge readings not distinguishable above background	3

TABLE 3.—SHIELDING FACTORS (INSIDE-OUTSIDE STRUCTURES AND VEHICLES)

Ranking	Shielding factor	Range of shielding factors
1. Heavy construction	4.60	2.27–8.50
2. Large light storage type buildings	2.87	2.45–3.66
3. Light construction, domicile types	2.36	1.26–4.11
4. Vehicles (pickup trucks)	2.21	1.45–4.5
5. Trailer type domiciles	1.56	1.22–1.82

PRE- AND POST-PLUMBBOB SERIES STRONTIUM 90 AND CESIUM 137 CONTENT IN MILK

Location	Date sampled	Type and origin of feed as indicated by owner of herd	Sr 90 μμc/g Ca*	Cs137 d/m/quart
Alamo, Nev	5- 2-57	Idaho hay, St. George concentrate	17.4	27
Do	8- 3-57	No information available	5.3	75
Do	10-31-57	Alfalfa pasture, St. George concentrate	5.0	44
Antimony, Utah	9-20-57	No information available	13.6	119
Do	10-21-	Dry feeding exclusively	10.0	121
Bishop, Calif	11- 6-57	Hay from local source	3.2	32
Fremont, Utah	9- 9-57	Hay 20%, pasture 80%, commercial feed	12.1	99
Do	9-21-57	No information	9.5	83
Do	10-19-57	Alfalfa pasture, commercial feed	4.9	56
Lund, Nev	11- 4-57	1957 hay, alfalfa pasture, local grain	3.2	71
Mesquite, Nev	8- 2-57	No information available		70
Do	10-23-57	Local hay, St. George feed	6.1	58
Milford Utah	4-29-57	1956 hay, home grown grain	3.1	63
Do	10-23-57	50% pasture, 50% 1957 hay, grain	2.7	29
Pahrump, Nev	11- 1-57	Home grown hay, ensilage, grain	6.0	31
Panguitch, Utah	9- 8-57	Local pasture	37.3	159
Do	9-20-57	do	17.0	94
Do	10-21-57	Old hay	26.2	182
St. George, Utah	8-31-57	1957 hay, third cutting, grain	2.6	45
Do	10-28-57	1957 hay and ensilage, grain	4.6	103
Veyo, Utah	7- 9-57	Hay from Enterprise, local pasture	7.2	68
Do	7-15-	No record taken	8.2	52
Do	8- 3-57	do	5.1	65
Do	9-10-57	Hay from Enterprise and local pasture	4.1	38
Do	10-27-57	Hay from 1957 cutting	4.0	45

*Micromicrocuries per gram of calcium.

TABLE 5.—MILK SAMPLES

Sample	Date of collection	Ash (grams/liter)	Gross activity micromicrocuries/gram ash	Ca (grams/liter)	I^{131}*†	Total Sr	Sr^{90} micromicrocuries/liter	Ba^{140}*	Cs^{137}
Glendale, Nev. area	6-20-58			1.066	0	14.1±1.3	4.5±0.7	3.1±1.4	45.0±1.6
Do	7-16-58	7.27	209.1±5.1	1.070	84	17.9±1.4	3.5±0.6	9.8±1.8	46.5±1.7
Do	8-26-48	7.26	191.5±5.0	1.226	**16.3	16.9±1.5	2.0±0.6	0.7±0.7	44.2±1.8
Do	9-17-58	7.33	192.4±5.0	1.097	18	26.6±1.6	3.5±0.5	5.0±1.6	47.1±1.8
Do	10-28-58	7.55	196.5±5.1	1.056	**293	24.8±1.7	1.8±0.3	**16.2±1.0	24.7±1.2
Do	11-26-58	7.75	182.9±5.0	1.145	**49	40.9±1.9	3.2±0.7	**3.6±0.8	43.7±1.3
Do	12-28-58	7.43	187.4±4.5	1.157	*†27	9.9±1.9	2.9±0.7	*0	26.1±1.2
Do	1-26-59	7.57	191.4±4.8	1.172	0	5.4±1.4	5.0±0.7	0	32.1±1.3
Do	2-18-59	7.50	189.8±7.8	1.154	3	5.4±1.2	3.1±0.5	2.1±1.6	25.8±1.1
St. George–Cedar City area, Utah	6-21-58			1.072	0	17.1±1.4	3.5±0.7	3.4±1.4	45.1±1.6
Do	7-11-58	7.26	197.6±5.1	1.040	43	10.6±1.3	3.2±0.6	5.4±1.2	35.7±1.5
Do	8-16-58	8.44	171.5±4.9	1.086	25.8	23.6±1.4	2.3±0.7	3.6±1.4	32.7±1.7
Do	10-15-58	7.47	204-7±5.0	1.074	0.0	30.7±1.9	2.6±0.7	0.0	32.4±1.3
Do	11-14-58	7.99	172.1±5.0	1.121	0	30.8±2.1	4.1±1.0	1.8±2.0	32.0±1.3
Do	1-13-59	7.59	185.9±5.4	1.135	0	9.9±1.3	3.5±0.5	0	34.4±1.3
Do	2-10-59	7.62	195.0±5.3	1.154	3	5.9±1.2	4.1±0.5	0	29.1±1.2

*Corrected for decay to time of collection.
**Uncorrected for decay to time of collection.
†I^{131} values had an error of ±20 μμc/l when analyzed.

TABLE 6.—SOILS*

Location	Strontium-90 (millicuries per square mile)
Tempiute, Nev	42. 3
Cedar City, Utah	36. 2
Lund, Nev	30. 7
Beaver, Utah	29. 6
Eureka, Nev	25. 6
St. George, Utah	24. 1
Alamo, Nev	15. 3
Bishop, Calif	14. 9
Caliente, Nev	14. 6
Overton, Nev	9. 7
Mesquite, Nev	5. 2
Barstow, Calif	1. 96

*Samples collected by Mr. Kermit Larson of UCLA, prepared for analyses by Dr. Lyle Alexander of the U.S. Department of Agriculture and analyzed by the Health and Safety Laboratory of the Atomic Energy Commission.

TABLES OF THE YIELDS OF UNITED STATES, UNITED KINGDOM AND UNION OF SOVIET SOCIALIST REPUBLICS

UNITED STATES AND UNITED KINGDOM NUCLEAR EVENTS

(Yield in Kilotons)

Year	Total fission yield	Total fission yield from events, the total yield of which was 1 MT or greater
1945	60	----------
1946	40	----------
1948	100	----------
1951	500	----------
1952–1954	37, 000	36, 000
1955	200	----------
1956	9, 000	8, 000
1957–1958	19, 000	14, 000

SOVIET NUCLEAR EVENTS

(Yield in Kilotons)

Inclusive	Total fission yield*
1945–1951	60
1952–1954	500
1955–1956	4, 000
1957–1958	21, 000

*A value of 50 percent has been arbitrarily selected for the fission of total yield ratio for all Soviet thermonuclear tests. As indicated in the tables, 50 percent is about the average fission to total yield ratio for all U.S./U.K. thermonuclear tests.

UNITED STATES, UNITED KINGDOM, AND SOVIET NUCLEAR EVENTS

(Yield in Kilotons)

Inclusive years	Fission yield*			Total yield	
	Air burst	Ground surface burst	Water surface burst	Air burst	Surface burst
1945–1951	190	550	20	190	570
1952–1954	1,000	15,000	22,000	1,000	59,000
1955–1956	5,600	1,500	6,000	11,000	17,000
1957–1958	31,000	4,400	4,600	57,000	28,000

*A value of 50 percent has been arbitrarily selected for the fission to total yield ratio for all Soviet thermonuclear tests. As indicated in the tables, 50 percent is about the average fission to total yield ratio for all U.S./U.K. thermonuclear tests.

APPENDIX 16

Foreign Research Reactor Grants

RESEARCH REACTOR GRANTS

(May 30, 1956–Dec. 31, 1959)

Country	Type	Power (thermal)	Manufacturer	Estimated project cost (millions)
Brazil, Sao Paulo [1]	Pool	5 mw	Babcock and Wilcox	$1.3
Spain, Madrid [1]	Pool	3 mw	International General Electric	1.0
Netherlands, Petten	Tank	20 mw	American Car and Foundry	3.9
Denmark, Risoe	Tank	5 mw	Foster-Wheeler	1.4
Japan, Tokai-mura	Tank	10 mw	American Machine and Foundry	1.5
Portugal, Lisbon	Pool	1 mw	American Machine and Foundry	1.0
Venezuela, Caracas	Pool	3 mw	International General Electric	5.0
Italy, Ispra [1]	Tank	5 mw	American Car and Foundry	3.6
Greece, Aghia Paraskeri	Pool	1 mw	American Machine and Foundry	1.3
Sweden, Studsvik	Tank	30 mw	American Car and Foundry	4.3
Israel, Rehovoth	Pool	1 mw	American Machine and Foundry	1.4
West Germany, Munich [1]	Pool	1 mw	American Machine and Foundry	3.1
Belgium, Mol	Tank	25 mw [3]	Centre d'Etudes de l'Energie Nucleaire. Nuclear Development Associates.	10.01
China, Hsinchius	Pool	1 mw	International General Electric	1.0
Austria, Vienna	Tank	5 mw [2]	American Machine and Foundry	4.0
Norway, Kjeller	Pool	10 kw	Norstom	0.8
Korea, Ahyang	Tank	100 kw	General Atomic	1.1
Thailand, Bangkok	Pool	1 mw	Curtis-Wright	0.82
Vietnam, Dalat	Tank	100 mw	General Atomic	0.75

[1] Grant paid. [2] Convertible to 12 mw. [3] Convertible to 50 mw.

Total number of grants—19. (This figure excludes the reactor grant of $500,000 made to the Philippines under special legislation.).

Estimated cost of projects to be assisted—$47,270,000.

APPENDIX 17

STATUS OF AGREEMENTS FOR COOPERATION IN THE CIVIL USES OF ATOMIC ENERGY AND SPECIAL AGREEMENTS

Cumulative numbers countries	Agreements	Country	Scope of exchange	Effective date
1	1	Argentina	Research	July 29, 1955
2	2	*Australia	Research and power	May 28, 1957
3	3	Austria	Research	July 13, 1956
4	4	*Belgium	Research and power	July 21, 1955
5	5	Brazil	Research	Aug. 3, 1955
6	6	*Canada	Research and power	July 21, 1955
7	7	Chile	Research	Aug. 8, 1955
8	8	China, Republic of	Research	July 18, 1955
9	9	Colombia	Research	July 19, 1955
10	10	Cuba	Research	Oct. 10, 1957
11	11	Denmark	Research	July 25, 1955
12	12	Dominican Republic	Research	Dec. 21, 1956
13	13	Ecuador	Research	Feb. 6, 1958
14	14	France	Research and power	Nov. 20, 1956
15	15	Germany, Federal Republic	Research and power	Aug. 7, 1957
	16	West Berlin, city	Research	Aug. 1, 1957
16	17	Greece	Research	Aug. 4, 1955
17	18	Guatemala	Research	Apr. 22, 1957
18	19	Iran	Research	Apr. 27, 1959
19	20	Ireland	Research	July 9, 1958
20	21	Israel	Research	July 12, 1955
21	22	Italy	Research and power	Apr. 15, 1958
22	23	Japan	Research and power	Dec. 5, 1958
23	24	Korea, Republic of	Research	Feb. 3, 1956
24	25	Lebanon	Research	July 18, 1955
25	26	*Netherlands	Research and power	Aug. 8, 1957
26	27	New Zealand	Research	Aug. 29, 1956
27	28	Nicaragua	Research	Mar. 7, 1958
28	29	Norway	Research and power	June 10, 1957
29	30	Pakistan	Research	Aug. 11, 1955
30	31	Peru	Research	Jan. 25, 1956
31	32	Philippines	Research	July 27, 1955
32	33	Portugal	Research	July 21, 1955
33	34	South Africa	Research and power	Aug. 22, 1957
34	35	Spain	Research and power	Feb. 12, 1958
35	36	Sweden	Research	Jan. 18, 1956
36	37	Switzerland	Research	July 18, 1955
	38	*Switzerland	Power	Jan. 29, 1957
37	39	Thailand	Research	Mar. 13, 1956
38	40	Turkey	Research	June 10, 1955
39	41	*United Kingdom	Research and power	July 21, 1955
40	42	Uruguay	Research	Jan. 13, 1956
41	43	Venezuela	Research	July 21, 1955
42	44	Viet-Nam	Research	July 1, 1959

SIGNED AND IN RATIFICATION PROCESS AS OF AUGUST 1959

				Date signed
		Austria	Research and power	July 22, 1959
	45	Brazil	Power	July 31, 1957
43	46	Costa Rica	Research	May 18, 1956
		Cuba	Research and power	Sept. 9, 1958
44	47	Iraq	Research	June 7, 1957
		Peru	Research and power	July 19, 1957
		Venezuela	Research and power	Oct. 8, 1958
45	48	Panama	Research	June 24, 1959

SUMMARY

In effect: 31 research and 13 power agreements with 42 countries and West Berlin.
Signed: 3 research and 5 power with 3 more countries (4 to supersede existing accords).

