UNITED STATES ATOMIC ENERGY COMMISSION

MAJOR ACTIVITIES

IN THE

ATOMIC ENERGY PROGRAMS

January–December 1965

UNITED STATES GOVERNMENT PRINTING OFFICE : JANUARY 1966

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FOREWORD

TEXT OF LETTER FROM PRESIDENT JOHNSON TO DR. GLENN T. SEABORG, CHAIRMAN, ATOMIC ENERGY COMMISSION, APRIL 18, 1965

"Dear Dr. Seaborg:

"I wish to thank you for the two very informative reports* describing the Atomic Energy Commission's activities during 1964.

"Since my association with our atomic energy programs began in the House of Representatives nearly 20 years ago as a member of the Joint Committee on Atomic Energy, I have followed the program closely.

"I want you and your fellow Commissioners to know that your reports impress me from a number of points of view.

"First, they present solid evidence that the Commission is pursuing a vigorous program of nuclear weapons research and development;

"Second, they make it clear that a steadily increasing proportion of the Commission's budget is being devoted to the peaceful applications of the atom, a matter which is particularly gratifying to me; and

"Third, they clearly reflect that the Nation is being well served through the healthy partnership of our Government with our industries and universities.

"As you and I have often discussed, it is essential at all times that we look far ahead in our planning for this vital activity. I would, therefore, like to convey to you some of my views and hopes in relation to the program.

"We have been able to maintain our clear superiority in nuclear weapons, while at the same time we have been responsible and realistic about our needs. The orderly cutback in the production of fissionable materials is a significant example of this realism.

"I appreciate the Commission's cooperation in the advancement of measures for effective arms control. I look forward hopefully—and confidently—to the day when our national security and the security of the human race can be further increased through agreements and actions among nations which build upon the important first step of the limited test ban treaty.

"I look for the continuation of the important progress that is being made in the peaceful uses of nuclear energy. For example, in the field of civilian nuclear power, I look forward to the development of the advanced converter and breeder reactors, which will be required for the more efficient and economical use of our Nation's nuclear fuel resources. Nuclear energy will fill an important role in partnership with fossil fuels in meeting the growing energy requirements of our Nation. As you know, I also anticipate that nuclear power will play a significant role in the desalting of sea water.

"It is characteristic of nuclear energy that its great potential is continually expanding. The full range of its ultimate contributions cannot be foreseen. We must continually press toward the discovery of areas and applications of which we have not yet dreamed, even as we strive to realize the full potential of the areas already defined.

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*The two reports referred to are the Commission's "Annual Report to Congress for 1964" and the supplemental report, "Fundamental Nuclear Energy Research—1964."

"Basic to all of the applications of nuclear energy is the conduct of fundamental research in the physical and biomedical sciences, and I favor the vigorous pursuit of these activities.

"On the other hand, we must also remember—keeping in mind always the essentiality of Government control of the uses of nuclear energy in the interest of the national security and public safety—that nuclear energy, after a period of intensive development, is now an integral part of the American industrial scene. It should not be regarded as a Government preserve. I look forward to the assumption by the private sector of our economy of a steadily increasing share of the responsibility for the development of the applications of nuclear energy.

"In the field of the application of radioactive isotopes, I would like to see continued emphasis on the development of this humanitarian tool for the diagnosis and treatment of disease. I believe that we have only begun to realize the potential of these remarkable substances for the alleviation of human suffering. I also want to encourage continued development of their application to industrial and other processes.

"In the field of space, we should continue the development of isotopic and reactor SNAP devices to enable us to take advantage of their unique application to the generation of electric power for our spacecraft. The recent successes of the nuclear-rocket reactor tests indicate that nuclear rockets can be ready for the long-range space missions of the future.

"In the field of education, the contributions made by the Commission are many and appreciated. I believe we can achieve even closer cooperation between the many Government laboratories and the universities throughout this country. The national resources in these laboratories can benefit the research and education processes in the universities. The laboratories will, in turn, greatly profit from their association with the universities.

"I wish to commend particularly a use of advanced planning by the AEC which is being carried out without much fanfare, but so very effectively. Thus, for example, the cutbacks in special nuclear materials production were planned sufficiently in advance so that the Commission, in cooperation with the local officials and business and labor people, could take appropriate actions, such as diversification programs, to minimize any significant economic impacts.

"Our capacity for achievement in atomic energy development never has been greater. The Commission has achieved a high degree of cooperation with private industry and the universities. The Congress, especially the Joint Committee on Atomic Energy, has effectively supported our nuclear program. This team in being—of government, industry, and the educational community—constitutes an unparalleled force for accomplishment. I look to the Commission to continue and further enhance these effective and harmonious relationships.

"On this course, I believe we shall ultimately achieve a society in which man can live in peace, enjoy the freedom and personal security to shape his destiny according to his individual beliefs, and have the leisure to contribute to the culture of his civilization. I recognize that our goals will not be easily reached. There will be disappointments and hard choices in priorities to adjust to continually changing requirements and circumstances. We have the will and the capacity. We also clearly have the duty. For if man would inherit from the generations that have preceded him, he must bequeath something of value to the generations that succeed him."

Sincerely,

(S) LYNDON B. JOHNSON.

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Part One

Developmental and Promotional Activities

The Atomic Energy Commission and Advisory Committee. The members of the Atomic Energy Commission in 1965 were *left to right:* Commissioner Gerald F. Tape, Commissioner John G. Palfrey, Commissioner James T. Ramey, Commissioner Mary I. Bunting, and Chairman Glenn T. Seaborg. Dr. Bunting's term expired on June 30 and she returned to her position as President of Radcliffe College, Cambridge, Mass. Photo *below*, made in July, shows the members of the AEC's General Advisory Committee. The Committee was originally established by the Atomic Energy Act of 1946, and continued by the Atomic Energy Act of 1954, to advise the Commission on scientific and technical matters relating to materials, production, and research and development. The members are appointed by the President. Shown *seated, left to right*, are: Dr. Darol Froman, Dr. John H. Williams, Dr. L. R. Hafstad, *chairman*, Dr Kenneth S. Pitzer, Dr. Stephen Lawroski; *standing:* William Webster, Dr. Manson Benedict, Dr. Norman F. Ramsey, and Dr. John C. Bugher. Not shown is Howard G. Vesper who replaced Dr. Pitzer when he retired from the Committee during the latter part of 1965. (See also Appendix 2.)

Chapter 1

THE ATOMIC ENERGY PROGRAM—1965

The year 1965 was one in which nuclear power was given routine consideration by a growing number of electric utilities as they planned for expansion of generating capacity; communities throughout the Nation sought to be the site selected for a proposed multimillion dollar research center which would greatly advance the Nation's high-energy physics program; new nuclear-associated businesses were broadening the economic base of geographical areas; and the power of the atom was foreseen as an "economic tool" in ever-increasing ways. It was a year in which there was an ever-increasing awareness of the part the atomic energy program could play, directly and indirectly, in the economic aspects of everyday life.

Listed below, in the order of their appearance in Part One of this Annual Report to Congress for 1965,[1] are "highlight" summaries of some of the more noteworthy activities and events of the year. Following the "highlights," are brief discussions of some of the year's more "significant developments." The regulatory and adjudicatory activities are summarized in Parts Two and Three. A supplemental report, "Fundamental Nuclear Energy Research—1965,"[2] describes many of the advances being made through AEC-sponsored basic research and development.

HIGHLIGHTS OF AEC PROGRAMS

Chapter 2—The Industrial Base

- Strengthening the economic base of the Richland, Wash., area began, as new contractor operators for the AEC's Hanford Works announced plans for conducting normal commercial activities in the area.
- The annual Bureau of Census survey showed a 14 percent increase in U.S. manufacturers' shipments of material for nuclear work.

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[1] This Annual Report to Congress for 1965 is available to the public under an alternate title, "Major Activities in the Atomic Energy Programs—January–December 1965," from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, for $1.50.

[2] "Fundamental Nuclear Energy Research—1965," is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, for $2.25.

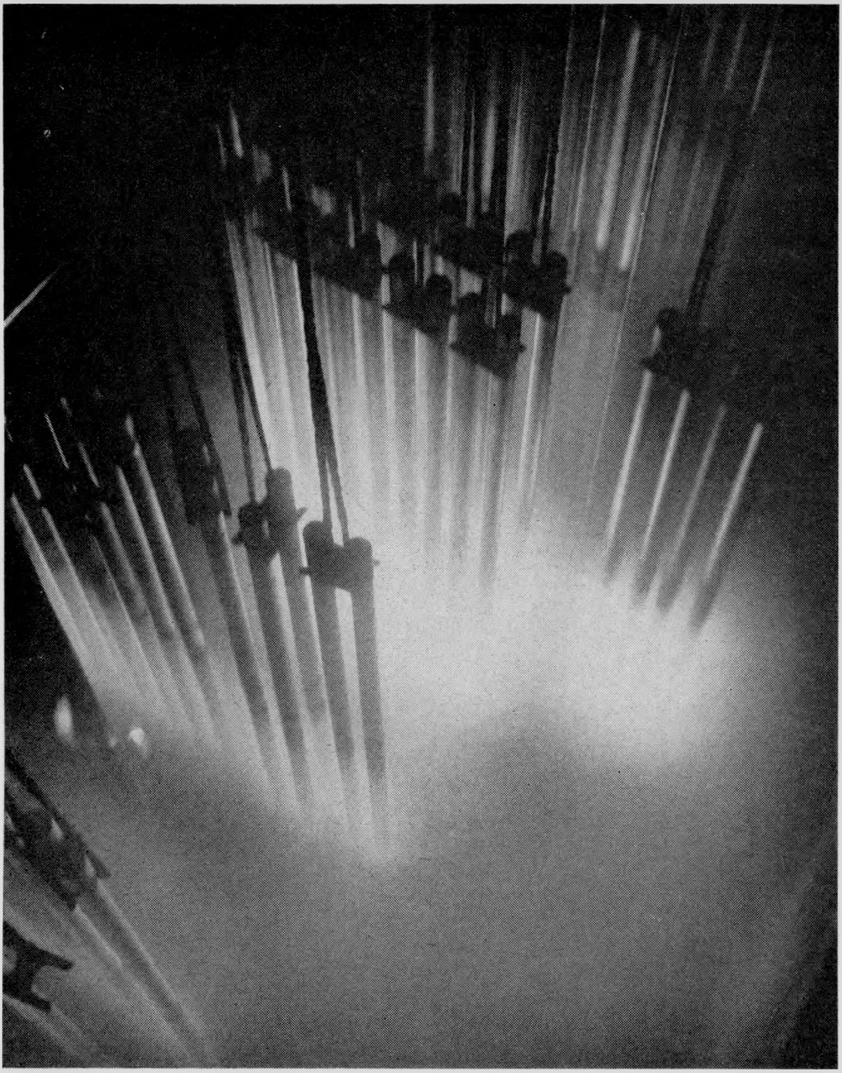
Royal Visitors. England's Princess Margaret and Lord Snowdon visited the AEC's Lawrence Radiation Laboratory on the University of California's Berkeley campus on November 6. They saw the 184-inch cyclotron and the use of this machine in the treatment of pituitary diseases such as Cushing's Disease and acromegaly. In the course of the visit the Director of the Laboratory, Dr. Edwin M. McMillan, used a model of the Bevatron accelerator to explain about high-energy physics. Shown above, foreground, are: Dr. McMillan, Lord Snowdon, and Princess Margaret. Mrs. McMillan and Dr. James Born are in background.

Chapter 3—Industrial Relations

● Employment in the atomic energy field, at both Government and private establishments, declined during 1965 due primarily to cutbacks in nuclear weapons production and from changes in reactor programs.

Chapter 4—Operational Safety

● The AEC's injury frequency rate for the past 23 years was 3.32 as compared to all-industrial rate of 8.17. The AEC's accidental property damage loss from fires over the 23-year period averaged less than one cent per $100 property evaluation as compared to the national average of private industry of 2.8 cents per $100 of property.