SPECIAL AGREEMENTS

	Scope of exchange	*Effective*
EURATOM	Joint Nuclear Power Program	Feb. 18, 1959
International Atomic Energy Agency (IAEA).	Supply of Materials, etc	Aug. 7, 1959
Australia	Mutual Defense Purposes	Aug. 14, 1957
Canada	*Mutual Defense Purposes	July 27, 1959
France	Mutual Defense Purposes, etc	July 20, 1959
Greece	*Mutual Defense Purposes	Aug. 11, 1959
Netherlands	*Mutual Defense Purposes	July 27, 1959
Turkey	*Mutual Defense Purposes	July 27, 1959
United Kingdom	*Mutual Defense Purposes	Aug. 4, 1958
	*Amendment to U.K. Mutual Defense Purposes Agreement.	July 20, 1959
Germany, Federal Republic	*Mutual Defense Purposes	July 27, 1959

*Classified agreements.

APPENDIX 18

MATERIALS SHIPMENTS TO FOREIGN COUNTRIES

SEPTEMBER 1958–DECEMBER 1959[1]

Date shipped	Country	Uranium		Other materials	Type of transaction	Purpose and remarks
		Kg. U-235	Percent enrichment U-235			
Sept. 16, 1958	Switzerland	0.661	20		Sale	University of Geneva Reactor.
Oct. 15, 1958	Denmark	1.125	90		Lease	Special fuel assays.
Oct. 29, 1958	Switzerland	.778	20		Sale	University of Basle Reactor.
Nov. 3, 1958	Germany			9 tons heavy water	Sale	Kernreaktor.
Nov. 12, 1958	Belgium			AM 241, CM 244	Gift	Liege University research minute quantity.
Nov. 19, 1958	Norway	1.984	1.5		Sale	Halden Reactor.
Nov. 21, 1958	Denmark	4.495	90		Lease	Riso Reactor.
Dec. 3, 1958	Denmark	1.683	90		Lease	Riso Reactor.
Dec. 9, 1958	Belgium	1.986	20		Sale	Univeristy of Lovanium, TRIGA.
Dec. 12, 1958	Brazil	5.729	20		Lease	Sao Paulo Reactor.
Dec. 19, 1958	Spain	[2]	90		Sale	Fission counter, Moncloa Reactor.
Dec. 20, 1958	Denmark	[2]	90		Sale	Fission counter material.
Sept. 4, 1958	France	5.352	20		Lease	Triton Reactor.
Oct. 21, 1958	France	64.840	1.6		Lease	EL 3 Reactor.
Dec. 16, 1958	France	7.390	1.5		Lease	ALIZE.
Dec. 19, 1958	France	7.377	1.5		Lease	ALIZE.
Dec. 24, 1958	France	7.348	1.5		Lease	ALIZE.
Dec. 29, 1958	France	7.397	1.5		Lease	ALIZE.
Jan. 7, 1959	Australia	4.438	90		Sale	Research.
Jan. 2, 1959	France	[2]	1.5		Lease	ALIZE.
Jan. 14, 1959	France	[2]	90		Sale	Research.

Jan. 13, 1959	France	12.225	1.5		Lease	ALIZE.
Jan. 14, 1959	Switzerland	.010	20		Sale	*University of Basle.*
Jan. 19, 1959	United Kingdom			U.233	Gift	Cross section measurements.
Jan. 26, 1959	Canada	3.882	90		Lease	McMasters University Reactor.
Jan. 26, 1959	Canada	(2)	90		Sale	Material for 2 mission counters.
Feb. 4, 1959	France	4.854	1.5		Lease	ALIZE.
Feb. 10, 1959	Canada			5 tons heavy water	Sale	AECL.
Feb 12, 1959	Italy	4.356	20		Lease	ISPRA Reactor.
Feb. 20, 1959	Canada			5 tons heavy water	Sale	AECL.
Feb. 27, 1959	Germany			20 GM, Depl.U	Sale	Research.
Mar. 3, 1959	Italy	(2)	90		Sale	Ispra flux mapping device.
Mar. 6, 1959	Canada			20 tons heavy water	Sale	AECL.
Mar. 13, 1959	France			115 GM, Depl.U	Sale	Research.
Mar. 23, 1959	United Kingdom	(2)	(2)		Exchange	Research.
Apr. 8, 1959	Norway	.266	1.5		Sale	Halden Reactor.
Apr. 9, 1959	France	3.753	19.87		Lease	*Triton Reactor.*
Apr. 24, 1959	France	5.935	3.5		Lease	For Elize fuel fabricator.
May 6, 1959	France	6.994	3.5		Lease	For Elize fuel fabricator.
May 13, 1959	Holland	(2)	(3)		Lease	University of Delft.
May 21, 1959	Germany	5.991	19.82		Lease	Siemens Reactor.
May 20, 1959	Canada	2.794	90		Sale	Research.
May 22, 1959	Canada	2.174	90		Sale	Research.
May 25, 1959	Japan	(2)	20		Lease	*Fission counter.*
June 3, 1959	France	2.451	3.5		Lease	Alize Reactor.
June 3, 1959	France	5.339	20		Lease	Minerva Reactor.
June 10, 1959	France			1 mg., NP-237	Gift	Research.
June 10, 1059	Denmark			1 mg. NP-237	Gift	Research.
June 10, 1959	France			500 GM, Depl.U	Gift	Research.
June 11, 1959	Belgium	3.675	90		Sale	BR-2 test reactor.
June 12, 1959	Canada	2.052	90		Lease	McMaster University Reactor.
June 12, 1959	Italy			500 GM, Depl. U	Sale	Research.
June 12. 1950	Italy	(2)	20		Sale	Milan Reactor.
June 6, 1959	Italy	2.332	20		Lease	Fuel for TRIGA.
June 6, 1950	Italy	(2)	90		Sale	Fission counter for TRIGA.
June 15, 1959	France	6.567	20		Lease	Fuel for Melusine and Triton.
June 18, 1959	Israel			AM-241, NP-237	Gift	Research.
June 18, 1959	Belgium			AM-241	Gift	Research.
June 19, 1959	France	2.902	20		Lease	Fuel for Melusine and Triton.
June 19, 1959	Sweden	(2)	90		Sale	Material for fission counters.
June 24. 1959	Canada	2.812	7.1		Sale	AECL.
July 7, 1959	Austria			0.838, U.233	Sale	Research.
July 8, 1959	Italy	1.500	20		Lease	Al. Reactor Milan.
July 10, 1959	France	.564	20		Lease	Melusine and Triton Reactors.
July 13, 1950	Switzerland			80 GM PU	Sale	Research.
July 15, 1959	Sweden	(2)	90		Sale	Research.
Aug. 3, 1959	France	.178	20		Lease	Minerva Reactor.
Aug. 3, 1959	Denmark			PU	Sale	Minute research quantity.
Aug. 5, 1959	France	(2)	90		Sale	Research.
Aug. 7, 1959	Denmark			GM PU	Sale	Research.
Aug. 14, 1959	Italy	6.591	20		Lease	Sorin Reactor.
Aug. 17, 1959	Belgium	(2)	90		Sale	Research.

See footnotes at end of table.

MATERIALS SHIPMENTS TO FOREIGN COUNTRIES—Continued

SEPTEMBER 1958–DECEMBER 1959 [1]—continued

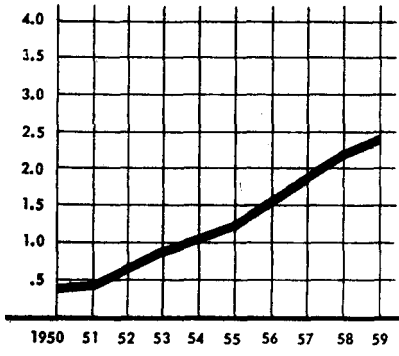
Date shipped	Country	Uranium		Other materials	Type of transaction	Purpose and remarks
		Kg. U-235	Percent enrichment U-235			
Aug. 26, 1959	United Kingdom	(2)	1.17		Loan	Harwell.
Sept. 4, 1959	France	2.443	3.49		Lease	Alize Reactor.
Sept. 8, 1959	Canada	.558	90		Lease	NRU Reactor.
Sept. 11, 1959	France			5.5 tons heavy water	Sale	EL-3 Reactor.
Sept. 18, 1959	France	2.515	3.49		Lease	Alize Reactor.
Sept. 21, 1959	Canada			(a) Normal	Sale	AECL.
Sept. 21, 1959	Denmark			11 tons heavy water	Lease	DR-3 Reactor.
Sept. 21, 1959	Denmark			6.4 tons heavy water	Sale	DR-3 Reactor.
Oct. 2, 1959	Germany			35.5 tons heavy water	Sale	Kernreactor.
Oct. 2, 1959	Italy			0.26 for PU	Gift	University of Paria.
Oct. 5, 1959	Germany	.076	20		Sale	Hamburg Research Reactor.
Oct. 7, 1959	Italy	.656	20		Lease	University of Palermo.
Oct. 12, 1959	India			14.8 tons heavy water	Lease	Trombay Reactor.
Oct. 16, 1959	France	.592	3.49		Lease	Alize Reactor.
Oct. 30, 1959	Switzerland			10 GM PU	Sale	Research.
Nov. 6, 1959	Switzerland			4.5 tons heavy wa r	Sale	Test Reactor.
Nov. 12, 1959	Australia	.467	90		Sale	Research.
Dec. 10, 1959	United Kingdom			5.0 kg. Depl. U	Sale	Research.
Dec. 11, 1959	Switzerland			1 gm. U-233	Sale	Research.
Dec. 29, 1959	Sweden	.003	90		Sale	Research.

[1] For earlier shipment data, see p. 282, Twenty-fifth Semiannual Report (July–December 1958) and pp. 44–45, Twenty-fourth Semiannual Report (January–June 1958).
[2] Amount less than 10 grams contained U-235.

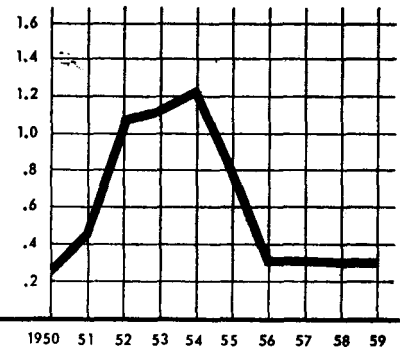
APPENDIX 19

Commission's Financial Report for Fiscal Year 1959

COST OF OPERATIONS



PLANT AND EQUIPMENT EXPENDITURES

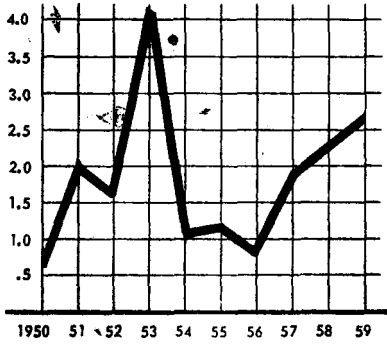


FINANCIAL TRENDS

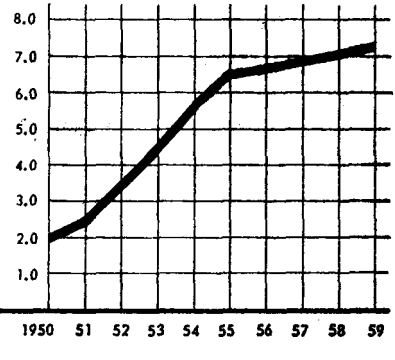
FISCAL YEARS 1950-1959

billions of dollars

FUNDS APPROPRIATED - NET



PLANT INVESTMENT AT JUNE 30



UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

October 12, 1959

MEMORANDUM TO THE COMMISSIONERS

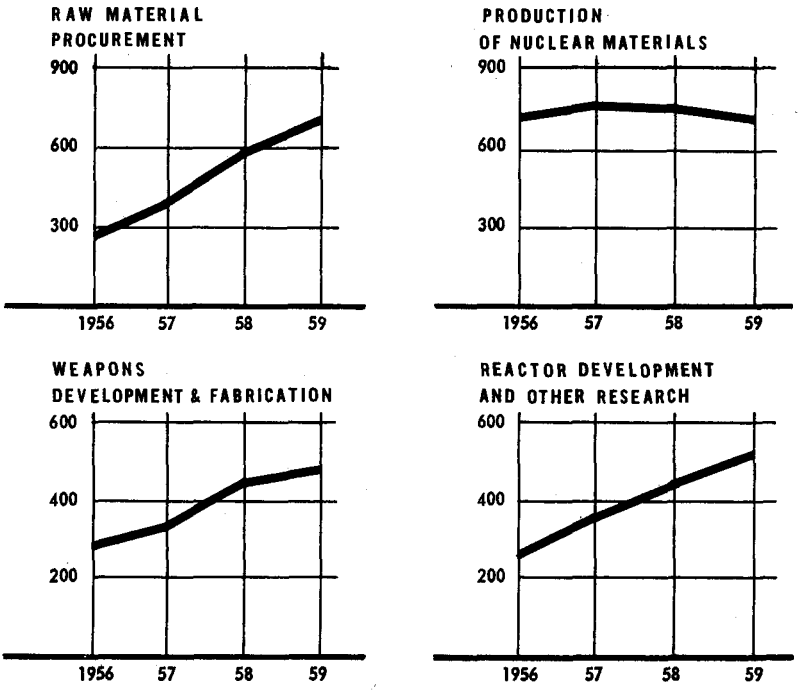
The Annual Financial Report of the Atomic Energy Commission for fiscal year 1959 is transmitted herewith. This report contains financial statements setting forth the financial position of AEC at June 30, 1959, the results of operations for fiscal year 1959, and other unclassified financial information.

DON S. BURROWS
Controller.

Honorable JOHN A. MCCONE, *Chairman.*
Commissioner JOHN F. FLOBERG.
Commissioner JOHN S. GRAHAM.
Commissioner JOHN H. WILLIAMS.

COST TRENDS

millions of dollars



FINANCIAL SUMMARY

The Atomic Energy Commission's intensified efforts in nearly all areas of the atomic energy field brought the net cost of operations to $2.5 billion in fiscal year 1959, an increase of 9 per cent over 1958. Reactor development, high energy physics, controlled thermonuclear energy, peaceful application of nuclear explosives, isotope development, research in the life sciences, weapons development and fabrication, and the procurement of uranium were expanding activities throughout the year.

- Reactor development costs for fiscal year 1959 totaled $356 million of which $105 million was for the development of specific civilian reactor concepts for stationary power use. The cost of the entire reactor research and development effort increased 16 per cent over 1958.

- Physical research programs cost $112 million in fiscal year 1959, an increase of 28 per cent over 1958. Included are thermonuclear research costs of $28 million which increased 46 per cent over 1958 and high energy physics costs of $28 million which increased 44 per cent over fiscal year 1958.

- Research costs in the life sciences amounted to $43 million in fiscal year 1959, an increase over 1958 of 19 per cent.

- Uranium concentrate purchases in fiscal year 1959 totaled $689 million, a 23 per cent increase over fiscal year 1958. Domestic purchases alone totaled $285 million which is an increase of 43 per cent when compared to fiscal year 1958.

- The cost of production of nuclear materials amounted to $713 million in fiscal year 1959, a decrease of $37 million from 1958. This reduction in costs was accomplished even though the quantities of materials produced increased.

- Weapons development and fabrication costs increased 11 per cent as compared to fiscal year 1958. Total cost amounted to $492 million in 1959.

- Financial support of nuclear training to encourage and maintain a high standard of nuclear technology and a growing body of science students amounted to $8 million in fiscal year 1959.

- The sales value of nuclear materials leased to domestic organizations and foreign governments amounted to $72 million at June 30, 1959, an increase over June 30, 1958 of $48 million.

- Radioisotope sales in fiscal year 1959 amounted to $2.5 million. During the year changes were made in the sales price of many of the commonly used radioisotopes. For example, the price of carbon-14 was reduced by 50 per cent.

- Transfers of schools and other community property to local governmental entities amounted to $17 million in fiscal year 1959. Sales of residential and commercial property by HHFA at Oak Ridge, Tennessee and Richland, Washington amounted to $51 million through June 30, 1959.

- Plant construction completed in fiscal year 1959 amounted to $237 million, including $101 million in new reactor development facilities.

- The total estimated cost of plant projects under construction at June 30, 1959 was $831 million. Costs of $250 million have been incurred on these projects through June 30, 1959.

- Additional plant projects of $269 million on which construction had not started were authorized bringing the total completed and authorized plant to $8.1 billion.

- Operating contractor employees numbered 105,195 at June 30, 1959, an increase of 1,905 over June 30, 1958.

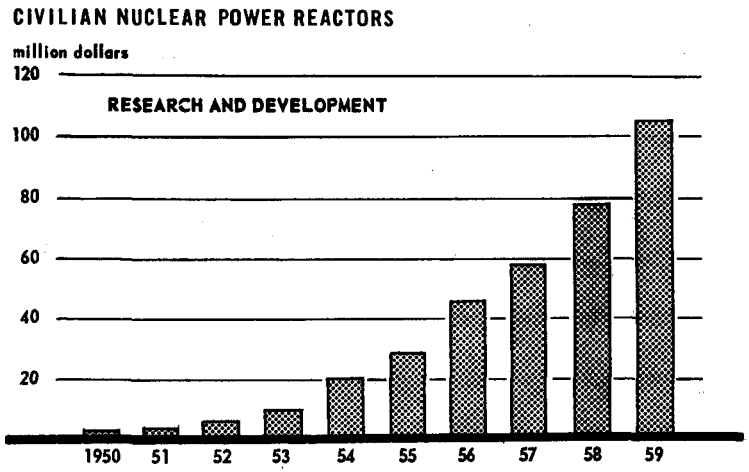
Depreciation expense and the cost of nuclear materials consumed in research and development are included in the operating costs shown in this report.

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CIVILIAN NUCLEAR POWER REACTORS

Nuclear power reactor technology is being advanced through the construction and operation of reactors ranging from small experiments to full-scale power plants. The projects include reactors financed entirely by AEC, cooperative arrangements providing for joint financing by AEC and private industrial organizations, and projects wholly financed by private industry.

AEC research and development costs of specific reactor concepts for stationary power use were $105 million in fiscal year 1959 as compared with $79 million in 1958. The chart below shows the trend of AEC civilian power reactor research and development costs for the ten years ended June 30, 1959.



Cooperative Power Reactor Projects

The table on the next two pages shows AEC and private industry participation in cooperative projects for the development and construction of full-scale nuclear power plants.

COOPERATIVE POWER REACTOR PROJECTS

	Start-up Date / Plant Capacity ekw (net)	Cumulative Costs Through June 30, 1959: AEC Assistance	Cumulative Costs Through June 30, 1959: Participants Cost [1]	Total Estimated Costs: AEC Assistance	Total Estimated Costs: Participants Cost [1]
		(in millions)			
Yankee Atomic Electric Company, Rowe, Massachusetts:	July 1960 110,000 ekw				
Research and development		$ 4.6	$ .2	$ 5.0	$ .4
Nuclear plant construction			9.3		32.5
Conventional plant construction			7.7		22.6
Waiver of fuel use-charges		.1		3.0	
Total		4.7	17.2	8.0	55.5
Power Reactor Development Co., Monroe, Michigan:	Aug. 1960 94,000 ekw				
Research and development			14.6		19.2
Nuclear plant construction			16.6		42.0
Conventional plant construction			4.7		17.0
Waiver of fuel use-charges				3.7	
Total			35.9	3.7	78.2
Rural Cooperative Power Assoc., Elk River, Minnesota:	Jan. 1961 20,000 ekw				
Research and development		.1		2.2	
Nuclear plant construction		1.6		9.4	
Conventional plant construction			2.7		3.4
Total		1.7	2.7	11.6	3.4
City of Piqua, Piqua, Ohio:	Sept. 1961 10,500 ekw				
Research and development		3.0		6.8	
Nuclear plant construction		.2		7.3	
Conventional plant construction			4.0		4.0
Total		3.2	4.0	14.1	4.0
Consumers Public Power District, Hallam, Nebraska:	Nov. 1961 75,000 ekw				
Research and development		8.4		26.2	
Nuclear plant construction		2.3	.1	24.0	5.7
Conventional plant construction			2.2		12.3
Total		10.7	2.3	50.2	18.0
Northern States Power Company, Sioux Falls, South Dakota:	May 1962 62,000 ekw				
Research and development		2.0	1.1	8.5	5.4
Nuclear plant construction					13.6
Conventional plant construction			.5		10.0
Waiver of fuel use-charges				1.8	
Total		2.0	1.6	10.3	29.0

	Start-up Date / Plant Capacity ekw (net)	Cumulative Costs Through June 30, 1959 — AEC Assistance	Cumulative Costs Through June 30, 1959 — Participants Cost [1]	Total Estimated Costs — AEC Assistance	Total Estimated Costs — Participants Cost [1]
		(in millions)			
Carolinas-Virginia Nuclear Power Assoc., Parr, South Carolina:	June 1962 17,000 ekw				
Research and development		$ 1.2	$ .2	$ 13.9	$ 6.7
Nuclear plant construction			.2		22.1
Waiver of fuel use-charges				1.2	
Total		1.2	.4	15.1	28.8
East Central Nuclear Group—Florida West Coast Nuclear Group, Western Florida:	Dec. 1963 50,000 ekw				
Research and development		.3	.5	11.7	17.9
Nuclear plant construction					7.8
Conventional plant construction					17.5
Waiver of fuel use-charges				1.5	
Total		.3	.5	13.2	43.2
Philadelphia Electric Company, York County, Pennsylvania:	Dec. 1963 40,000 ekw				
Research and development				14.5	
Nuclear plant construction					15.0
Conventional plant construction					12.0
Waiver of fuel use-charges				2.5	
Total				17.0	27.0
Fast breeder reactor technology		1.1		4.5	
Summary:	478,500 ekw				
Research and development		20.7	16.6	93.3	49.6
Nuclear plant construction		4.1	26.2	40.7	138.7
Conventional plant construction			21.8		98.8
Waiver of fuel use-charges		.1		13.7	
Total		$24.9	$64.6	$147.7	$287.1

[1] Amounts reported by participants.

The Shippingport Atomic Power Station

The Shippingport Atomic Power Station, the nation's first large-scale nuclear power plant first produced electricity in December 1957. Through June 30, 1959, approximately 4,950 equivalent full power hours of core life had been expended and the plant had generated about 338 million kilowatt hours gross electrical output. Power generated in fiscal year 1959 totaled 294 million kilowatt hours.

The Shippingport plant was constructed to obtain information relative to the design, operation and maintenance of central station nuclear power plants with the primary objective of advancing general power reactor technology. Many special features are incorporated in the reactor plant for this purpose and numerous tests are conducted as part of the Commission's power development program. Consequently, higher plant costs and reduced operating load factors result in power costs which do not represent costs that would be experienced if the plant were designed and operated solely to generate electricity.

The cost of research, development and operation related to the Shippingport Atomic Power Station was $24.8 million in fiscal year 1959. These costs include development of an improved fuel core and refueling methods, plant evaluation studies, other research and development costs, nuclear fuel consumed, depreciation, and other costs of operating the reactor. Income from sale of steam to Duquesne Light Company was $2.2 million.

Privately Financed Nuclear Power Development Projects

The table below lists the nuclear power development projects undertaken by private industry without financial assistance from AEC for the development and construction of reactors and electrical generation facilities.

	Plant Capacity ekw (net)	*Estimated Costs* [1] *(in millions)*	*Start-up Date*
Pressurized light water reactors:			
Consolidated Edison Co. of New York, Inc	255,000	$107.5	1961
Pennsylvania Electric Co., Saxton Station	5,000	8.4	1961
Boiling light water reactors:			
Pacific Gas and Electric Co.—General Electric Company (Vallecitos Boiling Water Reactor)	5,000	3.0	1957
Commonwealth Edison Co.—Nuclear Power Group, Inc. (Dresden Nuclear Power Station)	180,000	61.8	1960
Pacific Gas and Electric Co. (Humboldt Bay Project)	47,500	22.1	1962
Total	492,500	$202.8	

[1] Includes research and development and construction costs as reported by the project owners.

NUCLEAR POWERED MERCHANT SHIPS

AEC costs of research, development and tests of specific nuclear reactors for the application of nuclear power in the maritime service amounted to $4.7 million in fiscal year 1959, as compared with $1.5 million in 1958.

Construction costs for the first nuclear-powered merchant ship, the NS Savannah, are estimated at $45 million with $26 million for the reactor and related facilities being provided by the AEC and $19 million for the vessel hull and outfit being provided by the Maritime Administration. The NS Savannah was launched in July 1959 and is scheduled for completion in 1960. The following table shows the construction costs incurred by the AEC and the Maritime Administration through June 30, 1959.

NS SAVANNAH

	Construction Costs Through June 30, 1959		
	Atomic Energy Commission	Maritime Administration	Total
	(in thousands)		
Nuclear propulsion plant	$8,592		$ 8,592
Vessel hull and outfit		$6,303	6,303
Supporting facilities	64	398	462
Total	$8,656	$6,701	$15,357

Research and development costs including fuel development, engineering services and health physics studies relating to the NS Savannah's pressurized water propulsion reactor amounted to $1,763 thousand in fiscal year 1959.

Research, development and preliminary design work for marine use of the boiling water reactor concept and the gas-cooled reactor concept was continued in 1959. AEC costs were $290 thousand for the boiling water reactor and $2,333 thousand for the gas-cooled reactor. Maritime Administration costs related to the turbine and machinery for the gas-cooled reactor amounted to $1,797 thousand in fiscal year 1959.

The joint AEC-MA program also includes feasibility studies to develop advanced nuclear ships and work to support the operation of nuclear merchant ships. AEC costs in these areas amounted to $351 thousand while MA costs were $786 thousand in fiscal year 1959.

ARMY REACTORS

The following table shows a comparison of Army reactor research and development costs for fiscal years 1959 and 1958, by type of reactor.

	Fiscal Year	
	1959	1958
	(in thousands)	
Pressurized water	$1,706	$ 731
Boiling water	791	548
Gas-cooled	6,344	4,073
General support and advanced studies	535	306
Total	$9,376	$5,658

The pressurized water reactor located at Fort Belvoir, Virginia continued operating throughout the year under rigorous tests and has proved the suitability of this concept for military reactors. Development of an advanced core for use in a larger plant, undertaken at the request of the Department of Defense, is based primarily on the technology developed in this nuclear power plant.

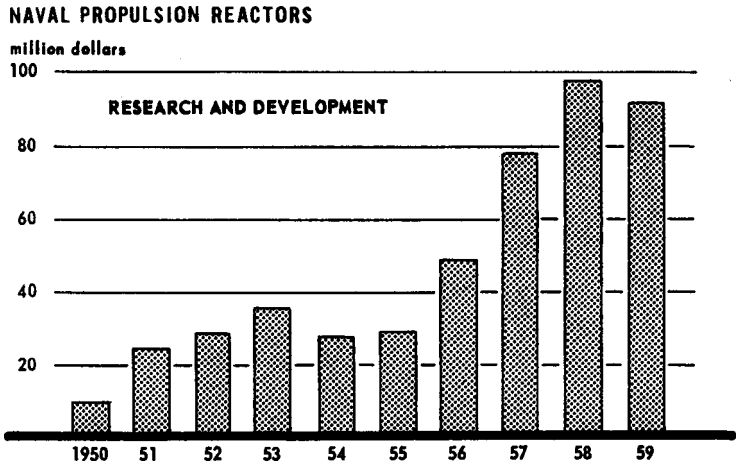
During the year the Fort Belvoir reactor continued to be used for research and development and training of military operators. Nevertheless, the reactor operated at a load factor of 40 per cent for fiscal year 1959, producing 6,480,000 net kilowatt hours of electricity.