Spent High Neutron Flux Fuel. Spent fuel assemblies from the high-flux operation at the Savannah River Plant illuminate a cooling basin by *Cerenkov* radiation. The high-flux operation is being carried out in one of the production reactors to produce transuranium isotopes such as curium 244. The neutron flux (5×10^{15} neutrons/cm^2-sec), heat flux, and coolant velocity are higher than those of any other operating reactor. In the photo, spent fuel from three different reactor charges are shown under 20 feet of water. The brightest assemblies (*top center*) were just discharged from the reactor; in front of them are assemblies that were discharged a month earlier. Barely visible on the lower extreme left are assemblies that have "cooled" by radioactive decay for 3½ months.

Chapter 5—Source and Special Nuclear Materials Production

- With the signing of the 11th contract for deferred delivery of uranium concentrates on November 26, negotiations for stretching-out the AEC's uranium procurement deliveries through 1970 were completed.
- Hanford's "N" reactor (previously referred to as the "NPR"—New Production Reactor) began routine plutonium production during the year. Electric power for the Washington Public Power Supply System using steam produced by the "N" reactor is expected by mid-1966. The reactor and generating facilities will, at that time, constitute the world's largest operating nuclear power station (800,000 ekw) and also the largest dual-purpose (plutonium production and electricity generation) reactor facility.
- During a high flux demonstration to expedite production of curium 244 and other transplutonium elements, a Savannah River production reactor attained the highest sustained neutron flux (5.4×10^{15}) of any reactor in the world. High specific activity cobalt 60 (in excess of 500 curies/gram) is being produced during the high-flux demonstration runs for special research applications, including heat source demonstration.

Chapter 6—The Nuclear Defense Effort

- Under Presidential authorization, the production of nuclear weapons in 1965 continued to meet the Department of Defense military requirements.
- The AEC continues to investigate advanced concepts to improve the capability of warheads to penetrate potential enemy defense systems.
- The Commission announced 27 underground nuclear tests during 1965, including the third joint AEC–DOD Vela Uniform (underground test detection) program event conducted in Alaska on October 29, 1965.
- The atmospheric test readiness capability was attained on January 1, 1965, and was maintained and improved through the year.
- Two more AEC-instrumented satellites for test detection in space were successfully placed in orbit in July, making a total of six such satellites now in orbit.

Chapter 7—Civilian Nuclear Power

- Private utilities announced plans to build six large nuclear central power stations—ranging in size up to nearly 900,000 electrical kilowatts (ekw)—which would nearly triple the existing nuclear electric capacity in this country. At the end of the year, 12 central station-type nuclear powerplants with a combined capacity of more than one million electrical kilowatts were in operation, and 15 such plants (including the Washington Public Power Supply System's 800,000 ekw facility at Hanford) with a potential combined capacity of more than 7.3 million ekw were under construction or committed for construction.

● Studies were completed—in coordination with the Department of Interior—of large nuclear power-desalting plants for Southern California and Israel; a cooperative study of a large nuclear power-desalting plant was initiated with the Government of Mexico; and the appli-

"*Water for Peace.*" On the same day that President Johnson announced the United States would undertake an international "Water for Peace" program to find solutions to man's water problems, the United States and Mexico signed an agreement for a joint technical and economic feasibility study for a large nuclear power and desalting plant in Mexico, near the Gulf of California. The study will be under the auspices of the International Atomic Energy Agency (IAEA). If built, the plant will provide power and water for portions of Arizona and California in the United States and to the Mexican states of Sonora and Baja California. Photo shows the October 7 agreement signing. *Left to right* in photo are: (*barely visible*) Sigvard Eklund, Director General of the IAEA; Mexico's Ambassador to the United States, Hugo Margain; AEC Chairman Glenn T. Seaborg; President Johnson; and in act of signing the agreement, Nabor Carrillo Flores of the Mexican Nuclear Energy Commission. The signing took place during the U.S.-sponsored First International Symposium in Water Desalination, October 3–9, in Washington, D.C., and which was attended by delegates from 55 nations and six international organizations.

cability of desalting to the water requirements of New York–New Jersey metropolitan areas was investigated.

- The world's first atom-powered merchant ship, the NS *Savannah*, went into regular commercial service.

Chapter 8—Nuclear Space Applications

- Development of nuclear-propelled rockets continued to progress as an advanced type of Rover space reactor completed a series of successful ground tests.
- The SNAP–10A was the first reactor power unit to be launched into orbit. It was remotely started after achieving a stable orbit and operated for 43 days in space before a sequence of failures in electronic components shut it down.
- An isotopic power system, the SNAP–27, is under development for use in NASA's Apollo program. It is planned for use in powering data-collecting-and-transmitting equipment which will be left on the lunar surface by astronauts.

Chapter 9—Auxiliary Electrical Power for Land and Sea

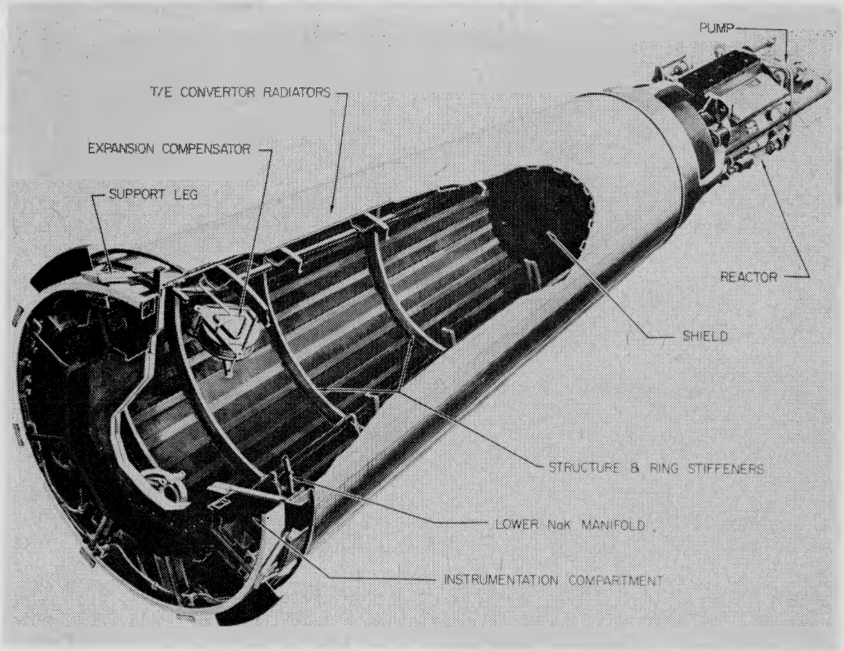
- Increased interest in oceanographic science is leading to identification of a number of potential uses of nuclear power generators for underwater applications.
- The first isotopic SNAP generator to be put into commercial use was installed on an oil rig in the Gulf of Mexico.

Chapter 10—Military Reactors

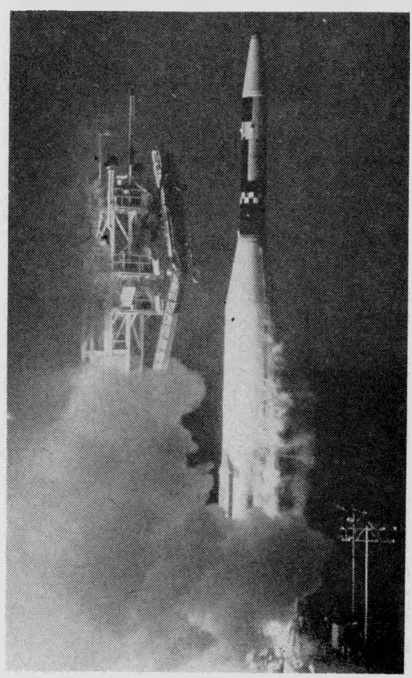
- There were 59 nuclear-powered ships and submarines in operation, and 45 more under construction or authorized, as the nuclear Navy entered its second decade of growth.

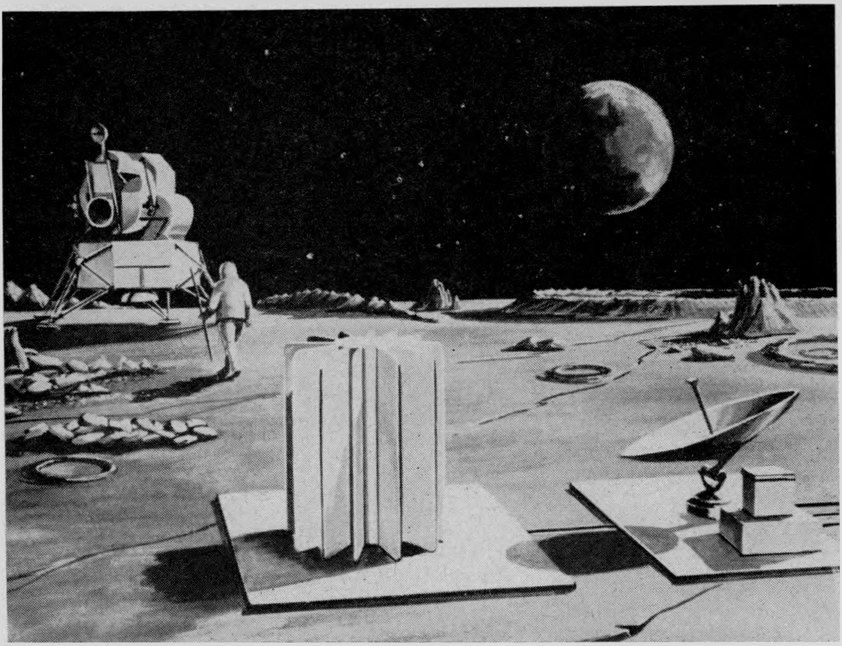
Chapter 11—Advanced Reactor Technology and Nuclear Safety Research

- A steering committee composed of key AEC officials was established to assure that the experimental information developed in the reactor safety research program is keyed to the needs of the continuing development of the nuclear industry and the requirements of the Commission's regulatory program.



First Reactor in Space. The *above* is a drawing of the major components of the compact SNAP–10A nuclear power system which was successfully orbited on April 3—the first operating reactor unit to be put into space. The nuclear reactor (top) provided heat for the generation of electricity by direct conversion (T/E—thermoelectric) units mounted along the cone-shaped structure. The 500-watt (electrical) SNAP–10A system was successfully operated for 43 days before a malfunctioning voltage regulator caused the reactor to shut down prematurely. Photo at *right* shows the launching from Vandenberg Air Force Base, Calif., aboard an Agena rocket which had been specially modified by Lockheed Aircraft Corp. The SNAP–10A was developed for the AEC by Atomics International, a division of North American Aviation, Inc.

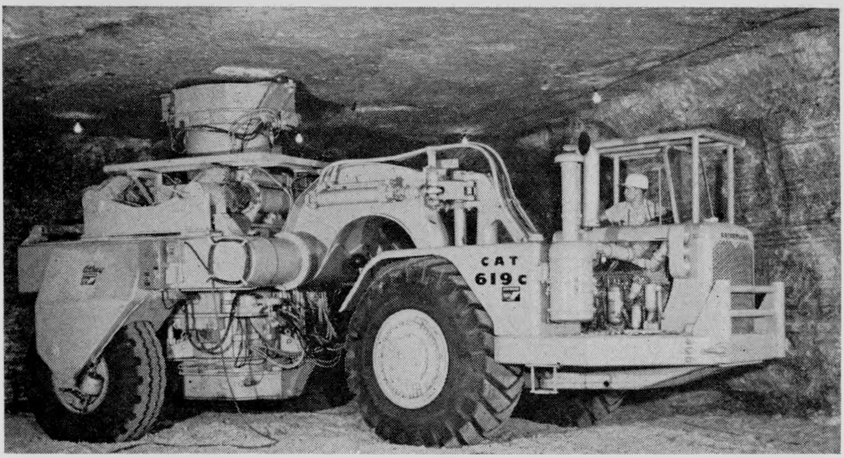




Nuclear Power on the Moon. Artist's concept of a SNAP–27 nuclear power generator (*center*) on the moon. The AEC has executed a contract with the General Electric Co. for development of the 50-watt, plutonium 238 fueled generator for use in the NASA Apollo Lunar Surface Experiment Package program. The nuclear device will supply power to the lunar experiment packages, one of which is shown at right, alongside the telemetry antenna. The lunar excursion module which will deliver the astronauts and the packages to the moon is at the *left* in this General Electric drawing. The packages, which will transmit selected measurements back to earth, will be left on the lunar surface for 6 months to a year so that a maximum amount of scientific information can be obtained.