A boiling water reactor prototype located at the National Reactor Testing Station, Idaho, achieved criticality on August 12, 1958. The reactor has since been operated to test plant performance and to train military operators.

A gas-cooled reactor experiment located at the National Reactor Testing Station, Idaho, is expected to achieve criticality early in December 1960. The reactor will be used to develop engineering data and to test components for use in a prototype mobile low-power reactor.

NAVAL PROPULSION REACTORS

Fiscal year 1959 costs of research, development and tests of naval propulsion reactors were $91 million, a decrease of $7 million from fiscal year 1958. The trend of costs since fiscal year 1950 is shown in the following chart.



The table below shows costs of research, development and operation of test facilities for submarine and surface ship naval reactors.

	Fiscal Year	
	1959	1958
	(in thousands)	
Submarines	$35,601	$44,864
Large ship prototype	25,826	29,663
Guided missile cruiser	3,011	4,338
Destroyer prototype	13,439	7,763
Operation of test facilities and other costs	12,737	10,636
Total	$90,614	$97,264

The first of two nuclear reactors for the large ship reactor prototype at the National Reactor Testing Station, Idaho, achieved full power operation in January 1959.

The advanced submarine reactor prototype at West Milton, New York operated at full power for the first time on October 1, 1958. A two-reactor nuclear propulsion plant of this type has been installed in the USS Triton which was launched at Groton, Connecticut on August 19, 1958. Construction continued during the year on the destroyer prototype plant at West Milton, New York.

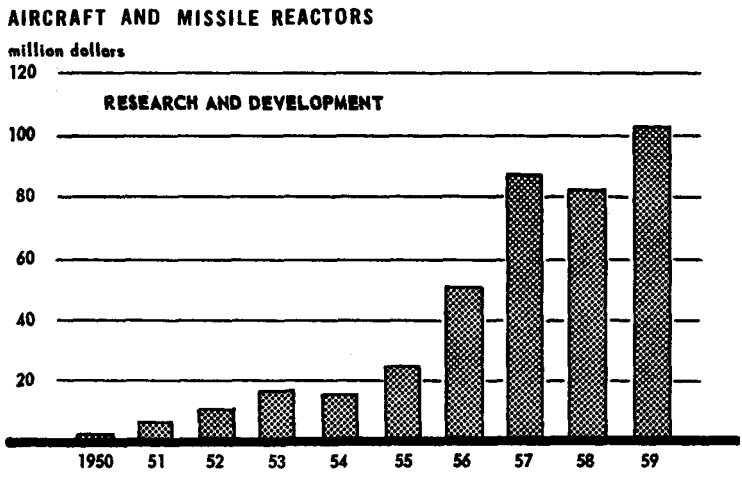
During fiscal year 1959 construction of the small submarine reactor prototype continued at Windsor, Connecticut. The initial reactor core was loaded on March 10, 1959 and initial tests were started.

AIRCRAFT AND MISSILE REACTORS

The cost of development of nuclear power plants for manned aircraft, missiles and auxiliary power sources amounted to $102 million in fiscal year 1959. The trend of research and development costs since fiscal year 1950 is shown in the chart on the next page.

The table below gives a comparison of 1959 and 1958 research and development costs related to manned aircraft and missile propulsion systems and auxiliary power sources.

	Fiscal Year	
	1959	1958
	(in thousands)	
Manned aircraft propulsion:		
Direct cycle reactor	$ 50,361	$43,359
Liquid cycle reactor	16,975	17,532
General research and development	4,486	5,139
Missile propulsion:		
Rocket (Project Rover)	14,010	8,187
Ramjet (Project Pluto)	8,810	4,292
Auxiliary power sources	7,696	3,437
Total	$102,338	$81,946



The major effort in the development of manned aircraft reactors is concentrated on high temperature fuel elements, moderator materials, shielding and various reactor components. General support work continued on advanced moderators, coolants and structural materials.

Research and development on nuclear rocket propulsion (Project Rover) was directed toward the fabrication, assembly and testing of the initial experimental reactor (KIWI-A), while the nuclear ramjet propulsion work (Project Pluto) was on the completion of design of the initial test reactor (TORY II) and the initiation of the hot critical experiments at the Nevada Test Site.

Research and development continued on long-term, light-weight sources of auxiliary power for use in space vehicles and other special applications.

REACTOR DEVELOPMENT COST SUMMARY

	Research and Development Costs [1]			*Construction Costs*		
	Cumulative Through June 30, 1959	*Fiscal Year 1959*	*Fiscal Year 1958*	*Costs Through June 30, 1959*	*Additional Construction Authorized*	*Total*
			(in millions)			
CIVILIAN NUCLEAR POWER REACTORS:						
Pressurized light water	$ 102.9	$ 26.1	$ 17.3	$ 49.2	$ 15.8	$ 65.0
Boiling light water	29.3	5.9	4.4	3.0	12.0	15.0
Heavy water	18.5	10.8	5.9	11.5	18.9	30.4
Organic moderated	15.5	6.1	5.5	1.1	13.9	15.0
Gas cooled	13.3	9.5	3.8		30.0	30.0
Sodium cooled	43.1	15.5	11.6	3.2	25.5	28.7
Fluid fuel	92.9	21.6	22.7	3.3	.8	4.1
Fast breeder	40.5	8.8	6.8	13.5	20.0	33.5
Other studies and development	1.9	1.0	.7	2.4	30.2	32.6
Total	357.9	105.3	78.7	87.2	167.1	254.3
ARMY REACTORS:						
Pressurized water	4.5	1.7	.7	1.7	7.9	9.6
Boiling water	2.4	.8	.6	1.6	.4	2.0
Gas cooled	12.1	6.4	4.1	.4	2.1	2.5
Other studies and development	1.3	.5	.3	.2	.8	1.0
Total	20.3	9.4	5.7	3.9	11.2	15.1
MERCHANT SHIP REACTORS	7.2	4.7	1.5	8.7	17.6	26.3
AIRCRAFT REACTORS:						
Manned aircraft:						
Direct cycle	177.8	50.3	43.4	29.1	20.4	49.5
Liquid cycle	133.9	17.0	17.5	.9		.9
Other studies and development	19.9	4.5	5.1	5.5		5.5
Missile propulsion:						
Rocket (Project Rover)	33.6	14.0	8.2	14.9	15.9	30.8
Ramjet (Project Pluto)	18.6	8.8	4.3	3.2	9.3	12.5
Auxiliary power sources	12.9	7.7	3.4	.4	1.9	2.3
Total	396.7	102.3	81.9	54.0	47.5	101.5
NAVAL REACTORS:						
Submarines	296.0	35.6	44.9	128.9	1.3	130.2
Large ship prototype	96.6	25.9	29.7	33.3	1.7	35.0
Guided missile cruiser	9.1	3.0	4.3			
Destroyer prototype	22.8	13.4	7.8	9.4	26.3	35.7
Other studies and development	43.5	12.7	10.6	6.5	1.3	7.8
Total	468.0	90.6	97.3	178.1	30.6	208.7
GENERAL	376.9	43.3	41.1	[2] 266.0	57.7	323.7
Total reactor development costs	$1,627.0	$355.6	$306.2	$597.9	$331.7	$929.6

[1] Includes depreciation.

[2] Includes equipment.

GENERAL REACTOR RESEARCH AND DEVELOPMENT

Research and development effort on general reactor systems, fuel and fuel cycles, fuel element separations systems, and disposal of radioactive wastes cost $43 million in fiscal year 1959, an increase of $2 million over 1958.

	Fiscal Year	
	1959	1958
	(in thousands)	
Engineering physics and advanced reactor development	$ 9,431	$ 7,289
Reactor fuels and materials development	10,379	6,274
Reactor components development	1,903	1,438
Fuel element separations systems development	6,037	8,138
Waste storage and disposal systems	3,620	3,238
Reactor safety	8,427	8,573
Operations of service facilities and miscellaneous	3,505	6,118
Total	$43,302	$41,068

PEACEFUL APPLICATION OF NUCLEAR EXPLOSIVES

Research and development costs for peaceful application of nuclear explosives (Plowshare) were $2,486 thousand in fiscal year 1959 as compared with $326 thousand in 1958. Preliminary steps are being taken to evaluate applications of nuclear explosives to industrial purposes. This includes studies and research, design and development of prototype devices, and the performance of work preparatory to industrial experiments.

ISOTOPE DEVELOPMENT

AEC is assisting in the establishment of regional university centers where the application of isotopes to solving scientific problems can be studied and is sponsoring research to develop new industrial and commercial uses of isotopes and high-level radiation, and the development of new and improved isotope production processes. The cost in fiscal year 1959 for isotope development work was $2 million.

RESEARCH LABORATORIES

A major portion of AEC research and development is conducted in government-owned laboratories operated by educational institutions and industrial concerns. The investment in completed AEC-owned research facilities at June 30, 1959 was $1.1 billion. These facilities include research and development reactors, accelerators, and general laboratory buildings, equipment and research devices.

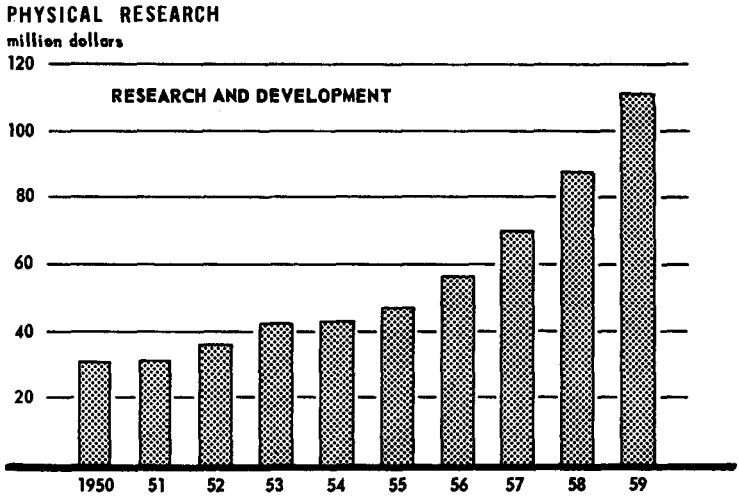
The research and development work conducted in AEC-owned laboratories includes civilian and military reactor design and development; physical research; research in the life sciences; weapons design, development and test; and research to improve nuclear materials production processes and techniques. The seven laboratories shown below are the principal centers of the Commission's research effort. The operating costs of these laboratories together with the costs incurred at other AEC-owned installations and the cost of work performed in facilities owned by universities, industrial and other privately owned organizations are included in the costs of the various research disciplines shown throughout this report.

	Investment in Completed Plant June 30		*Operating Costs Fiscal Year*	
	1959	*1958*	*1959*	*1958*
		(in thousands)		
Los Alamos Scientific Laboratory, Los Alamos, New Mexico	$140,538	$127,822	$ 61,657	$ 57,581
Argonne National Laboratory, Lemont, Illinois	107,499	97,227	38,797	34,067
Oak Ridge National Laboratory, Oak Ridge, Tennessee	135,399	132,292	56,559	52,976
Brookhaven National Laboratory, Upton, Long Island, New York	74,722	60,897	20,634	19,598
Lawrence Radiation Laboratory, Livermore and Berkeley, California	81,147	67,159	74,258	61,344
Bettis Field (including Naval Reactor Facility at NRTS, Idaho), Pittsburgh, Pennsylvania	95,637	52,939	59,779	66,876
Knolls Atomic Power Laboratory, Schenectady, New York	73,434	50,892	34,389	34,997
Total	$708,376	$589,228	$346,073	$327,439

PHYSICAL RESEARCH

Basic investigations of the natural laws of nature, ranging from the nuclear interactions at high energies to the effects of irradiations on the behavior and properties of materials, and research effort to harness thermonuclear energy are the major areas under study in physical research.

The costs related to chemistry, metallurgy, physics and controlled thermonuclear research in fiscal year 1959 were $112 million, an increase of $25 million or 28 per cent over fiscal year 1958. The chart below shows the trend of costs from fiscal year 1950 through 1959.



The following table shows a comparison of costs in major scientific areas for fiscal years 1959 and 1958.

	Fiscal Year	
	1959	*1958*
	(in thousands)	
High energy physics	$ 27,517	$19,146
Controlled thermonuclear research	27,685	19,012
Chemical properties and reactions	19,356	15,957
Nuclear structure and neutron physics	14,518	13,203
Metallurgy and materials research	9,348	7,742
Chemical production processes	5,712	5,751
Physical and chemical methods of isotope separation	2,733	1,972
Computer research and development	2,191	2,042
Other physical research	3,258	2,894
Total	$112,318	$87,719

High Energy Accelerators

High energy accelerators are used to discover and investigate the elementary particles from which all matter is made.

Experimentation in high energy physics requires large numbers of scientific and technical personnel, complex devices to accelerate particles to the desired energy and instruments to measure and control particles traveling at speeds approaching the velocity of light. The eight largest accelerators in operation or under construction in the United States are shown below.

U. S. HIGH ENERGY ACCELERATORS
(One billion electron volts or greater)
(dollar amounts are in millions)

In Operation

	Lawrence Radiation Laboratory (Bevatron)	*Brookhaven National Laboratory (Cosmotron)*	*California Institute of Technology (CIT)*	*Cornell University*
Particle	Proton	Proton	Electron	Electron
Energy	6.2 Bev	3.2 Bev	1.2 Bev	1.2 Bev
Start-up	1953	1952	1953	1953
Plant and equipment at June 30, 1959:				
Original cost	$9.7	$9.3	$1.3	$ [1]
Modifications:				
Completed	3.4		.3	
Not completed	.8	3.7		
Fiscal year 1959 operating cost:				
Cost of operations	1.9	[2]	.2	.2
Research and development	3.1	[3] 3.5	.4	

Under Construction

	Brookhaven Nat'l Lab. (AGS)	*Argonne Nat'l Lab. (ZGS)*	*Harvard U. and MIT (CEA)*	*Princeton U. and Univ. of Pa. (PPA)*
Particle	Proton	Proton	Electron	Proton
Energy	25–30 Bev	12.5 Bev	6 Bev	3 Bev
Start-up	1960	1962	1961	1961
Estimated cost of plant and equipment	$31.0	$29.0	$11.6	$11.2
Estimated annual operating costs:				
Operating	3.0	3.7	1.9	1.4
Research and development	3.4	3.8	2.8	2.3

[1] Owned by the Office of Naval Research.
[2] Shut down for repairs in fiscal year 1959.
[3] Includes cost of repairs.

Controlled Thermonuclear Research

In fiscal year 1959 the cost of the research effort to harness thermonuclear energy for the production of power was $28 million, an increase of $9 million or 46 per cent over 1958. Four different major approaches are being pursued in the effort to develop a device to heat deuterium or deuterium-tritium gas to the levels required for thermonuclear reactions and to contain the reacting plasma for an adequate time.

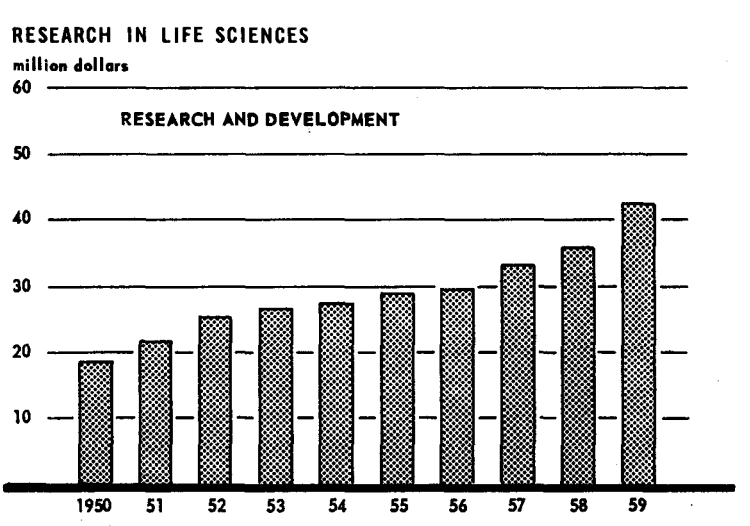
Laboratory	*Approach*	*Fiscal Year 1959*			*Cumulative Costs Through June 30, 1959*
		Scientific Effort	*Research and Development Costs*	*Construction Costs*	
		(man-years)	*(in thousands)*		
Lawrence Radiation Laboratory.	Pinch and collapse, magnetic mirror and astron.	68	$ 6,698	$ 879	$26,972
Los Alamos Scientific Laboratory.	Pinch and collapse	42	3,047	281	10,872
Oak Ridge National Laboratory.	Hot-ion trapping	84	4,182	700	10,251
Princeton University	Stellarator	93	12,076	6,016	30,343
Other sites	General research	34	1,682		4,915
Total		321	$27,685	$7,876	$83,353

The stellarator approach at Princeton University represents 51 per cent of the costs incurred in fiscal year 1959 for the controlled thermonuclear program. These costs include research, development and fabrication of the model "C" stellarator.

RESEARCH IN THE LIFE SCIENCES

The effects of exposure to radiation hazards and the beneficial medical uses of radioactive materials require intensive research in the evaluation, study and determination of standards for permissible exposure to radiation under various conditions, treatment of radiation injury, radiation protection and measurement of radiation fallout.

The cost of research in life sciences amounted to $43 million in fiscal year 1959, an increase of $7 million or 19 per cent over 1958. The chart on the next page shows the trend of these costs from fiscal year 1950 through 1959.



The following table gives a comparison of costs and scientific effort in the major areas of investigation in fiscal years 1959 and 1958.

	Research Costs.		*Scientific Effort*	
	FY 1959	*FY 1958*	*FY 1959*	*FY 1958*
	(in thousands)		*(man-years)*	
Development of radiation standards:				
Permissible exposure levels	$18,614	$15,809	919	854
Environmental contamination and waste disposal	4,191	2,722	214	176
Treatment of radiation injury	3,493	3,166	140	119
Dosimetry and instrumentation	1,992	2,037	95	94
Radiation protection	1,520	871	6	4
Radiation measurement	1,085	666	29	18
	30,895	25,271	1,403	1,265
Sampling and analysis of fallout	2,474	1,833	121	100
General life science research	9,412	8,854	426	360
Total	$42,781	$35,958	1,950	1,725

EDUCATION AND TRAINING

The continued financial assistance to colleges, universities, graduate students and high school teachers, in order to encourage and maintain a high standard of nuclear technology and a growing body of science students and technicians, cost $8 million in fiscal year 1959. The table below shows the type of assistance under this program and gives a comparison with fiscal year 1958.

	Fiscal Year	
	1959	1958
	(in thousands)	
Grants for purchase of equipment	$3,894	$ 6,580
Operation of schools	1,675	1,800
Training of teachers	665	665
Fellowships	924	620
Development of pedagogical tools	54	97
Other costs	375	400
	7,587	10,162
Use charges waived	183	91
Total	$7,770	$10,253

Grants for purchase of equipment. AEC provides financial assistance to universities and colleges for the purchase of nuclear equipment and materials for use in teaching nuclear physics, radiochemistry, reactor physics, reactor engineering, fuel metallurgy, chemical processing of fuel materials and training in the life sciences. The equipment includes reactors, subcritical assemblies, reactor simulators, heat transfer loops, metallurgical furnaces, solvent extraction columns and similar items. In fiscal year 1959 grants of $3,894 thousand were made to 128 institutions.

Operation of schools. AEC sponsors training schools and courses for qualified scientific students in fields of reactor and radioisotope technology, life science research and radiation health protection. Tuiton is not charged for employees of AEC contractors and other Federal agencies enrolled in these schools and courses.

TRAINING SCHOOLS AND COURSES, FISCAL YEAR 1959

	Number of Students			Operating Cost
	Foreign	Domestic	Total	(in thousands)
International Institute of Nuclear Studies and Engineering	104	12	116	$ 735
Oak Ridge Institute of Nuclear Studies	64	240	304	360
Puerto Rico Nuclear Center	20	69	89	337
Shippingport Supervisors Course	4	20	24	96
Reactor Hazards and Supervision Course	26		26	79
Monitoring Techniques Course	11		11	3
Oak Ridge School of Reactor Technology		60	60	65
Total	229	401	630	$1,675

Training of teachers. Attendance at summer institutes increased from 380 in fiscal year 1958 to 510 in fiscal year 1959. Summer institutes were established in 1956 for the teaching of radiation biology to high school science teachers and reactor technology to university faculty members.

Fellowships. To permit graduate work in nuclear aspects of health physics, industrial hygiene and medicine, engineering and other areas of scientific reseach, fellowships are granted by AEC in amounts of $1,600 to $5,000 per year, plus an allowance for dependents. For the 1958–59 academic year 215 fellows were in attendance at 35 universities under this program.

Nuclear materials loaned. Neutron sources, reject natural uranium slugs and other nuclear material not available commercially are loaned without charge to schools having AEC licenses to possess these materials. The sales value of such materials on loan to educational institutions at June 30, 1959, was $7,994 thousand and the use charges waived in fiscal year 1959 were $183 thousand.

SALE OF MATERIAL AND OTHER INCOME

Source and special nuclear material with licensees and foreign governments increased to $72 million at June 30, 1959 from $24 million at June 30, 1958. These amounts represent the established sales price of the material. The following table shows the sales value of material by type of licensee at June 30, 1959 and the amount of material subject to use charges versus that on which use charges are waived.

SOURCE AND SPECIAL NUCLEAR MATERIALS LEASED AT JUNE 30, 1959

	Total Inventory [1]	*Subject to 4% Use Charge*	*Not Subject to Use Charge*
		(in thousands)	
Domestic:			
Industrial organizations . .	$58,909	$37,080	$21,829
Educational and research institutions	8,355		8,355
Other Federal agencies . . .	1,354		1,354
Foreign countries	3,389	3,389	
Total.	$72,007	$40,469	$31,538

[1] At established prices.

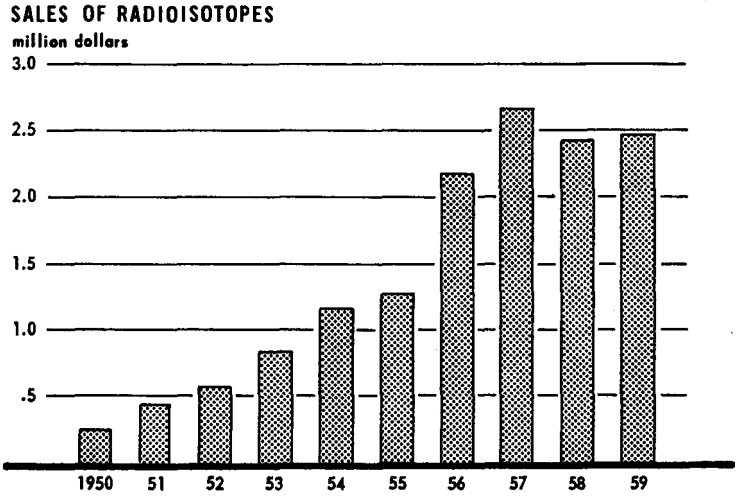
Income from sales of materials, services and other sources for fiscal year 1959 amounted to $14 million. The table on the next page shows the major sources of this income.

SALES AND OTHER INCOME

	Fiscal Year 1959 (*in thousands*)
Sale of source and nuclear materials	$ 1,353
Sale of heavy water	3,327
Sale of radioisotopes	2,498
Sale of steam or heat	2,223
Income from services	1,032
Use-charges earned	1,058
Other income	2,880
Total	$14,371

Sales of Radioisotopes

Radioisotope sales in fiscal year 1959 amounted to $2.5 million. Foreign sales of radioisotopes increased to $414 thousand, 25 per cent more than in fiscal year 1958.



The Oak Ridge Multicurie Fission Product Pilot Plant was placed in operation on August 7, 1958, increasing the availability of radioisotopes cesium-137, strontium-90, cerium-144, and promethium-147. During the year AEC also agreed to increase the quantity of krypton-85 and tritium available to industry.

The table below shows a comparison of sales of radioisotopes for fiscal years 1959 and 1958:

	Quantity		*Sales Dollars* [1]	
	1959	*1958*	*1959*	*1958*
	(curies)		*(in thousands)*	
Cobalt-60	208,769	133,000	$ 659	$ 651
Iodine-131	748	1,072	325	518
Phosphorus-32	165	197	171	241
Polonium-210	4,882	1,172	208	181
Carbon-14	12	8	263	215
Cesium-137	13,885	5,409	27	149
Krypton-85	2,089	2,032	35	34
Tritium	15,804	3,334	31	25
Iridium-192	6,203	5,516	20	22
Strontium-90	88	10	1	4
Promethium-147	501	189	2	5
All others			756	381
Total			$2,498	$2,426

[1] Includes research discounts granted to users under the AEC radioisotope research support program of $304 thousand in 1959 and $253 thousand in 1958.

The following table shows domestic and foreign sales of radioisotopes for fiscal year 1959:

	Quantity		*Sales Dollars*	
	Domestic	*Foreign*	*Domestic*	*Foreign*
	(curies)		*(in thousands)*	
Cobalt-60	149,543	59,226	$ 426	$233
Iodine-131	714	34	311	14
Phosphorus-32	157	8	163	8
Polonium-210	3,850	1,032	174	34
Carbon-14	12		262	1
Cesium-137	8,465	5,420	16	11
Krypton-85	2,033	56	34	1
Tritium	15,294	510	30	1
Iridium-192		6,203		20
Strontium-90	88		1	
Promethium-147	501		2	
All others			665	91
Total			$2,084	$414

AEC reduced the price of carbon-14 by 50 per cent on June 1, 1959. The new price is $13 per millicurie or fraction of a millicurie. The former prices ranged from $22 to $28, depending upon the quantity of carbon-14 purchased. On June 1, 1959, the sales price of chlorine-36, thallium-204, iridium-192 and iron-59 were reduced, while prices were increased for calcium-45, copper-64, gold-198, sodium-24 and yttrium-90. The sales price of iodine-131 was reduced 20 to 25 per cent effective August 1, 1959. The new price is 30 to 40 cents per millicurie depending upon the quantity purchased.

The number of licenses granted for use of radioisotopes increased 36 percent from June 30, 1958 to June 30, 1959. The following table gives a comparison of the number of licensees by type of organization.