Chapter 12—The Plowshare Program

- The AEC received its first proposal from industry for conducting a joint project to investigate the application of a deep buried nuclear explosion to stimulate the flow of natural gas from a relatively impermeable formation where normal production techniques are uneconomical. Two other feasibility studies—for copper ore recovery, and gas storage—are currently underway.
- One nuclear excavation experiment was conducted during the year, and progress continued to be made in developing "clean" explosives and emplacement methods to minimize the release of radioactivity in nuclear excavation.



Project Salt Vault. After 6 years of preliminary studies and work, the AEC's Project Salt Vault—to demonstrate the suitability of rock salt deposits for long-term storage of solidified high-level radioactive wastes, such as those from power reactor fuel reprocessing—reached the semifinal stage in late 1965. Since the solid wastes which eventually will be buried in the mine are not currently available, irradiated fuel elements from the Engineering Test Reactor in Idaho were emplaced in the Kansas salt mine to simulate the radiation and heat typical of canned solidified wastes. Photo *above* shows the underground waste transporter, a specially designed trailer coupled to a conventional two-wheel tractor, used in the Carey Salt Co. mine near Lyons, Kans. to carry canisters of radioactive waste from the waste-charging shaft to the experimental area. A 19-ton lead cask provides the shielding for personnel. The tractor and trailer were assembled inside the mine, 1,000 feet below the earth's surface. Photo *below* shows the holes in the salt floor, 12 feet deep and lined with stainless steel, used to contain the radioactive fuel assembles in the experiment. The holes are located in a room 30 feet wide, 60 feet long, and 14 feet high. Instrumentation is provided to obtain necessary data. The radioactive waste disposal tests are being conducted by Oak Ridge National Laboratory, which is operated by Union Carbide Corp. for the U.S. Atomic Energy Commission.

Chapter 13—Isotopes and Radiation Development

- Out of 180 firms which expressed an interest for cooperative arrangements with the AEC, 78 companies were selected to participate in a program under which samples of their wood products would be converted to wood-plastics.
- Petitions requesting clearance for unrestricted public consumption of six species of radiation processed fish fillets were filed with the Food and Drug Administration.
- The AEC announced its withdrawal, in favor of industry, from the routine production and distribution of antimony 125, calcium 45, iron 59, selenium 75, tin 113, and zinc 65.

Chapter 14—Facilities and Projects for Basic Research

- During the year, additional new laboratories were provided for several biomedical research efforts.
- Organization of the Civil Defense Research Programs at Oak Ridge National Laboratory was completed. An initial project under this program was an improved method for urban sheltering through the study of a tunnel-grid shelter installation in a 25-square mile area of Detroit, Mich.
- The Commission prepared a "Policy for National Action in the Field of High Energy Physics" which, after being concurred in by other executive agencies, was forwarded by the President to the Congressional Joint Committee on Atomic Energy. In order to implement one of the major plans in this report, the Commission initiated site selection procedures for a new national accelerator laboratory which will include as its principal research instrument a high-intensity proton accelerator in the 200 billion electron volt (Bev) energy range. A preliminary design report and cost estimate for this unique scientific research tool was submitted by the Lawrence Radiation Laboratory in June 1965. (Also see discussion under "Some Significant Developments" section of this Chapter 1.)
- Three new reactors of importance to the basic physical research program, the Ames Laboratory Research Reactor, the Oak Ridge High Flux Isotope Reactor, and Brookhaven's High Flux Beam Reactor, achieved nuclear criticality during 1965.

Chapter 15—International Cooperation

- More than 21 of the nations with which the United States now has bilateral Agreements for Cooperation in the Civil Uses of Atomic

Energy have agreed to the administration by the International Atomic Energy Agency of safeguards over U.S.-supplied nuclear materials and equipment.

- In 1965, three enriched uranium fueled power reactors were contracted for by other countries for a new total of 15 power reactors built, under construction, or planned abroad using U.S.-produced enriched uranium.
- During the First International Symposium on Water Desalination, October 3–9, President Johnson announced that the United States would undertake a "Water for Peace" program as a step toward solving the world's water-shortage problem. The symposium was attended by delegates from 55 nations and six international organizations. The AEC is represented on the Interagency Committee for Foreign Desalting, which will provide guidance on foreign desalting programs, and took an active part in the symposium since nuclear energy is expected to play an important part in the Water for Peace program.

Chapter 16—Nuclear Education and Information

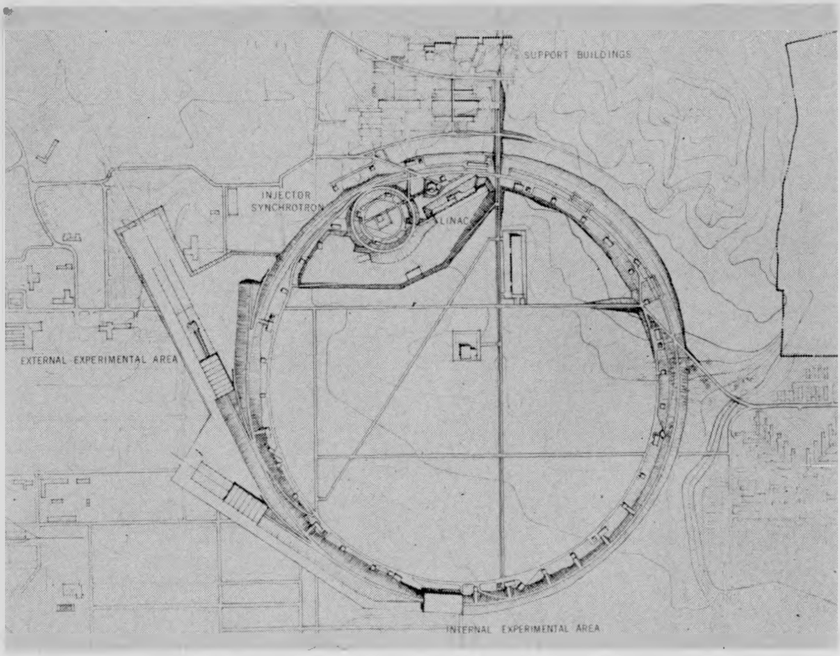
- Under a nuclear engineering pilot program, 50 trainees were selected by 13 participating universities during September for graduate work in this field.
- Four new specialized information and data centers for nuclear science and technology were established, bringing to 19 the number of such centers sponsored by the AEC.

SOME SIGNIFICANT DEVELOPMENTS

PROPOSED NATIONAL ACCELERATOR LABORATORY

The Atomic Energy Commission received 126 proposals from 46 States recommending more than 200 sites for the location of a planned national accelerator laboratory. The central facility of this laboratory would be a 200 billion electron volt (Bev) proton synchrotron, about a mile in diameter (see also Chapter 14—Facilities and Projects for Basic Research).

In April of 1965, the Commission entered into an agreement with the National Academy of Sciences (NAS) for the evaluation of sites proposed for this new facility. The NAS appointed a special



200 Bev Accelerator. As a part of the study made for the AEC by Lawrence Radiation Laboratory (LRL), Berkeley, a design study report on a proposed 200-billion electron volt (Bev) national accelerator facility was submitted. The preliminary engineer-architect design work which was started during 1965, is based on this LRL study. The proposed accelerator would really be a system of four accelerators, one feeding another in series. Inside the main ring there would be first, a preinjector, a conventional Cockcroft-Walton accelerator to produce a beam of 0.75-million electron volt protons which pass to a linear accelerator 500 feet long, where the protons' energy would be increased to 200 Mev. The protons would then be directed into the injector proton synchrotron (or booster), a ring of magnets and radiofrequency (RF) accelerating stations 647 feet in diameter. Here the energy of the beam would be stepped up to 8 Bev. The protons would then be injected into the main ring, a circle of 500 magnets nearly a mile in diameter (4,528 feet), containing about 20,000 tons of steel. A vacuum tube about the size of a man's arm would thread the entire ring, and in this magnetic racetrack protons would make 60,000 revolutions in one second continuously being accelerated by RF electric fields and reaching an energy of 200 Bev. The giant ring would be housed in a tunnel under 20 feet or more of earth for radiation shielding. The intensity of the beam (3×10^{13} protons per pulse) will be about 10 times higher than present machines, with 30 pulses per minute.

committee, known as the Site Evaluation Committee,[3] to perform the task. In their evaluation, the NAS was asked to give particular attention to the detailed technical requirements, the scientific benefits, and such other factors associated with sites as would assure scientific productivity and success of this high energy physics enterprise.

In September, the Commission, after careful consideration of the 126 proposals for more than 200 sites, asked the NAS to consider each proposal on which there was sufficient data to indicate the location met the basic criteria established for the site—85 proposals were in this category. As part of the further evaluation, inspection visits were made to each of the locations that met the minimum criteria by the eight teams of AEC personnel formed for this task. The visits afforded an opportunity to clarify uncertainties and to obtain firsthand additional information. These inspections were completed in early December.

During May, as a preliminary step toward providing better cost estimates for future congressional authorization for the project, the Commission had selected a coalition of four firms to perform advance architect-engineer services concerned with the development of the scope of work and cost estimate for such a facility. The firms are Daniel, Mann, Johnson, and Mendenhall, Los Angeles; the Office of Max O. Urbahn, New York; Seelye, Stevenson, Value and Knecht, Inc., New York; and George A. Fuller Co., New York. The firms, referred to as DUSAF, are undertaking the design work as a joint venture.

SLAC POWER LINE

Work on the Stanford Linear Accelerator Center (SLAC) near Palo Alto, Calif., progressed during the year toward its anticipated completion in late 1966 (see Chapter 14—Facilities and Projects for Basic Research). Previously, construction of the overhead high-voltage power line to supply the accelerator had been held up for a considerable period by court actions by the town of Woodside. The AEC's plans for the powerline included a specially designed type of pole that would blend in with the countryside, and extraordinary measures would be taken to avoid any unnecessary removal or destruc-

[3] NAS Committee—Chairman, Dr. Emanuel Piore, Vice President for Research and Development, International Business Machines Corp.; Prof. Robert Bacher, Provost, California Institute of Technology; Prof. Harvey Brooks, Dean of the Division of Engineering and Applied Physics, Harvard University; Prof. Val. L. Fitch, Princeton University; Prof. William B. Fretter, University of California, Berkeley; Prof. William F. Fry, University of Wisconsin; Prof. Edwin L. Goldwasser, University of Illinois; Dr. Crawford H. Greenewalt, Chairman, Board of Directors, E. I. du Pont de Nemours and Co., Inc.; Dr. G. Kenneth Green, Chairman, Accelerator Department, Brookhaven National Laboratory; Dr. Herbert E. Longenecker, President, Tulane University.

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tion of trees or despoilage of the natural landscape. However, the town of Woodside and the county of San Mateo contended that the line would mar the natural beauty of the area and should be placed underground.