ORGANIZATIONS WITH RADIOISOTOPE LICENSES

	June 30	
	1959	*1958*
Medical institutions and physicians	2,098	1,723
Industrial organizations	1,511	1,298
Federal and state laboratories	1,027	350
Colleges and universities	269	232
High schools, foundations, and other institutions	123	88
Total	5,028	3,691

INTERNATIONAL COOPERATION

The United States Government has entered into a joint program with the European Atomic Energy Community (EURATOM), consisting of Belgium, France, Italy, Luxembourg, The Netherlands and West Germany, to provide 1,000,000 electrical kilowatts of nuclear power in the Community with reactors of United States design over the next four to six years. AEC's participation consists of a joint program of research and development and a deferred payment plan for reactor fuel and guarantees as to fuel life and fabrication cost. Ten million dollars has been authorized for expenditure by AEC through fiscal year 1960 under the joint United States-Euratom research and development program.

To assist foreign nations in the advancement of nuclear technology, AEC also established a deferred payment plan for enriched power reactor fuel to be furnished to foreign countries and international organizations under agreements for cooperation. This arrangement provides for nuclear power projects not to exceed a combined capacity of 500,000 electrical kilowatts. These projects must be scheduled for operation before June 30, 1964, and involve United States designs and a substantial portion of United States components. A proposed nuclear power plant in Italy has been approved by the United States for benefits under the deferred payment plan. With the exception of this project, however, the 500,000 electrical kilowatt deferred payment plan is available only to non-Euratom countries.

The United States concluded an agreement for cooperation with the International Atomic Energy Agency (IAEA) under which the latter may draw from the 5,000 kilograms of U-235 offered by President Eisenhower in 1956. These materials are for distribution by the IAEA to member states for use, under Agency safeguards, in nuclear research and power projects.

COMMUNITIES

Public Law 221 approved in 1955 authorized the sale, to occupants or other interested parties, of the houses, apartments, business buildings and land in the Oak Ridge, Tennessee and Richland, Washington communities. The Act also provided for transferring municipal facilities and utilities to the city governments or for selling them to other organizations. Executive Order 10657 issued in 1956 placed responsibility for real estate sales and financing under the Act with the Administrator of the Housing and Home Finance Agency.

Through June 30, 1959, HHFA sales of housing and other AEC property amounted to $51 million and transfers of municipal and school facilities valued at $18 million were made to local governmental entities. As a result of the sale and transfer of community property, revenues for fiscal year 1959 decreased $2.3 million from 1958 and operating costs decreased $3.6 million. The following tables show a comparison of the results of community operations.

COMMUNITY OPERATIONS
(in millions)

Service	Cost		Revenues	
	1959	1958	1959	1958
Municipal	$11.1	$12.4	$ 1.7	$ 1.3
Utilities	3.6	3.3	4.2	4.0
Real estate	5.1	7.5	5.4	8.4
Hospital	3.3	3.5	1.9	1.8
Total	$23.1	$26.7	$13.2	$15.5

Community	Net Cost FY 1959	Net Cost FY 1958	Increase (Decrease)
Oak Ridge, Tennessee	$3.5	$ 4.2	$ (.7)
Los Alamos, New Mexico	3.6	3.5	.1
Richland, Washington	2.7	3.5	(.8)
Sandia, New Mexico	.1		.1
Total	$9.9	$11.2	$(1.3)

The status of community property sales by HHFA at June 30, 1959 was as follows.

	Total	Residential		Commercial Property	Nonprofit Organizations
		Vacant Lots	Houses		
	(dollars are in thousands)				
Oak Ridge, Tennessee:					
Offered for sale	6,468	1,604	4,625	206	33
Number of units sold	5,553	869	4,510	145	29
Net book value	$26,139	$ 535	$21,723	$3,479	$402
Sales price	$21,150	$ 966	$17,528	$2,569	$ 87
Richland, Washington:					
Offered for sale	5,425	253	4,847	314	11
Number of units sold	4,863	192	4,659	10	2
Net book value	$32,949	$ 150	$30,602	$2,186	$ 11
Sales price	$29,625	$ 293	$26,925	$2,405	$ 2

The appraised value of each property offered for sale has been posted in the community by the Federal Housing Administration. Sales of single and duplex houses are made at appraised value, less a discount of 15 per cent to priority purchasers and 10 per cent to those who do not avail themselves of the indemnity provisions contained in Sections 63 through 66 of the Act.

Transfers of municipal and school facilities to local governmental entities during fiscal year 1959 were as follows.

	Cost	*Accumulated Depreciation*	*Net Book Value*
		(in thousands)	
Oak Ridge, Tennessee:			
City of Oak Ridge—Municipal street system	$10,380	$5,665	$ 4,715
Richland, Washington:			
City of Richland—City hall and fire stations	1,375	202	1,173
Richland School District	15,265	4,075	11,190
Total	$27,020	$9,942	$17,078

Additional transfers of community property will be made amounting to approximately $34 million at Oak Ridge and $28 million at Richland.

AEC's investment in completed community facilities at June 30, 1959 was as follows.

	Total	*Oak Ridge*	*Los Alamos*	*Richland*	*Other*
			(in millions)		
Investment—June 30, 1958	$229.2	$82.1	$72.1	$68.1	$6.9
Additions—Fiscal Year 1959	5.7	.6	1.5	3.5	.1
Less—Sales	(26.6)	(6.2)		(20.4)	
Transfers	(27.0)	(10.4)		(16.6)	
Retirements	(2.3)	(.5)	(.7)	(1.0)	(.1)
Investment—June 30, 1959	179.0	65.6	72.9	33.6	6.9
Accumulated depreciation	(56.9)	(23.8)	(19.5)	(11.7)	(1.9)
Net Investment—June 30, 1959	$122.1	$41.8	$53.4	$21.9	$5.0

The principal additions completed during the year were school facilities at Los Alamos, New Mexico, and utility facilities at Oak Ridge, Tennessee and Richland, Washington.

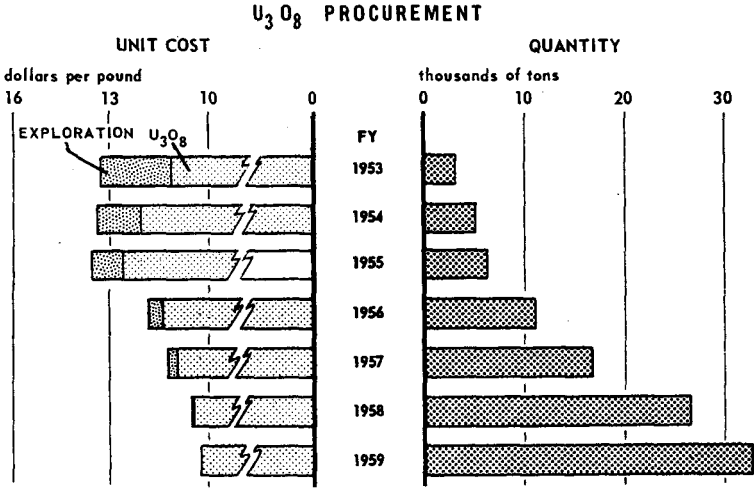
PRODUCTION OF NUCLEAR MATERIALS

The cost of production of nuclear materials, excluding the cost of raw materials used, was $713 million in fiscal year 1959, a reduction of $37 million from 1958. This reduction in costs was accomplished even though the quantities of materials produced increased. The investment in feed materials plants, gaseous diffusion facilities, and production reactors and separations facilities was $4.2 billion at June 30, 1959.

PROCUREMENT OF RAW MATERIALS

Uranium Concentrates (U_3O_8)

The chart below shows the unit cost and quantity of U_3O_8 procured in fiscal years 1953 through 1959.



The cost and quantities of uranium concentrates (U_3O_8) procured for fiscal years 1959 and 1958 are shown below.

	Total Cost		*Quantity*		*Average Cost*	
	1959	*1958*	*1959*	*1958*	*1959*	*1958*
	(in thousands)		*(tons U_3O_8)*		*(dollars per lb)*	
Domestic	$285,168	$199,995	15,162	10,244	$ 9.40	$ 9.76
Canadian	293,618	204,104	13,506	9,475	10.87	10.77
Overseas	110,294	156,519	4,658	6,657	11.84	11.75
Total	$689,080	$560,618	33,326	26,376	$10.34	$10.63

The costs shown above represent all costs incurred by the Commission in connection with procurement of uranium concentrates, including bonus payments to miners for the initial production of ore. The prices paid to suppliers for U_3O_8 produced in privately owned domestic mills averaged $9.18 per pound in fiscal year 1959 as compared with $9.58 in fiscal year 1958.

An important factor in the price is the yield of U_3O_8 for each ton of ore milled by the supplier. The following table shows the average yield and the approximate number of tons of ore milled for AEC procurement.

URANIUM PROCUREMENT STATISTICS

	Domestic	*Canadian*	*Overseas*[1]
Ores milled for AEC	6,700,000 tons	12,300,000 tons	13,900,000 tons
U_3O_8 procurement by AEC	15,162 tons	13,506 tons	4,658 tons
U_3O_8 per ton of ore milled	4.5 lbs	2.2 lbs	0.7 lb

[1] Includes South African gold ores of which uranium is a byproduct.

The AEC-owned processing mill at Monticello, Utah is scheduled to be closed January 1, 1960. It is expected that the ore produced in the Monticello area will be processed by privately-owned mills.

From the beginning of the Atomic Energy program to July 1, 1955, 83 per cent of the uranium purchased by the United States came from foreign sources. Between July 1, 1955 and June 30, 1962, 47 per cent of AEC's uranium purchases will be from domestic sources and 53 per cent from foreign. Of the outstanding contracts and commitments for the period June 30, 1962 through December 31, 1966, 84 per cent of the uranium which the AEC now is committed to buy will come from domestic sources.

Other Raw Materials

Other raw material costs were $11 million in fiscal year 1959 as compared with $36 million in 1958. The AEC uranium ore stockpile was reduced by usage at AEC's Monticello plant and sales to privately-owned processing mills to $21 million at June 30, 1959 from $34 million at June 30, 1958.

WEAPONS DEVELOPMENT AND FABRICATION

The cost of development, fabrication and testing of weapons, weapons parts, and weapons storage and surveillance was $492 million in fiscal year 1959 as compared with $444 million in fiscal year 1958. These amounts exclude the cost of source and special nuclear materials contained in weapons or consumed in weapons research and tests. The investment in completed plant and equipment for weapons production and storage at June 30, 1959 was $785 million.

Financial Statements

UNITED STATES ATOMIC ENERGY COMMISSION
COMPARATIVE BALANCE SHEET

Assets	*June 30, 1959*	*June 30, 1958*
	(in thousands)	
CASH:		
In U. S. Treasury	$1,629,550	$1,505,834
With integrated contractors	25,628	21,429
	1,655,178	1,527,263
WORKING CAPITAL ADVANCES:		
With other Federal agencies	23,142	42,758
With nonintegrated contractors	2,328	2,679
	25,470	45,437
ACCOUNTS RECEIVABLE:		
From other Federal agencies	1,124	1,594
Other, less allowance for uncollectible accounts of $183 thousand in 1959 and $129 thousand in 1958	12,246	21,498
	13,370	23,092
INVENTORIES:		
Source and nuclear materials in research and leased	402,390	346,443
Special reactor material	112,937	107,611
Stores, less allowance for loss of $10,624 thousand in 1959 and $11,148 thousand in 1958	90,326	89,537
Isotopes	8,634	7,644
Other special materials	18,067	18,439
	632,354	569,674
PLANT:		
Completed plant and equipment	7,043,027	6,839,651
Less—Accumulated depreciation	1,900,265	1,685,109
	5,142,762	5,154,542
Construction work in progress	249,757	271,146
	5,392,519	5,425,688
COLLATERAL FUNDS AND OTHER DEPOSITS	20,694	21,007
PREPAYMENTS	22,593	40,623
TOTAL ASSETS	$7,762,178	$7,652,784

Liabilities and AEC Equity	June 30, 1959	June 30, 1958
	(in thousands)	
LIABILITIES:		
Accounts payable and accrued expenses	$ 229,409	$ 278,863
Advances from other Federal agencies	158,518	159,629
Funds held for others	9,608	8,570
Deferred credits	1,077	883
TOTAL LIABILITIES	398,612	447,945
AEC EQUITY, JULY 1	7,204,839	7,082,799
Additions:		
Funds appropriated—net	2,635,335	2,333,974
Nonreimbursable transfers from other Federal agencies	15,625	1,354
	2,650,960	2,335,328
Deductions:		
Net cost of operations—after special items	2,524,516	2,290,056
Less—change in inventories of research and leased materials	55,947	105,184
	2,468,569	2,184,872
Nonreimbursable transfers to other Federal agencies	23,242	27,620
Funds returned to U. S. Treasury	422	796
	2,492,233	2,213,288
AEC EQUITY, JUNE 30	7,363,566	7,204,839
TOTAL LIABILITIES AND AEC EQUITY	$7,762,178	$7,652,784

The notes on the following page are an integral part of this statement.

NOTES TO THE BALANCE SHEET

1. For security reasons certain inventories 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, 1959, this silver had a value of $59.2 million.
3. In addition to the liabilities shown on the balance sheet, AEC had at June 30, 1959:
   a. commitments related to the procurement of source materials estimated at $3.8 billion;
   b. contingent liabilities related to contracts for the supply of electric power for the Oak Ridge, Paducah and Portsmouth production facilities. If cancellation notice had been given at June 30, 1959 the estimated liabilities would have amounted to $329 million;
   c. contingent liabilities as guarantor of loans to the extent of $81 million;
   d. contingent liabilities for claims against the Federal Government or AEC contractors of approximately $10.5 million;
   e. commitments for accrued annual leave of AEC employees of $6.2 million; and
   f. commitments applicable to future periods represented by unpaid obligations of $897 million.