When the town first sought to challenge AEC's authority to proceed to construct a Government transmission line to serve the SLAC project, the U.S. District Court for the Northern District of California upheld AEC's right to condemn a right-of-way and construct the line. This decision was appealed to the Ninth Circuit Court of Appeals which, on May 20, 1965, reversed the District Court and held that Congress intended by section 271 of the Atomic Energy Act of 1954, as amended, to subject the AEC to the authority and regulations of local agencies in regard to the generation, sale, or transmission of electric power.

Subsequently, the language of section 271 was clarified by Congressional action to conform to the original intent of Congress underlying the previous text—that the AEC is not subject to such local authority or regulations in regard to the generation, sale, or transmission of electric power. The amendin g bill was signed into law by the President on August 24, 1965. His accompanying statement indicated that in the interest of the SLAC project, the AEC should proceed with its plan to build the overhead power line and take special measures to protect the natural environment. The President's statement also expressed the view that the Federal Government should immediately undertake a program of accelerated research in the technology of placing high-voltage transmission lines underground, and that the AEC should agree to replace its overhead line with an underground line when full power is required for the period—estimated to be sometime between 5 and 7 years—assuming that the local area has made reasonable progress with its own efforts to underground the powerlines in the community.

DETERMINATION ON STATUTORY FINDING OF PRACTICAL VALUE

Currently, civilian nuclear power reactors are licensed by the AEC under section 104b of the Atomic Energy Act of 1954, as amended, as facilities involved in the conduct of research and development activities leading to the demonstration of practical value for industrial or commercial purposes. Section 102 of the Act provides that whenever the Commission has made a statutory finding in writing that any type of utilization or production facility has been sufficiently developed to be of practical value for industrial or commercial purposes,

Productive Land Management. A comprehensive land management program was initiated by the AEC at its Savannah River Plant in South Carolina in 1952 in cooperation with the U.S. Forest Service. Since that time, 90 million pine seedlings have been planted on 80,000 acres of land in the 200,000-acre reservation. Book value of the pine plantations in 1965 was $20 million and the value is appreciating at the rate of $2 million annually. The 1965 book value is about $1 million more than the Federal Government paid for the land on the Savannah River Plant site. At intervals, pulpwood and sawtimber are sold to private dealers on a high-bid basis. The *above* picture is a scene of an area of the Savannah River Plant in 1955. The photo *below* shows the same area as it appeared in 1965.

the Commission may thereafter issue licenses for facilities of that type only under section 103, which concerns commercial licenses.

A finding of practical value under section 102 would, in essence, be a determination that direct Federal financial assistance would no longer be available for certain types of reactors to be constructed. In effect, this is already the situation for the light-water reactors since, in recent years, no construction permits for new projects involving Federal assistance for nuclear electric plants utilizing boiling water or pressurized water reactors have been authorized.

During January, a legislative-type public hearing [4] was held before an *ad hoc* board at AEC Headquarters, Germantown, Md. Testimony was received from representatives of the coal, petroleum, and railroad industries, mine workers' union, reactor manufacturers, State governments, and utility companies. During March, the board certified the Record of the Hearing to the Commission.

In December, the Commission determined that there has not yet been sufficient demonstration of the cost of construction and operation of light-water reactor, nuclear electric plants to warrant making a statutory finding that any types of such facilities have been sufficiently developed to be of practical value within the meaning of section 102 of the Atomic Energy Act.

REGULATORY PROGRAM STUDY

In January, the Commission appointed a seven-member panel [5] from outside the Government to conduct a comprehensive study of the AEC's regulatory program in the areas of (*a*) the overall policies applied and being developed to administer the nuclear facility licensing function, and (*b*) the decision-making process in the regulatory program. In July, the panel, composed of persons with long experience and diverse backgrounds in the atomic energy field, submitted its report with a set of recommendations for improving the facility licensing process. (See Part Two, Regulatory Activities.)

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[4] See pp. 15–17, "Annual Report to Congress for 1964."

[5] Regulatory Review Panel—*Chairman*. William Mitchell, Washington, D.C., attorney and former General Counsel of the AEC; Dr. Manson Benedict, head of the Department of Nuclear Engineering, Massachusetts Institute of Technology, Cambridge; Roger J. Coe, Vice President, Yankee Atomic Electric Co., Boston, Mass.; Dr. Emerson Jones, President, Technical Management, Inc., Lincoln, Nebr.; Dr. C. Rogers McCullough, Senior Vice President, Nuclear Utility Services, Washington, D.C.; James F. Young, Vice President-General Manager, Atomic Products Division, General Electric Co., San Jose, Calif.; and Dr. Walter H. Zinn, Vice President, Combustion Engineering, Windsor, Conn.

PRICE-ANDERSON INDEMNITY ACT

A comprehensive study by the AEC of operations under the Price-Anderson indemnity legislation [6] led during 1965, to congressional action to extend the Act by 10 years beyond its expiration date of August 1, 1967. The extension (Public Law 89–210) was signed by the President on September 29, 1965, and gives the private insurance business a larger role in the nuclear industry. The extension is of particular importance to the continued growth of the nuclear power program. (See Part Two, Regulatory Activities.)

LOS ALAMOS COMMUNITY DISPOSAL

Progress continued during 1965 toward termination of AEC ownership and management of the Los Alamos, N. Mex., community. Los Alamos was built during World War II by the Federal Government as the secret site at which the atomic bomb was developed. The termination of Federal ownership and management is in accordance with the objectives of the Atomic Energy Community Act of 1955, as amended.[7]

Utility Systems

In August, the Commission agreed to supply water, electricity, and natural gas to Los Alamos County for resale to consumers. The utility distribution systems in the community will be transferred to the county in 1967, along with various municipal installations.

Transfer of the community telephone facilities awaits evaluation of proposals from companies which seek to serve the community. Such proposals were invited by the AEC on September 15. The AEC's selection of a transferee will not be announced until after January 31, 1966. Proposers were given until that date to submit evidence of legal authority to operate a telephone system in the community.

Municipal Functions

The Commission has entered into contracts with Los Alamos County for performance of certain municipal functions so that the county can gain operating experience before transfer of municipal installations by AEC. Several additional contracts were entered into with

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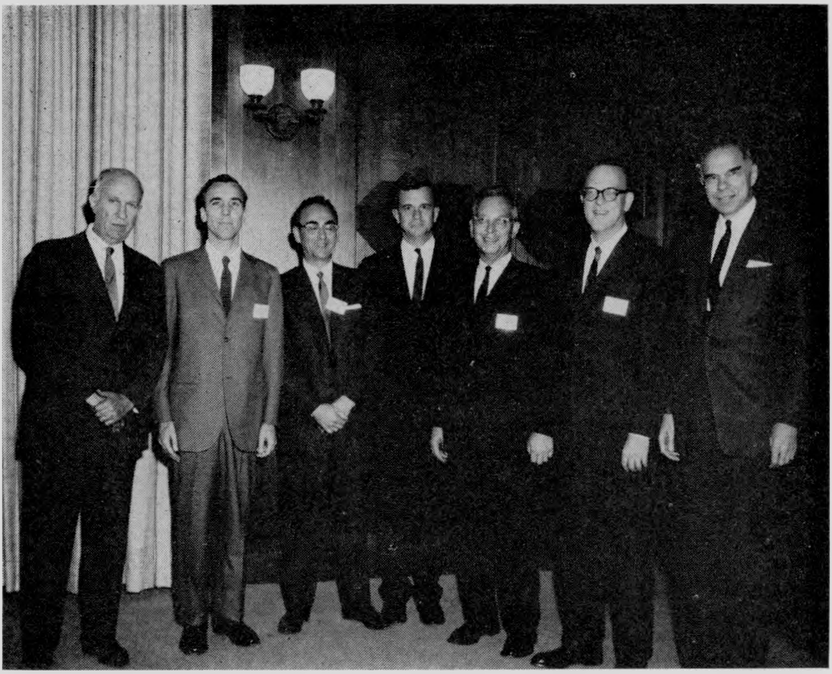
[6] Section 170, Atomic Energy Act of 1954, as amended, which was enacted by Congress in 1957.

[7] See pp. 24–26, "Annual Report to Congress for 1964."



Lawrence Award Winners. Five young nuclear scientists received a gold medal, a citation, and $5,000 each on April 29 as co-winners of the AEC's annual E. O. Lawrence Memorial Award. The five awardees are shown flanked by Dr. John H. Lawrence (*left*), brother of the late Dr. Ernest O. Lawrence, who invented the cyclotron and in whose memory the award is given, and AEC Chairman Glenn T. Seaborg (*right*). The winners were (*left to right*) Dr. Arthur C. Upton (*second from left*), Oak Ridge National Laboratory, Oak Ridge, Tenn.—"for outstanding contributions to radiobiology and to the pathology of radiation injury." Dr. George A. Cowan, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.—"for notable accomplishments and leadership in the application of radiochemistry to weapon diagnostics and for the measurement of fundamental physical quantities using nuclear explosions as neutron sources." Dr. Theodore B. Taylor, Defense Atomic Support Agency, Washington, D.C.—"for outstanding contributions to the design of nuclear weapons and for his significant role in the development of the TRIGA research reactor." Mr. Floyd L. Culler, Oak Ridge National Laboratory, Oak Ridge, Tenn.—"for meritorious contributions to the development of processes for the recovery of irradiated nuclear fuels." Mr. Milton C. Edlund, Babcock & Wilcox Co., Lynchburg, Va.—"for his role in writing the first authoritative book on nuclear reactor theory, for major contributions to the development of many reactors including the Homogeneous Reactor Test, the Consolidaed Edison Thorium Reactor and the powerplant of the NS *Savannah*, and for inventing the ingenious principle of the Spectral Shift Control Reactor." Dr. Lawrence is an Associate Director of the AEC's Lawrence Radiation Laboratory and Director of its Donner Laboratory on the University of California's Berkeley campus.

Fermi Award Presentation. Vice Admiral Hyman G. Rickover (USN) received the eighth Enrico Fermi Award from President Johnson on January 14, 1965. The presentation was made just 3 days before the 10th anniversary of the first sea voyage of the first nuclear-powered submarine, the *Nautilus.* Admiral Rickover, currently serving in a dual capacity as Director of the AEC's Division of Naval Reactors and the Navy's Assistant Chief of the Bureau of Ships for Nuclear Propulsion had been named the 1964 recipient of the AEC's Fermi Award (see pp. 31–32, "Annual Report to Congress for 1964"). The award consists of a gold medal, a citation, and $25,000. Admiral Rickover's citation included ". . . . For engineering and administrative leadership in the development of safe and reliable nuclear power and its successful application to our national security and economic needs. . . ." The Admiral has directed the development and construction of the Navy's fleet of nuclear submarines and surface ships and the AEC's Shippingport, Pa., nuclear power facility. Photo shows (*left to right*) President Johnson, Admiral Rickover, AEC Commissioner James T. Ramey, and AEC Chairman Glenn T. Seaborg.

the county during the year. The AEC is providing financial assistance to enable the county to contract for services and hire employees as part of its preparations for assuming full municipal responsibilities.

Sale of Real Property

Platting of the community was completed during 1965. The AEC's classification of properties in the community and the FHA-appraised values of approximately 1,500 single-family and duplex properties were posted on August 30. On October 19, the Administrator of the U.S. Housing and Home Finance Agency made a formal finding that there was a "reasonable possibility" that the sales program could be completed satisfactorily. The first offerings of individual houses (single and duplex) were made on November 1, and the first house was sold to a priority purchaser on November 18.

Predisposal Construction Projects

During the year, further work was done on community road and street improvements and rehabilitation of utility systems, and classrooms were added to several schools. Plans were completed for a new county court house and administration facility and construction bids were solicited; bids exceeded the Government estimate requiring certain redesign and readvertising.

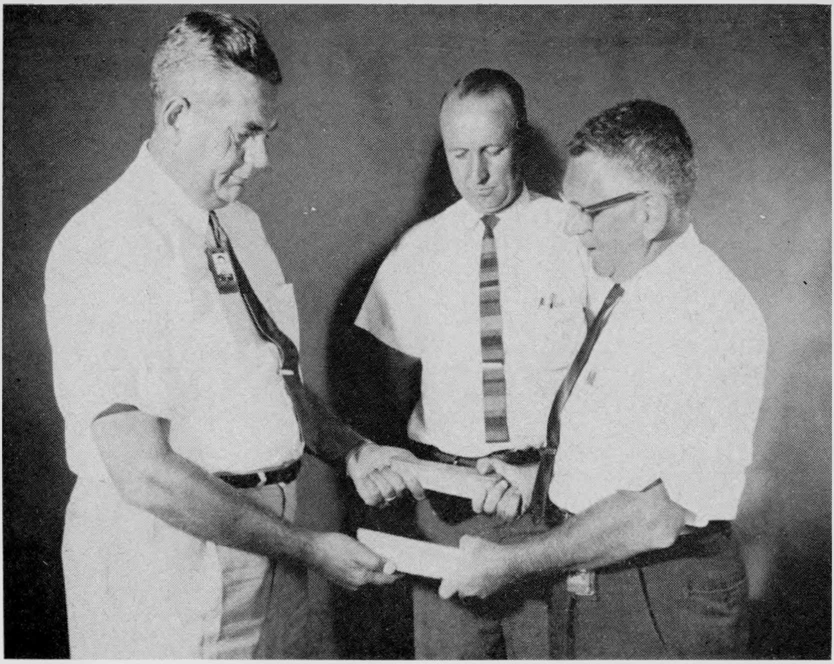
Private Housing Construction

Private housing construction, which will help to alleviate the housing shortage at Los Alamos, continued during the year in the Barranca Mesa and White Rock areas of Los Alamos County. An additional 141 lots were offered for sale by the AEC on Barranca Mesa. Private contractors have completed or have under construction approximately 337 homes on Barranca Mesa. Eight subdivisions in White Rock, in which approximately 375 homes have been completed or are under construction, are being developed by private builders. Adjacent to White Rock are two additional subdivisions, called Pajarito Acres, in which 191 three- to five-acre tracts are being privately developed. An additional 57 homes have been completed or are under construction in these areas.

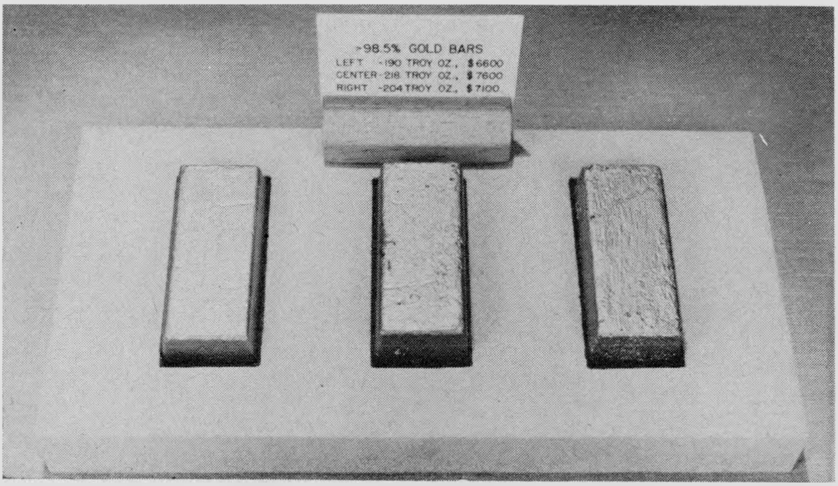
CIVIL RIGHTS ACT

Title VI of the Civil Rights Act of 1964 provides that no person in the United States shall on the ground of race, color, or national origin, be excluded from participation in, be denied benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance.

Pursuant to the Civil Rights Act of 1964, the Commission issued a regulation (10 CFR 4) effective January 30, 1965, which implements



Gold Recovery. During the normal maintenance and improvement of gaseous diffusion plant equipment, large quantities of contaminated aluminum scrap are generated. Facilities installed at the AEC's Paducah Gaseous Diffusion Plant for the smelting and recovery of this material have recently been used for recovery of gold from gold-plated parts. The gold is made into bars of greater than 98 percent purity. Photo *above* shows a Paducah Plant official transferring recovered gold to an AEC representative for return to the U.S. Treasury. Photo *below* shows some of the gold recovered during 1965. Over $100,000 credit has been realized to date from the gold recovery program at the Union Carbide Corp.-operated plant.



title VI with respect to AEC programs of financial assistance. At year's end, approximately 3,200 assurances of compliance with title VI and the AEC regulation had been received from current, and prospective, recipients of financial assistance from the AEC.

AEC Federal Equal Employment Opportunity Program

As an integral part of its regular recruitment program, the AEC continued to intensify efforts to obtain well qualified minority group candidates for direct AEC employment. During fiscal year 1965, the percentage of Negro employment within AEC increased from 2.9 percent to 4.3 percent.

Chapter 2

THE INDUSTRIAL BASE

During the year, as companies added nuclear-related work to their operations and new firms were founded, the industrial base for the Nation's nuclear energy effort continued to broaden. The Commission increased its solicitation of industry views and plans especially with regard to future planning in the use of nuclear energy.

CONTRACTOR REPLACEMENT AND DIVERSIFICATION

The major growth factors in the broadening industrial base for the Nation's atomic energy program were associated with the contractor replacement and diversification activities at the AEC's Hanford, Wash., complex. The private business diversification being undertaken by the AEC's new operating contractors at the Hanford Works is providing the beginnings of a broadened economic base for the nearby communities; if present estimates materialize, there should be little or no net reduction in the long-term employment in the area. Efforts to put to productive use AEC facilities no longer being fully used were having an effect in such communities as Oak Ridge, Tenn., Paducah, Ky., and Portsmouth, Ohio.

ACTIVITIES AT HANFORD

The selection of contractors to replace the General Electric Co. as operating contractor for the AEC's plants and facilities near Richland, Wash., was completed during 1965.

As a result of the President's January 1964 announcement[1] of a reduction in the rates of production of plutonium and enriched uranium, three of the nine plutonium producing reactors at Hanford have been shut down. In addition, one of the two chemical-separation plants is scheduled for shutdown in 1967. The Commission has cooperated extensively with the dynamic local community leadership

[1] See pp. 17–23, "Annual Report to Congress for 1964."

provided by a group known as the Tri-City Nuclear Industrial Council (representing the communities of Richland, Kennewick, and Pasco), to reduce the economic impact of the shut downs through diversification of the local economic base.

At the end of the year, six new contractors were involved in taking over operations previously performed by the General Electric Co. at Hanford. The AEC and General Electric in January 1964 had announced a mutual decision that General Electric would withdraw from its role as the single operating contractor for the Hanford Works, a function the company had conducted since 1946. In addition to its primary concern that the new contractors be qualified to continue the standards of excellence which have characterized operations under AEC programs at Hanford, the Commission has sought to assist in stimulating diversification of the economic base of the "Tri-Cities Area" by giving consideration to the additional private business activity each contractor has proposed to bring into the area, if selected.

NEW CONTRACTORS

Laboratory Operations

On Januray 4, 1965, the Battelle Memorial Institute of Columbus, Ohio, took over operation of the AEC laboratory activities at Hanford. At the same time, the laboratory facilities were renamed the Pacific Northwest Laboratory. Battelle has announced that, over a 10-year period, it will carry out a $19 million private construction program in the Tri-Cities area. Battelle estimates that its private work will employ at least 200 additional persons by 1970.

Reactor Operations and Fuel Preparation

The Commission selected Douglas United Nuclear, Inc.—a joint venture formed by Douglas Aircraft Co., Santa Monica, Calif., and United Nuclear Corp., Centreville, Md.—to operate initially five, and ultimately all six, of the plutonium-production reactors currently in use at Hanford, together with the related fuel-preparation facilities, and to continue surveillance of the shut down reactors. Douglas United Nuclear commenced operations under the contract on November 1, 1965. In furthering diversification of the economic base of the area, the joint venture and the parent companies will:

(*1*) Invest $6.6 million in private facilities in the Richland area, and thus create an estimated 300 new jobs by 1970.

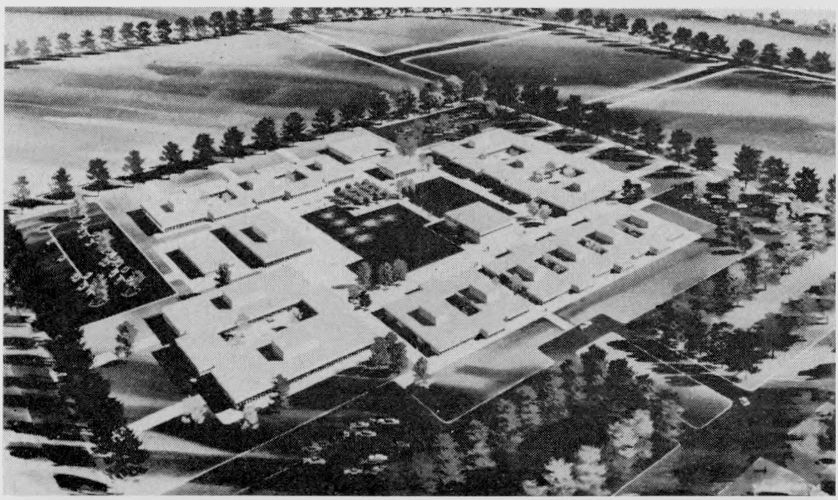
(2) Contribute to the University of Washington, $100,000 a year for five years toward establishment of a Graduate Study Center at Richland.

(3) Establish a small business investment corporation, with initial capital of $150,000, to assist in the formation and growth of new small businesses in the area.

General Electric Co. will continue to operate the "N" reactor and associated fuel preparation facilities until the reactor has demonstrated satisfactory operation. (See Chapter 5—Source and Special Nuclear Materials Production.)

Chemical Separations

Isochem, Inc., of Richland, Wash., joint venture of the U.S. Rubber Co., and Martin-Marietta Corp., both with headquarters in New York City, will operate the Hanford chemical separations facilities begin-

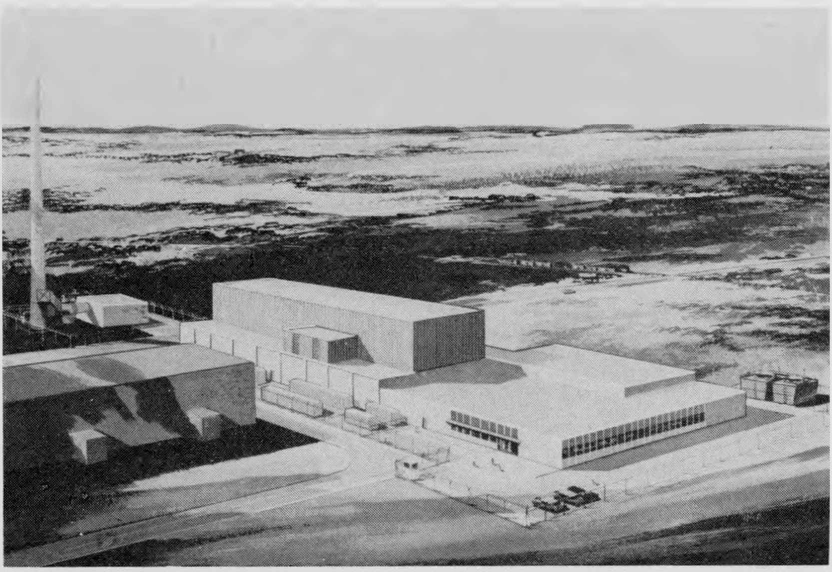


New Private Research Facility. After taking over as the AEC's operating contractor for the Pacific Northwest Laboratory (formerly Hanford Laboratories), the Battelle Memorial Institute announced it would also undertake a $19-million private construction program at nearby Richland. The drawing is an architect's aerial conception of the construction program planned to extend over a 10-year period. Buildings on the *lower right* side of the rectangle are a mathematics building (*left*) and research operations building (*right*). These two structures, together with the 300-seat auditorium (above research operations) and multipurpose pool at *left* will be in the first phase of construction. Other structures are projected for construction in future stages. The pools will contain the cooling system evaporation sprays, and have trees surrounding them to create an oasis-like character to contrast with the area surrounding the site.

ning January 1, 1966. Isochem will build and commercially operate a $8 million plant for converting and encapsulating fission products from Hanford's radioactive wastes. The new plant is expected to create about 150 jobs by 1970. (See "Fission Products Production" item in Chapter 5.)