AUDITOR'S STATEMENT

We have examined the balance sheet of the Atomic Energy Commission as at June 30, 1959 and the accompanying statement of operations for the fiscal year then ended. Our examination was made in accordance with generally accepted auditing standards and accordingly included verification of selected transactions, tests of accounting records and such other auditing procedures as contemplated by the AEC internal audit program and considered necessary in the circumstances. We did not verify the value, or related quantities, of source and nuclear materials appearing in the balance sheet; it should be noted, however, that there exist within AEC separate programs of surveillance for these materials.

In my opinion, subject to the foregoing, the statements mentioned above present fairly the assets, liabilities and equity of the Atomic Energy Commission as at June 30, 1959 and the operating costs for the fiscal year then ended, in conformity with AEC policies, contractual provisions and generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Charles F. Schenk

Assistant Controller for Auditing.

September 30, 1959

UNITED STATES ATOMIC ENERGY COMMISSION

COMPARATIVE STATEMENT OF OPERATIONS

(includes depreciation)

	Fiscal Year Ended	
	June 30, 1959	*June 30, 1958*
	(in thousands)	
Production costs:		
Procurement of raw materials	$ 699,996	$ 596,391
Production of nuclear materials	713,247	750,178
Weapons development and fabrication	491,981	443,536
	1,905,224	1,790,105
Development of nuclear reactors:		
Civilian nuclear power development	105,233	78,732
Naval propulsion	90,614	97,264
Aircraft and missile reactors	102,338	81,946
Army reactors	9,376	5,658
Merchant ship	4,737	1,557
General research and development	43,302	41,068
	355,600	306,225
Research costs:		
Physical research	112,318	87,719
Research in the life sciences	42,781	35,958
Peaceful application of nuclear explosives	2,486	326
Isotope development	2,077	289
	159,662	124,292
Community operations:		
Expenses	23,081	26,676
Revenues	(13,189)	(15,514)
	9,892	11,162
Education and training	7,587	10,162
AEC administrative expenses	50,135	46,435
Security investigations	6,995	7,596
Cost of materials sold and other expenses	15,924	18,803
Sales of materials and other income	(14,371)	(16,191)
Net cost of operations [1]	2,496,648	2,298,589
Special items:		
Transfer of community property	17,078	
Obsolete facilities written off	15,969	16,975
Adjustments to costs of prior years—net	(5,179)	(25,508)
Net cost of operations—after special items	$2,524,516	$2,290,056

[1] Includes costs incurred for procurement of raw materials and production of special nuclear materials and weapons parts and assemblies. Includes depreciation of $285 million in 1959 and $275 million in 1958.

U. S. GOVERNMENT INVESTMENT IN THE ATOMIC ENERGY PROGRAM

From June 1940 through June 1959

	Amount (in millions)	
Appropriation payments—net:		
National Defense Research Council	$ .5	
Office of Scientific Research and Development	14.6	
War Department (including Manhattan Engineer District):		
Fiscal year 1943	77.1	
Fiscal year 1944	730.3	
Fiscal year 1945	858.6	
Fiscal year 1946	366.3	
Fiscal year 1947—part	186.0	
		$2,233.4
Atomic Energy Commission:		
Fiscal year 1947—part	146.1	
Fiscal year 1948	477.6	
Fiscal year 1949	627.3	
Fiscal year 1950	534.3	
Fiscal year 1951	920.5	
Fiscal year 1952	1,669.4	
Fiscal year 1953	1,812.7	
Fiscal year 1954	1,930.5	
Fiscal year 1955	1,861.9	
Fiscal year 1956	1,633.5	
Fiscal year 1957	1,931.6	
Fiscal year 1958	2,267.9	
Fiscal year 1959	2,541.2	
		18,354.5
Total payments—net		20,587.9
Unexpended balance of appropriations, June 30, 1959 [1]		1,460.7
Unexpended balance of appropriations transferred to other Federal agencies		22.0
Total funds appropriated		22,070.6
Less:		
Collections paid to U. S. Treasury	54.0	
Property and services transferred to other Federal agencies without reimbursement, net of such transfers received from other Federal agencies	88.6	
Cost of operations including depreciation and obsolescence from June 1940 through June 30, 1959	14,564.4	
		14,707.0
AEC Equity at June 30, 1959 as shown on Balance Sheet		$7,363.6

[1] Appropriations of $2,652 million for fiscal year 1960 were approved August 18, 1959.

Ten-Year Summary of Financial Data

533136—60 ——40

UNITED STATES ATOMIC

TEN-YEAR SUMMARY

(in thousands

	1959	*1958*	*1957*	*1956*
Cost of operations [1]	$2,496,648	$2,298,589	$1,918,258	$1,607,973
Procurement of raw materials	699,996	596,391	397,813	278,946
Production of nuclear materials	713,247	750,178	762,815	730,972
Weapons development and fabrication	491,981	443,536	337,183	280,765
Development of nuclear reactors	355,600	306,225	255,667	168,853
Civilian	105,233	78,732	58,196	45,880
Military	202,328	184,868	168,729	101,410
Other	48,039	42,625	28,742	21,563
Physical Research	112,318	87,719	69,657	56,547
Controlled thermonuclear	27,685	19,012	11,128	7,066
High energy physics	27,517	19,146	17,595	11,981
Other	57,116	49,561	40,934	37,500
Research in life sciences	42,781	35,958	33,148	29,849
Community operations—net	9,892	11,162	8,897	8,954
Administrative expenses	50,135	46,435	38,499	38,195
Other expenses and income—net	20,698	20,985	14,579	14,892
Plant construction and equipment costs incurred during the year	$ 298,979	$ 289,744	$ 317,022	$ 301,682
Total AEC assets, excluding inventories of certain products at June 30	$7,762,178	$7,652,784	$7,397,911	$7,368,272
Plant investment at June 30 (gross)	$7,292,784	$7,110,797	$6,907,896	$6,713,061
Production plants	5,552,646	5,494,440	5,392,464	5,212,776
Research and development facilities	1,124,543	937,682	792,633	753,468
Communities	179,013	229,197	267,293	299,292
Other	186,825	178,332	144,289	200,501
Plant construction in progress at June 30	249,757	271,146	311,217	247,024
Funds appropriated—net	$2,635,335	$2,333,974	$1,898,700	$ 834,227
Operations	2,385,406	2,225,470	1,740,400	[2] 1,146,400
Plant acquisition and construction	249,929	108,504	158,300	[4] (312,173)
Employment at June 30	121,858	120,973	119,368	110,143
AEC employees	6,785	7,021	6,823	6,583
Operating contractor employees	105,195	103,290	98,176	90,238
Construction contractor employees	9,878	10,662	14,369	13,322

[1] Includes depreciation.

[2] Includes transfer to operations of $571 million appropriated in prior years as plant and equipment funds.

ENERGY COMMISSION

OF FINANCIAL DATA

of dollars)

1955	*1954*	*1953*	*1952*	*1951*	*1950*
$1,289,535	$1,039,178	$ 904,596	$ 684,181	$ 494,638	$ 414,766
193,586	142,793	82,153	72,510	47,490	38,600
588,445	409,735	318,255	205,746	140,822	129,944
258,706	250,025	257,488	229,178	163,594	111,970
114,557	99,334	104,091	64,448	44,472	31,530
28,064	20,103	10,201	5,903	3,202	1,288
53,011	42,010	53,209	39,501	30,011	9,148
33,482	37,221	40,681	19,044	11,259	21,094
48,221	43,630	41,846	34,671	29,833	28,885
4,718	1,741	800	150	50	
8,583	7,802	8,644	5,948	5,262	5,010
34,920	34,087	32,402	28,573	24,521	23,875
28,898	26,974	26,295	24,536	21,245	17,806
10,321	11,822	15,157	16,363	17,322	19,895
34,027	34,671	35,514	31,432	24,541	22,868
12,774	20,194	23,797	5,297	5,319	13,268
$ 842,504	$1,215,141	$1,125,579	$1,082,174	$ 459,192	$ 256,126
$8,077,836	$8,144,414	$8,014,455	$4,692,584	$3,680,333	$2,216,487
$6,487,301	$5,705,405	$4,579,089	$3,496,957	$2,516,014	$2,104,433
4,645,750	2,957,784	2,118,137	1,327,335	1,287,447	1,251,022
707,107	616,548	548,009	338,836	233,702	184,393
299,290	300,248	298,454	287,999	281,727	261,831
206,202	215,691	184,913	179,705	121,936	112,399
628,952	1,615,134	1,429,576	1,363,082	591,202	294,788
$1,209,860	$1,042,492	$4,136,476	$1,605,756	$2,032,143	$ 702,931
1,098,978	886,483	808,935			
110,882	156,009	3,327,541			
112,555	141,949	148,799	149,371	99,126	63,739
6,013	6,123	6,894	6,662	5,646	4,941
82,936	73,312	71,775	58,101	47,745	39,095
23,606	62,514	70,130	84,608	45,735	19,703

Plant and Equipment

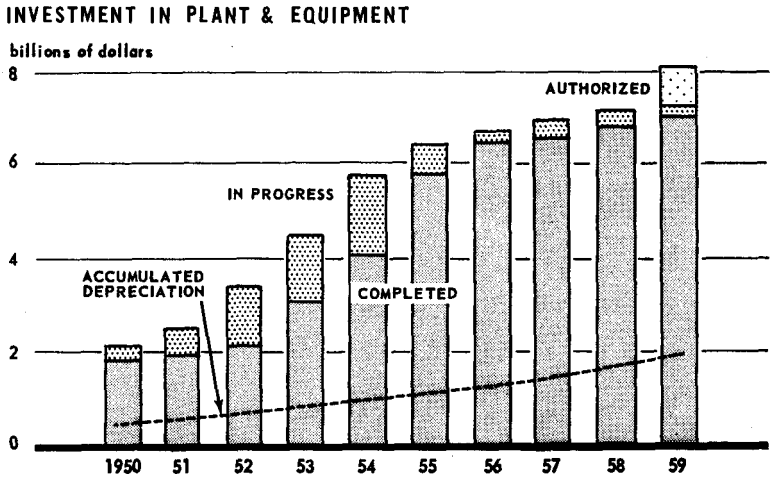
PLANT AND EQUIPMENT

AEC-owned plant and equipment includes plants for the preparation of feed materials; gaseous diffusion plants for the separation of the fissionable isotope uranium-235 from the stable isotope uranium-238; reactors for the production of plutonium, isotopes and other reactor products; facilities for the fabrication and test of weapons; reactors for testing materials and equipment components; reactor prototypes; and research laboratories. AEC-owned completed plant, at cost, increased to $7.0 billion at June 30, 1959 from $6.8 billion at June 30, 1958.

The estimated cost of plant under construction or authorized at June 30, 1959 totaled $1.1 [1] billion. Costs incurred through June 30, 1959 on plant under construction amounted to $250 million, leaving the estimated costs to be incurred subsequent to June 30, 1959 at $850 million. A major portion of this authorized plant expansion is for construction of reactors and related facilities and for facilities to be used in high energy and controlled thermonuclear research.

The chart below shows the investment in completed plant, accumulated depreciation, and costs incurred on partially completed plant projects at the end of each fiscal year from 1950 through 1959. For fiscal year 1959, the chart also shows plant projects authorized prior to June 30, 1959 for construction or completion in subsequent periods.

[1] Includes plant projects of $165.4 million authorized in Public Law 86-50 approved June 23, 1959.



INVESTMENT IN PLANT AND EQUIPMENT

JUNE 30, 1959

(*at cost*)

	Completed Plant	*Construction in Progress*	*Total*	*Percent of Total*
		(*in thousands*)		
Production:				
Raw materials	$ 7,215	$ 2	$ 7,217	.1
Feed materials	251,940	3,950	255,890	3.5
Gaseous diffusion plants	2,314,766	18,341	2,333,107	32.0
Production reactors and separations areas	1,599,277	14,132	1,613,409	22.1
Weapons production and storage	785,177	21,502	806,679	11.1
Heavy water	261,643	30	261,673	3.6
Other production facilities	332,628	11,852	344,480	4.7
Total production	5,552,646	69,809	5,622,455	77.1
Research and development:				
Laboratories	771,442	64,787	836,229	11.4
Reactors	238,586	67,900	306,486	4.2
Accelerators	58,473	39,079	97,552	1.4
Weapons test facilities	56,042	1,213	57,255	.8
Total research	1,124,543	172,979	1,297,522	17.8
Communities	179,013	2,962	181,975	2.5
Other	186,825	4,007	190,832	2.6
Total	$7,043,027	$249,757	$7,292,784	100.0

Changes in investment in plant and equipment during the fiscal year were as follows.