Support Services

ITT Federal Support Services, Inc., a new Richland, Wash., subsidiary of International Telephone and Telegraph Corp., New York City, will operate the Hanford support facilities and provide services to other operating contractors, beginning March 1, 1966. Included are transportation and maintenance, plant utilities, purchasing and warehousing, and certain administrative services. During the first 5 years of operation, the new contractor and its corporate affiliates will invest approximately $2 million in a regional complex of facilities for



New Private Radioisotope Facility. An artist's concept shows the proposed Fission Products Conversion and Encapsulation Facility planned for private construction at the AEC's Hanford complex, near Richland, Wash. The $8-million plant will be used to prepare and package useful radioactive byproducts of Hanford for marketing. Isochem, a subsidiary of U.S. Rubber Co. and Martin Marietta Corp., was awarded, during February, a contract to operate the Hanford Chemical Processing Department. Isochem will build and commercially operate the conversion and encapsulation facility. It is one of several new enterprises being established in the Richland area as a result of the AEC's contractor diversification at Hanford.

manufacturing electronic components and providing a variety of technical and engineering services. It is expected that such private work will create 350 additional jobs by 1970.

Automatic Data Processing

Since July 1, 1965, Computer Sciences Corp., of El Segundo, Calif., has been providing the computing and data processing services for the AEC programs at Hanford. The company is providing additional computer equipment with its own funds and expects to centralize some of its private operations at Richland as well as to seek further private work to be done there. The firm's private work will require approximately 60 positions by 1970.

Radiation Protection Services

United States Testing Co., Inc.,[2] of Hoboken, N.J., has constructed a new $250,000 facility in Richland to perform radiation-protection services for AEC programs at Hanford under a fixed unit-price contract, effective January 4, 1965. In addition, the company is performing work for others on a private basis in commercial instrument maintenance and calibration, nondestructive testing, glassware calibration, and engineering inspection. Fifty additional jobs are expected to be created by 1970.

LAND RELEASE

The AEC has leased 1,000 acres of the Hanford site to the State of Washington for use by the State in developing nuclear industry. The State has subleased 100 acres to California Nuclear, Inc., of Pleasanton, Calif., for purposes of land-burial of low-level radioactive waste.

The AEC has announced that 39,000 acres of land on the Wahluke Slope in the safety buffer-zone around the production reactors, adjoining the northeast perimeter of the Hanford reservation, is being made available for nonresident farming under controlled conditions. Most of the area becomes available as a result of the shutdown of the "F" and "H" reactors. The action will permit utilization of one of the more productive natural resources of the area. Irrigation will be under the jurisdiction of the U.S. Bureau of Reclamation, which will also handle leasing arrangements, in accordance with agreements reached by the AEC and the Bureau.

[2] Not an affiliate of the U.S. Government.

GENERAL OBSERVATIONS ON HANFORD ACTIVITIES

While it would be premature to make predictions concerning the future effects of the changes at Hanford, the Commission is highly pleased with the initial results of the contractor-replacement program. It has been most encouraging that so many large and capable private firms in this country showed an interest in operating portions of the Hanford Works—and also that they found opportunities for private investment in the area. The cooperative effort with the residents, through the Tri-City Nuclear Industrial Council, has been important to the progress made to date. The Commission plans to continue working with the community representatives to maximize diversification of the local economy. Not only the AEC, but the administration as a whole, is watching this program closely. It may well be that what is being done at Hanford will prove to be applicable at other locations that may now, or in the future, face similar substantial cutbacks in employment with a probability of consequent adverse economic effects.

NRTS CONTRACTOR REPLACEMENT

On May 3, the AEC announced it was inviting proposals from industry for operation of its test reactors, chemical processing plant, and associated research and development and for support services work at the National Reactor Testing Station (NRTS) near Idaho Falls, Idaho, under a single, cost-plus-fixed-fee contract.

The main facilities to be operated under the contract include the Idaho Chemical Processing Plant and related facilities, the Materials Testing Reactor, the Engineering Test Reactor, and the Advanced Test Reactor.

Support services are to be provided for the entire NRTS by the new contractor. These services include such things as operation of the bus system, technical library, radioactive waste disposal facilities, analytical laboratory, metallurgical and hot cells, motor-pool, cafeteria, printing, photography, and maintenance shops and will also conduct general stores purchasing and warehousing.

This work is currently performed for the AEC by the Phillips Petroleum Co. Phillips will continue to conduct the extensive nuclear safety program and associated activities at the NRTS. Besides Phillips, other contractors conducting Commission works at the NRTS include the Argonne National Laboratory, Westinghouse Electric Corp., General Atomic, and General Electric Co.

Included in the invitation, among other things, was a requirement that the new contractor must not currently have a major operating or on-site services contract with the AEC. Consideration was also to be given to the degree of interest in the commercial atomic energy industry as evidenced by the firm's activity and investment in the field.

At year's end, two proposals had been received—one from General Dynamics Corp. and a joint proposal from Aerojet-General Corp. and Allied Chemical Corp. These proposals were being evaluated with selection action expected to be completed early in 1966.

OTHER DIVERSIFICATION ACTIONS

In cooperation with local leaders at Oak Ridge, Tenn., Paducah, Ky., and Portsmouth, Ohio, the AEC has actively sought new uses for production facilities at those locations, which are no longer being fully used. Particular emphasis has been placed upon making laboratory, testing, machine shop engineering, and other unique research and development and fabrication skills available for use by other Government agencies.

Facility Utilization by Others

In support of the U.S. Department of the Interior desalination program, the engineering skills available at Oak Ridge are being applied in the conceptual design of large evaporator plants and in the development of many of the plant components which will be required when large desalting systems are built.

Development and fabrication of unique items of hardware for aerospace and other applications are being performed at the Paducah and Oak Ridge installations, for the National Aeronautics and Space Administration and for the Department of Defense.

At the Portsmouth plant, AEC's action in making warehouse space temporarily available, in cooperation with local development efforts, led to permanent location of a new automobile parts manufacturing plant at Waverly, Ohio. The company will build its own facility shortly, and eventually will employ 250 persons.

INDUSTRIAL PARTICIPATION ASPECTS

The Commission, in accordance with section 1b of the Atomic Energy Act of 1954, as amended, has a responsibility to help develop and strengthen free competition in private enterprise.

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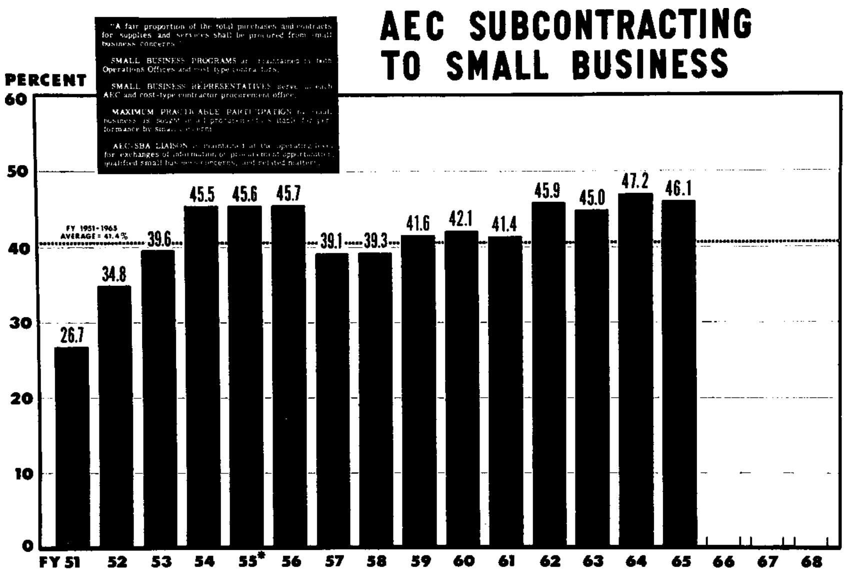
AEC ACTIONS IN COOPERATION WITH INDUSTRY

During 1965, some of the many cooperative steps the Commission has taken with industry to help achieve a competitive nuclear industry came to fruition. Some of these were:

- The negotiation of contracts for the stretch-out program on raw material purchases was completed. It is anticipated that, as AEC ore contracts expire by 1970, the uranium mining industry will be sustained by private sales. (See "Raw Materials" section, Chapter 5.)
- The first AEC base-load guarantee to encourage a private spent-fuel reprocessing industry became effective as irradiated fuels were turned over to the first privately owned reprocessing plant. Owned and operated by Nuclear Fuel Services, Inc., the target date for commercial operation is January 1966. The plant began receiving ir-



	51	52	53	54	55*	56	57	58	59	60	61	62	63	64	65
SUBCONTRACT DOLLARS TO SMALL BUSINESS (Millions of Dollars)	209.7	259.0	311.6	241.2	153.9	211.1	224.3	216.0	220.5	262.9	277.4	338.0	334.9	364.9	312.3
SUBCONTRACT DOLLARS - TOTAL	785.5	743.5	783.0	529.0	337.9	461.8	574.2	550.0	530.3	624.0	669.2	736.0	744.5	772.8	677.3

*Does not include three Kiewit Co. Subcontracts at Portsmouth, Ohio which are in the nature of prime contracts.

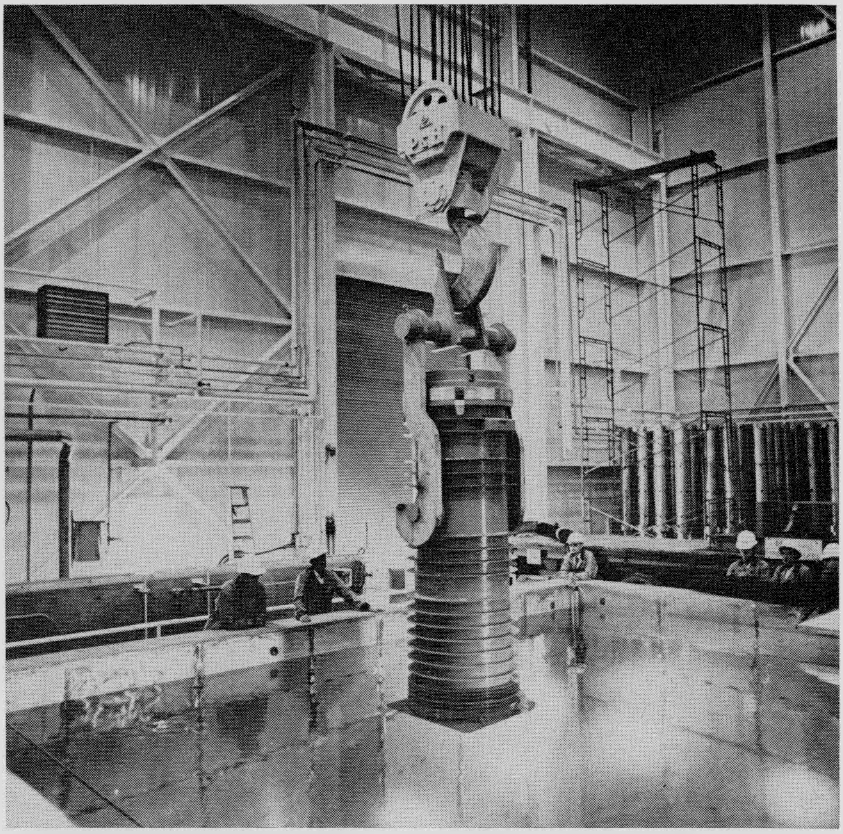
Small Business's Share. Small business participation under the AEC's prime contracts and subcontracts continued to receive emphasis throughout the AEC organization and by AEC's major cost-type contractor purchasing officers. Small business received a significant share of the total AEC subcontract awards during fiscal year 1965, totaling $312.3 million, or 46.1 percent of the $677.3 million total subcontract awards. The small business share of the AEC subcontracts for the period, 1951 through 1965, was 41.4 percent. The chart shows, on a percentage basis, the share of AEC subcontracts that have gone to small business during the past 15 years.

radiated fuel elements during June. The Commission is studying what steps, if any, it should take to encourage additional reprocessing capacity. (See "Fuel Reprocessing" item, Chapter 5.)

- The development of central station nuclear power technology has reached the point where a number of additional utilities are purchasing nuclear powerplants without the financial incentives of the cooperative Power Reactor Demonstration Program. These and additional projects now under consideration by utilities will help encourage a competitive base of reactor component suppliers. (See Chapter 7—Civilian Nuclear Power.)
- In connection with the award of operating contracts, the Commission's policy of taking into account the interest and investment made by members of the civilian nuclear industry is beginning to bear results. The contractor replacement activities at Hanford and NRTS described earlier in this chapter have provided several of these companies, as well as other companies selected, an opportunity to participate directly in the Government's atomic energy program. (See "Activities at Hanford" and "NRTS Contractor Replacement" items in this chapter.)
- Informal discussions with utility organizations and atomic equipment companies to learn of their plans are continuing. The information will be used by the Commission in its internal long-range planning for the continued development of the nuclear energy program. (See "Meetings With Utilities and Equipment Firms" item, this chapter.)
- The Advisory Committee on Isotopes and Radiation Development is aiding in broadening the industrial interest in isotopes. The Committee's composition has been gradually changed over the past year to bring in additional representatives from the various segments of the isotope industry; it also cooperated in an industrial survey. (See "Technology Utilization" item, Chapter 13—Isotopes and Radiation Development.)

Industry Associations

Good channels of communication between private industry and the AEC are essential to the maintenance of the U.S. position as a world leader in peaceful applications of atomic energy. Formal meetings were held by the Commission with groups such as the Atomic Industrial Forum, the U.S. Chamber of Commerce, and the Edison Electric Institute. Informal meetings were held by the AEC staff with other industry groups with an active interest in the atomic energy program such as the National Association of Manufacturers, the American Public Power Association, the National Rural Electric Cooperative Association, the National Security Industrial Association, the Aerospace Industries Association, and the Manufacturing Chemists' Association. The meetings provide for a free exchange of ideas and a means of resolving common problems.



First Private Reprocessing. A 23-ton cask containing a single fuel element from the Yankee Atomic Electric Co.'s Rowe, Mass., nuclear reactor is lowered into the unloading pool at Nuclear Fuel Services (NFS) reprocessing plant at West Valley, N.Y. It was the first such shipment to be received at private industry's first nuclear reprocessing plant. The fuel element was removed underwater and transferred to an adjoining storage pool where it will remain until undergoing reprocessing. Through chemical purification, the unspent portion of the nuclear fuel will be recovered and made available for reuse in a reactor. Commercial operation of the $28 million NFS project will begin in January 1966. NFS is a majority-owned subsidiary of W. R. Grace & Co.

Meetings with Utilities and Equipment Firms

Over the past several years, the Commission has been holding informal discussions with utility organizations interested in atomic power to learn of their plans. Such discussions have provided the Commission with an opportunity to receive industry's comments and outlook in regard to the growth of the nuclear industry and have a bearing on the Commission's planning for the future. These meetings, 11 of which took place this year, have been held with more than 30 utilities and utility groups. They have enabled the Commission to obtain a better understanding of the factors utilities consider in selecting new plants and reactor manufacturers.

In these meetings, the trend toward industrial concentration and ways of stimulating the growth of a competitive industry have also been discussed.

Recently, the discussions have been extended to include meetings with the principal atomic equipment companies. Ten meetings with equipment companies were held during 1965 and involved frank exchanges of viewpoints between the Commission and industry. On one hand, the companies are concerned about their future role in the nuclear industry; on the other hand, the Commission is keenly interested in encouraging the healthy development of a competitive nuclear industry.

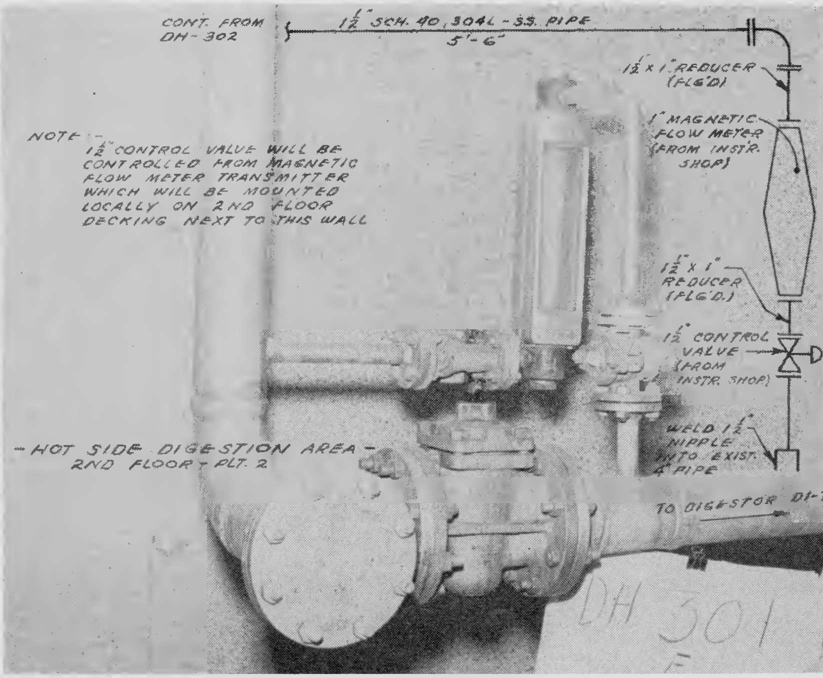
Utility Survey

As an extension of its previous efforts in forecasting the growth of nuclear power, the AEC during the year conducted a spot survey of electric utilities to obtain additional first-hand information regarding their future growth and plans. This information will be used by the AEC in its long-range planning for continued reactor development, diffusion plant operation, regulatory staff level of activity, and other portions of its overall program.

Contacts were made throughout the Nation with approximately 50 private and public utility organizations, constituting over one-half of the present total national electric generating capability. Discussions were also held with appropriate national organizations, such as the American Public Power Association, the National Rural Electric Cooperative Association, the Edison Electric Institute, and the Atomic Industrial Forum, as well as with the Rural Electrification Administration.

INDUSTRIAL CAPABILITY

Private industry has developed a capability [3] to provide almost all the materials, equipment, and services needed in the generation of electric power from enriched uranium. A major important exception is the enrichment of uranium in the uranium 235 isotope that is accomplished in the Government-owned gaseous diffusion plants at Oak Ridge, Tenn., Paducah, Ky., and Portsmouth, Ohio. In the absence of commercial enriching facilities, "toll enrichment" is provided for



Photographic Engineering "Drawings." The National Lead Co. of Ohio, operator of the AEC's Feed Materials Production Center at Fernald, Ohio, is using a photographic technique to make engineering "drawings." The method all but eliminates costly drafting time and is particularly useful when changes are to be made in existing equipment. Photographs are taken of the equipment involved on 2¼" x 2¼" black-and-white negatives. After development, the negatives are mounted in microfilm aperture cards which can be filed, sorted, and retrieved with standard punched-card equipment. The mounted negatives are enlarged and 18" x 24" matte-surfaced prints are made on which it is a simple matter for the engineer to sketch in the desired changes, as shown above, using a black marking crayon.

[3] For a complete report on the private atomic energy industry, see *The Nuclear Industry—1965*, available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, for $0.55.

in the legislation which authorized private ownership of special nuclear material.[4] The AEC has prepared and published for public comment, a draft of proposed criteria under which this service would be offered. (See "Private Ownership Act Implementation" item, Chapter 5.)

PRIVATE NUCLEAR INDUSTRY GROWTH

During the year, there were a number of changes in the nuclear industry that, despite some withdrawals or contractions of operations, showed a continuing over-all growth of industrial capability.

Some 1965 Changes

Three firms—the Continental Oil Co., Reynolds Electric Co., and Edgerton, Germeshausen and Grier, Inc.—have formed a new company called CER Geonuclear, Inc. This firm proposes to assist other companies in familiarization with Plowshare (peaceful uses of nuclear explosives) technology and ultimately, when industrial applications of nuclear explosives are ready for commercial use, to offer a complete service to industry in which AEC would supply only the nuclear device and assure compliance with safety requirements. Holmes and Narver, Inc., and R. F. Beers, Inc., are also offering similar services.

The Atlas Corp. closed its mill at Mexican Hat, Utah, but will continue to process ore at its mill at Moab, Utah. Vitro Chemical Co., Salt Lake City, Utah, and the Cotter Corp., Canon City, Colo., are no longer processing uranium ores.

Kerr-McGee completed a new plant near Oklahoma City for the production of uranium metals, oxides, and compounds. Nuclear Fuel Services completed a new facility at Erwin, Tenn., to produce uranium oxide microspheres by a new process. Minnesota Mining and Manufacturing ceased production of coated uranium particles.

The Allied Chemical Co. plant at Metropolis, Ill., may be reopened in 1966 for uranium hexafluoride production after having been closed since June 30, 1964.

The Westinghouse Electric Corp. will concentrate more on the production of commercial and rocket fuels. Capacity previously used to fabricate Navy fuel will be devoted to this work.

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[4] See pp. 12–15, "Annual Report to Congress for 1964."

Babcock & Wilcox began production of radioisotopes for commercial sale at its Lynchburg, Va., facility. Isochem, Inc. (jointly owned by U.S. Rubber and Martin-Marietta) has taken initial steps toward private construction of an $8 million plant which will separate useful radioisotopes from waste products at the AEC's Hanford Works, Richland, Wash. Iso-Serve, Inc., one of the principal producers of radioisotopes, changed its name during the year to Cambridge Nuclear Corp.

The Gamma Process Co. was established and will use the Westinghouse hot cells at Waltz Mill, Pa., for encapsulation of cobalt 60 and other work.

The Newport News Shipbuilding & Dry Dock Co. announced the formation of a subsidiary, Nuclear Engineering & Construction Co., Inc., to engage in specialized work (refueling and periodic overhaul) on land-based nuclear plants. The firm has had prior experience in nuclear work as builder of the nuclear carrier *Enterprise* and 22 nuclear submarines, and has refueled the *Enterprise* and the nuclear cruiser *Long Beach.*

A third company [5] entered the low-level waste management field with the licensing of California Nuclear, Inc., to operate a burial site at Richland, Wash.

The X-Ray Monitoring Co. and its subsidiary, the Atomic Film Badge Corp., Long Island City, N.Y., terminated their activities relating to film badges. The United States Testing Co. entered this field with the establishment of a private laboratory at Richland, Wash.

SHIPMENTS OF ATOMIC ENERGY PRODUCTS

Shipments of specialized atomic energy products during 1964, as reported by the Bureau of the Census,[6] reached $261 million, an all-time high and 14 percent above the 1963 total of $228 million.

These totals do not include shipments of nuclear instruments which formerly were included in the Census survey for the years prior to 1963. Nuclear instruments are now included by the Census Bureau in a survey of the instrument industry. The 1964 figures for this survey were not available at the time of printing this report.