	Completed Plant	*Construction in Progress*	*Total*
		(*in thousands*)	
Investment—June 30, 1958	$6,839,651	$271,146	$7,110,797
Construction and equipment costs		298,979	298,979
Additions to completed plant	320,368	(320,368)	
Plant retirements	(63,387)		(63,387)
Transfer of community facilities	(27,020)		(27,020)
Sale of community facilities by HHFA	(26,585)		(26,585)
Investment—June 30, 1959	$7,043,027	$249,757	$7,292,784

AEC PLANT AND EQUIPMENT

(at cost)

BY LOCATION

June 30, 1959

Location and Operating Contractor	*Completed Plant and Equipment*	*Estimated Cost of Projects Under Construction*	*Projects Authorized Construction Not Started*	*Total*
		(in millions)		
CALIFORNIA:				
Lawrence Radiation Laboratory, University of California:				
Berkeley	$ 31.7	$ 12.5	$ 3.9	$ 48.1
Livermore	49.5	34.3	1.7	85.5
Research facilities, Sandia Corporation, Livermore	7.7	.4	.4	8.5
Medical research facilities, University of California, Los Angeles	1.1	.2	.3	1.6
Salton Sea Base, Sandia Corporation, Salton Sea	7.0	.2		7.2
Research facilities, California Institute of Technology, Pasadena	[1] 1.7			1.7
Reactor and research facilities, Atomics International Division, North American Aviation, Inc., Canoga Park	12.7	8.7		21.4
COLORADO:				
Grand Junction:				
Uranium handling and sampling facilities, Lucius Pitkin, Inc	1.4		.1	1.5
Exploration and general facilities, Lucius Pitkin, Inc	4.9			4.9
Total, Grand Junction	6.3		.1	6.4
Rocky Flats Plant, Dow Chemical Company, Boulder	71.6	1.9	.4	73.9
CONNECTICUT:				
Connecticut Aircraft Nuclear Engine Laboratory, Pratt and Whitney, Middletown	[1] [2] 4.3			4.3
Linear accelerators, Yale University, New Haven	2.6	.1		2.7
Submarine reactor facilities, Combustion Engineering, Inc., Windsor	.4	13.8		14.2
DISTRICT OF COLUMBIA:				
Research equipment, Naval Research Laboratory, Washington	[1] 2.4			2.4

Location and Operating Contractor	*Completed Plant and Equipment*	*Estimated Cost of Projects Under Construction*	*Projects Authorized Construction Not Started*	*Total*
		(in millions)		
FLORIDA:				
Pinellas Plant, General Electric Company, Clearwater	$ 9.9	$ .4	$ .2	$ 10.5
IDAHO:				
National Reactor Testing Station:				
Phillips Petroleum Company:				
Chemical processing plant	49.0	9.1	5.4	63.5
Materials testing reactor	13.8	1.2		15.0
Engineering test reactor	12.3	.3		12.6
Reactor facilities	12.4	1.7	15.5	29.6
General facilities	18.1	4.3	2.0	24.4
Total	105.6	16.6	22.9	145.1
Westinghouse Electric Corporation:				
Large ship reactor	32.8	2.2		35.0
Submarine thermal reactor	13.8			13.8
Other research facilities	9.2	.5		9.7
Total	55.8	2.7		58.5
Aircraft nuclear propulsion facilities, General Electric Company	33.3	21.9		55.2
Reactor facilities, Argonne National Laboratory	3.9	30.8	1.0	35.7
Organic moderated reactor experiment, North American Aviation, Inc	2.1	.2		2.3
Knolls Atomic Power Laboratory, General Electric Company			18.5	18.5
Total, NRTS	200.7	72.2	42.4	315.3
ILLINOIS:				
Argonne National Laboratory, University of Chicago, Lemont	103.6	55.5	16.2	175.3
Argonne Cancer Research Hospital, University of Chicago, Chicago	4.6	.1		4.7
INDIANA:				
Dana heavy water plant, E. I. du Pont de Nemours and Co., Dana	[3] 98.7			98.7
IOWA:				
Research Laboratory, Iowa State College, Ames	7.6	2.3	4.1	14.0
Iowa ordnance plant, Mason and Hanger, Burlington	[4] 29.6	1.4	.2	31.2

Location and Operating Contractor	Completed Plant and Equipment	Estimated Cost of Projects Under Construction	Projects Authorized Construction Not Started	Total
		(in millions)		
KENTUCKY:				
Paducah:				
Paducah Gaseous Diffusion Plant, Union Carbide Nuclear Company	$ 747.2	$ 2.4	$ 2.3	$ 751.9
Feed Materials Plant, Union Carbide Nuclear Company	26.8	.4		27.2
Total, Paducah	774.0	2.8	2.3	779.1
MARYLAND:				
AEC Headquarters, Germantown	15.4	.9	.9	17.2
MASSACHUSETTS:				
Research equipment, Edgerton, Germeshausen and Grier, Boston	[1] 1.1			1.1
Cambridge electron accelerator, Harvard University, Cambridge	.1	11.5		11.6
Raw materials development laboratory, National Lead Company, Winchester	1.3			1.3
MINNESOTA:				
Linear accelerator, University of Minnesota, Minneapolis	[1] 1.7			1.7
Boiling water power reactor, Rural Cooperative Power Association, Elk River		9.4		9.4
MISSOURI:				
Kansas City Plant, Bendix Aviation Corporation, Kansas City	[5] 22.1	4.7	.9	27.7
Feed Materials Plant, Mallinckrodt Chemical Works, Weldon Spring	54.9	.8	.7	56.4
NEBRASKA:				
Sodium graphite power reactor, Consumers Public Power District, Hallam		24.0		24.0
NEVADA:				
Mercury:				
Nevada Test Site, Reynolds Electrical and Engineering Company	30.0	13.8	8.2	52.0
Laboratory equipment, Lawrence Radiation Laboratory	[1] .5			.5
Research facilities, Edgerton, Germeshausen and Grier	2.1	.1		2.2
Total, Mercury	32.6	13.9	8.2	54.7

Location and Operating Contractor	*Completed Plant and Equipment*	*Estimated Cost of Projects Under Construction*	*Projects Authorized Construction Not Started*	*Total*
		(in millions)		
NEVADA (*Continued*):				
Tonopah:				
Research facilities, Reynolds Electrical and Engineering Company	$ .6	$ .5		$ 1.1
Research facilities, Sandia Corporation	.9			.9
Total, Tonopah	1.5	.5		2.0
NEW JERSEY:				
Merchant ship reactor, Camden		26.3		26.3
New Brunswick Laboratory, Atomic Energy Commission, New Brunswick	2.0	.1		2.1
Picatinny Arsenal Ordnance Facility, Atomic Energy Commission, Dover	[4] 1.6	.1		1.7
Princeton:				
Princeton-Pennsylvania proton accelerator, Princeton University		11.2		11.2
Model C stellarator facilities, Princeton University		9.9		9.9
Research facilities, Princeton University	2.7	.2		2.9
Total, Princeton	2.7	21.3		24.0
NEW MEXICO:				
Albuquerque:				
Sandia Laboratory, Sandia Corporation	67.4	12.8	$ 2.7	82.9
South Albuquerque Works, ACF Industries, Inc	18.4	.8	.2	19.4
Total, Albuquerque	85.8	13.6	2.9	102.3
Los Alamos:				
Los Alamos Scientific Laboratory, University of California	139.3	18.9	3.9	162.1
Community and general maintenance facilities, The Zia Company	129.0	2.0	2.5	133.5
Los Alamos Hospital, Los Alamos Medical Center, Inc.	2.9			2.9
Total, Los Alamos	271.2	20.9	6.4	298.5
NEW YORK:				
Brookhaven National Laboratory, Associated Universities, Inc., Upton	74.7	50.8	4.6	130.1
Fuel processing facility, Sylvania Corning Nuclear Corporation, Hicksville	2.3			2.3

Location and Operating Contractor	Completed Plant and Equipment	Estimated Cost of Projects Under Construction	Projects Authorized Construction Not Started	Total
		(in millions)		
NEW YORK (*Continued*):				
New York City:				
Computing and other research facilities, New York University	$ 1.5			$ 1.5
Accelerator and research facilities, Columbia University	1.7		$ .8	2.5
Total, New York City	3.2		.8	4.0
Boron plant, Olin Mathieson Chemical Corp., Niagara Falls	7.8			7.8
Research laboratory, University of Rochester, Rochester	5.0	$ .5		5.5
Schenectady:				
Machine tools, Army Ordnance, Atomic Energy Commission	[1] 2.5			2.5
Knolls Atomic Power Laboratory, General Electric Company	41.8	1.5	.7	44.0
Total, Schenectady	44.3	1.5	.7	46.5
Knolls Atomic Power Laboratory, General Electric Company, West Milton	31.6	35.7	.1	67.4
OHIO:				
Aircraft nuclear propulsion facilities, General Electric Company, Lockland	[1] [2] 7.6	1.2		8.8
Portsmouth:				
Portsmouth Gaseous Diffusion Plant, Goodyear Atomic Corporation	748.9	1.9	1.2	752.0
Feed Materials Plant, Goodyear Atomic Corporation	8.0			8.0
Total, Portsmouth	756.9	1.9	1.2	760.0
Feed Materials Plant, National Lead Company, Fernald	110.0	2.5	.8	113.3
Mound Laboratory, Monsanto Chemical Company, Miamisburg	29.4	3.2	4.1	36.7
Organic moderated power reactor, City of Piqua, Piqua			7.3	7.3
PENNSYLVANIA:				
Bettis Plant, Westinghouse Electric Corporation, Pittsburgh	39.7	8.5	1.2	49.4
Accelerator and research facilities, Carnegie Institute of Technology, Pittsburgh	1.3			1.3
Pressurized Water Reactor, Duquesne Light Company, Shippingport	47.3	2.1	5.0	54.4

Location and Operating Contractor	*Completed Plant and Equipment*	*Estimated Cost of Projects Under Construction*	*Projects Authorized Construction Not Started*	*Total*
		(in millions)		
SOUTH CAROLINA:				
Savannah River Plant, E. I. du Pont de Nemours and Co., Inc., Aiken:				
Production reactor facilities	$ 620.6	$ 6.1	$ 15.6	$ 642.3
Separations facilities	259.5	15.7	1.3	276.5
Feed materials production facilities	6.1	.3		6.4
Heavy water production facilities	163.6			163.6
Works laboratory	44.6	10.0		54.6
General facilities	163.7	4.0	1.2	168.9
Total, Aiken	1,258.1	36.1	18.1	1,312.3
TENNESSEE:				
Oak Ridge:				
Research laboratory, Oak Ridge Institute of Nuclear Studies	2.8	.1	.2	3.1
Agriculture Research Laboratory and Farm, University of Tennessee	1.0		.2	1.2
Experimental gas cooled reactor			30.0	30.0
Oak Ridge Gaseous Diffusion Plant, Union Carbide Nuclear Company	830.0	25.8	3.0	858.8
Fabrication and development facilities, Union Carbide Nuclear Company	365.9	18.0	2.0	385.9
Oak Ridge National Laboratory, Union Carbide Nuclear Company	135.4	38.1	6.9	180.4
Service facilities	13.5	.2	.2	13.9
Total	1,348.6	82.2	42.5	1,473.3
Community services, Oak Ridge	65.6	3.0	.2	68.8
TEXAS:				
Production and development facilities, Mason & Hanger, San Antonio	.1	2.4		2.5
Pantex Plant, Mason & Hanger, Amarillo	[4] 23.3	.3	.2	23.8
UTAH:				
Monticello:				
Uranium ore processing plant, National Lead Company	5.8			5.8
Community services, National Lead Company	.5			.5
Total, Monticello	6.3			6.3
VIRGINIA:				
Army Package Power Reactor No. 1, Alco Products, Inc., Fort Belvoir	2.5	.2		2.7

Location and Operating Contractor	Completed Plant and Equipment	Estimated Cost of Projects Under Construction	Projects Authorized Construction Not Started	Total
		(in millions)		
WASHINGTON:				
Hanford Works, General Electric Company, Hanford:				
Production reactor facilities	$ 484.9	$166.3	$ 11.8	$ 663.0
Separations facilities	232.9	10.6		243.5
Feed materials production facilities	38.7	.2		38.9
Works laboratory	45.7	24.0	.5	70.2
General facilities	147.9	8.5	1.8	158.2
Total	950.1	209.6	14.1	1,173.8
Community services, General Electric Company, Richland	33.6	.3	.1	34.0
WEST VIRGINIA:				
Huntington pilot plant, International Nickel Company, Huntington	4.6			4.6
WYOMING:				
Army Package Power Reactor No. 2, The Martin Co., Sundance		3.0		3.0
PUERTO RICO:				
Puerto Rico Nuclear Center, University of Puerto Rico, Mayaguez	.3	3.5	.1	3.9
JAPAN:				
Research facilities, National Academy of Science, Hiroshima	1.9			1.9
MARSHALL ISLAND:				
Eniwetok Proving Grounds, Holmes and Narver, Inc., Eniwetok	32.7	1.3		34.0
ALL OTHER:				
Various locations:				
Weapons storage facilities	182.9	6.7	1.5	191.1
Other	49.6	19.3	73.9	142.8
Total, All Other	232.5	26.0	75.4	333.9
Total	$7,043.0	$830.6	$[6] 268.7	$8,142.3

[1] Equipment only.

[2] Basic plant owned by U. S. Air Force.

[3] Transferred to U. S. Army in July 1959.

[4] Basic plant owned by U. S. Army.

[5] Basic plant owned by U. S. Navy.

[6] Includes plant projects of $165.4 million authorized in Public Law 86-50 approved June 23, 1959.

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ERRATA SHEET

Major Activities in the Atomic Energy Programs—January–December 1959

Page 11—Footnote No. 6:
insert (*NYO–2977*) after the title "Radioisotopes in Industry".

Page 58—First line of the unnumbered table:
under the heading "Former Capacity" the figure should be *833* instead of 883; total of "Former Capacity" column should be *1,277* instead of 1,297.

Page 73—Seventeenth line:
make "S1G" read *S1C.*

Page 83—Sixth line of first paragraph:
make "28 million" read *$2.8* million.

Page 117—Third paragraph:
First sentence, make calendar year read *1959* instead of 1958.

Page 120—Footnote No. 13:
insert (*AL1–52*) after Radiation; make price read *$2.50* instead of $5.50.

Page 134—First line at top of page:
replace word "publication" with word *declassification.*

GPO : 1960 O - 541015