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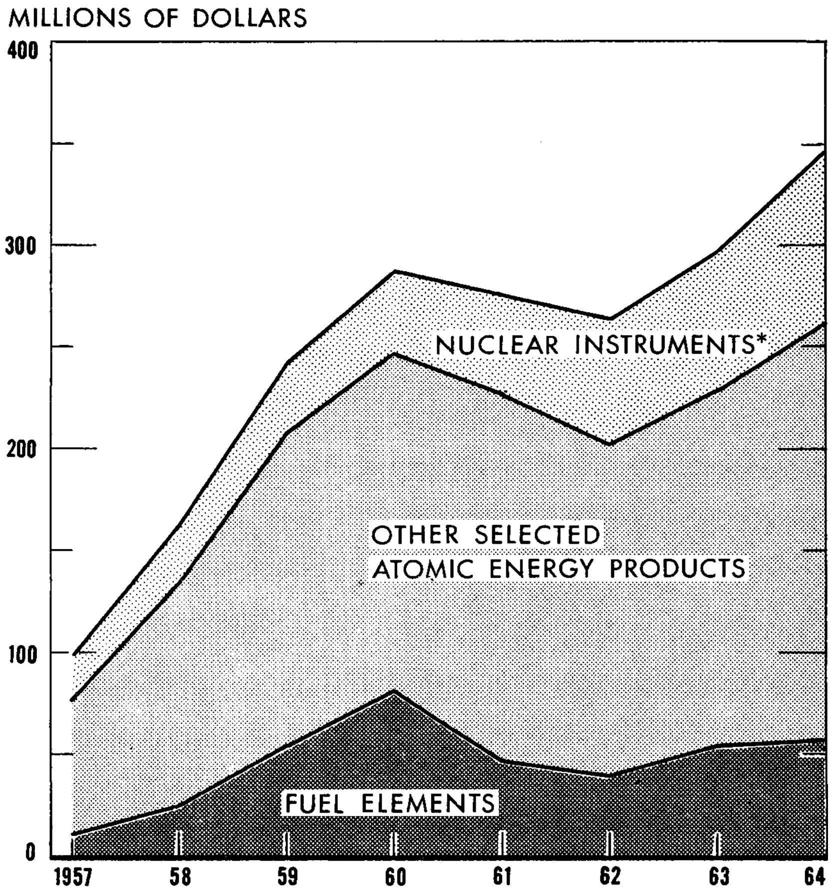
[5] Nuclear Engineering Co. operates low-level waste burial facilities at Beatty, Nev., and Morehead, Ky. Nuclear Fuel Services operates a burial site at West Valley, N.Y.

[6] The report, "Selected Atomic Energy Products—1964" [Series M38Q(64)-1], is available from the Bureau of Census, Washington, D.C., 20233, for $0.25.



Shipments of Products. **Chart shows the relative volumes of shipments of atomic energy products from privately owned facilities over the calendar years 1957–64 as based on data collected by the annual Bureau of Census surveys. The volume of nuclear instruments shipments for 1963 and 1964 are estimates by the AEC's Division of Industrial Participation staff.**

DEVELOPMENT WORK IN INDUSTRIAL LABORATORIES

Table 1 shows the distribution of AEC research and development (exclusive of that related to production and weapons activities) by type of organization. Both the dollar value of work in industrial laboratories and the percentage of such work in terms of total research and development expenditures decreased in 1965, the first decrease since this information was initially collected in 1958. This reflects increases in the cost of research and development work at AEC laboratories in the physical sciences and in biology and medicine rather than a significant trend in reactor development work. In reactor work, expenditures decreased overall by about five percent with somewhat comparable reductions in levels at both AEC laboratories and in industrial facilities.

TABLE 1.—DISTRIBUTION OF RESEARCH AND DEVELOPMENT EXPENDITURES

[Fiscal years—millions of dollars]

Type of Organization	RD [1]		R [2]		BM [3]		ID [4]		PNE [5]		Total	
	1964	1965	1964	1965	1964 [6]	1965	1964	1965	1964	1965	1964	1965
Industrial	197.5	180.9	1.3	1.4	1.5	1.0	2.2	1.9	------	------	202.5	185.2
AEC laboratories	283.9	267.1	145.3	189.3	48.5	53.2	4.2	5.3	12.5	10.7	494.4	525.6
Universities	2.8	2.4	52.0	56.9	14.8	16.0	0.8	0.8	------	------	70.4	76.1
Other nonprofit	4.1	3.3	2.4	1.1	3.3	3.9	0.4	0.3	------	------	10.2	8.6
Other Government	14.0	23.8	2.9	2.7	2.9	3.1	0.3	0.5	------	------	20.1	30.1
Total [7]	502.3	477.5	203.9	251.4	71.0	77.2	7.9	8.8	12.5	10.7	797.6	825.6

[1] Reactor development.
[2] Physical research.
[3] Biology and medicine.
[4] Isotopes development.
[5] Peaceful nuclear explosives.
[6] Revised.
[7] These totals do not agree exactly with totals shown in the Annual Financial Report. Depreciation on Commission-owned facilities and cost of special nuclear material consumed are not included here but are included in the Annual Financial Report. Also, this table includes some estimates of expenditures based on contract commitments.

SOUTHERN INTERSTATE NUCLEAR BOARD

During the year, the Commission worked closely on several projects with the Southern Interstate Nuclear Board (SINB), the executive agency of the Southern Interstate Nuclear Compact.[7]

Two briefing sessions on commercial uses of atomic energy were held in cooperation with the SINB at Oak Ridge, Tenn., one in May and a second in August. Each session was attended by more than 100 leaders from the southern States.

[7] Section 4 of Public Law 87–563 specifically authorized the AEC to cooperate with SINB in areas of common interest. Nathaniel Welch of Auburn, Ala., was appointed in April 1963 by the late President Kennedy to serve as Federal Representative to the Southern Interstate Nuclear Board, the executive agency of the Southern Interstate Nuclear Compact. Mr. Welch's reporting channel to the President is through the Chairman of the AEC.

Contract Studies

One AEC contract was placed with the Board for a survey of problems related to shipments of reactor fuel elements. A particular objective of this study is to develop ways of encouraging the shipment of irradiated fuels from abroad for reprocessing in the United States. Under another contract the SINB was studying mechanisms which could bring irradiated wood-plastic materials into commercial production with special reference to the southern States and to Appalachia.

The Commission also cooperated with the SINB, NASA, and the Department of Commerce in a study-work project on the value of nuclear and space technologies to the industrial resources of Charleston, W. Va. This was an experimental effort to test the idea of using new technologies to increase employment in economically depressed areas such as Appalachia.

ACCESS PERMIT PROGRAM

The Access Permit Program continues to provide private industry with access to classified information for peaceful, private uses of atomic energy. Initiated in 1955, over the years it has provided a means by which about 2,000 individuals and organizations have kept abreast of classified developments in nuclear work of interest to them.

The largest number of Access Permits, 1,432, were in effect in 1958. Since then, the number has declined as research and development work on peaceful applications of atomic energy have been progressively declassified. As of the end of November 1965 there were 495 Access Permits in effect (376 for access to Secret Restricted Data, and 117 for Confidential) as compared with 547 a year earlier (416 for Secret and 131 for Confidential). Table 2 on page 42 shows the principal fields of interest.

TABLE 2.—ACCESS PERMIT HOLDERS BY PRINCIPAL FIELDS OF INTEREST

	Nov. 30, 1964	Nov. 30, 1965
Batteries (nuclear)	2	3
Chemical processing and equipment	35	22
Components (except reactor components)	35	23
Consulting	67	59
Controlled thermonuclear field	5	5
Design and construction of atomic energy facilities	45	36
Electronic systems	17	11
Fuel element fabrication	30	30
General nuclear research and development	73	66
Information services	10	14
Instruments	32	33
Insurance evaluation	51	45
Investment and banking	2	0
Isotope production and utilization	34	34
Legal assistance and accounting	18	17
Machinery	16	14
Ore refining and production of feed materials	11	7
Radiation hazards and effects	40	32
Radioactive waste	18	18
Reactor—Central station	69	61
Reactor—Components	43	37
Reactor—Heating	4	6
Reactor—Other	10	11
Reactor—Propulsion	21	25
Reactor—Research	10	14
Shield materials	13	15
Special materials	39	34
Surveys for potential use or need	15	12
Training and education	12	13
Transportation and storage	4	5
Weapons and components	7	3
Others (Not elsewhere classifiable)	29	21
Total	807	726

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

Chapter 3

INDUSTRIAL RELATIONS

Employment in the atomic energy field, at both Government and private establishments, declined during 1965. However, the efforts of the AEC, its contractors and others, in assisting in the placement of surplus contractor employees helped to minimize the impact of these reductions.

MANPOWER IN THE ATOMIC ENERGY FIELD

The annual survey of manpower in the atomic energy field which is conducted by the Bureau of Labor Statistics (BLS) for the AEC shows employment in industrial establishments in the atomic energy field of 139,200 in January 1965, compared to 145,000 in January 1964, a reduction of 4 percent. The reduction in Government-owned establishments was 2.1 percent, and in privately owned establishments was 9.7 percent. (See Table 1, Appendix 4 for a two-year comparison by economic segment of personnel employed in Government-owned and privately owned establishments in 1964 and 1965.)

The page 44 table reflects employment changes (on a preliminary data basis) in occupational categories at industrial establishments in the atomic energy field as of January 1965 in comparison with January 1964.

Employment in the atomic energy field in economic segments, which are not included in the BLS survey of industrial establishments, was estimated in January 1965 at 45,000. These segments are: uranium mining, private nonprofit research laboratories, university research and teaching, construction of nuclear facilities, and the Federal service.

AEC CONTRACTOR EMPLOYMENT

Employment at Government-owned establishments operated by AEC prime cost-type contractors engaged in production, research,

	January 1964	January 1965	Actual change	Percent change
Government-owned plants:				
Engineers	13, 795	13, 300	−495	−3. 6
Scientists	8, 905	9, 363	+458	+5. 1
Technicians	15, 287	15, 429	+142	+0. 9
All other	70, 754	68, 325	−2, 429	−3. 4
Total	108, 741	106, 417	−2, 324	−2. 1
Scientists and engineers in research and development work	16, 037	16, 439	+402	+2. 5
Privately owned plants:				
Engineers	7, 060	6, 726	−334	−4. 7
Scientists	2, 122	1, 999	−123	−5. 8
Technicians	7, 068	6, 592	−476	−6. 7
All other	20, 043	17, 470	−2, 573	−12. 8
Total	36, 293	32, 787	−3, 506	−9. 7
Scientists and engineers in research and development work	4, 675	4, 658	−17	−0. 4

(Table 2 in the *Appendix 4 shows employment by occupational categories in* Government-owned and privately owned industrial establishments by economic segments as of January 1965.)

development, maintenance, and test activities continued to decline in 1965 as shown below:

Employment	*Date*	*No. of contractors*
109, 875	December 1963	38
109, 250	December 1964	36
100, 940	November 1965	36

Of the 100,940 employees, 41.9 percent were production and related (manual); 24.2 percent were clerical and related (nonmanual); and 18.8 percent were nonsupervisory scientists and engineers. The remaining 15.2 percent were executive, administrative, and professional personnel other than nonsupervisory scientists and engineers.

Employment Reductions

The reductions during the year stemmed primarily from cutbacks previously announced in 1964 in the weapons program and from changes in reactor development programs announced in 1965.

On September 27, 1965, the weapons modification facility operated by Mason & Hanger-Silas Mason Co. at Clarksville, Tenn., was closed. Shifts in reactor program emphasis led to the closing, starting in July, of the Connecticut Advanced Nuclear Engineering Laboratory (CANEL) at Middletown, Conn.; the termination of the Army Gas-Cooled Reactor program at the National Reactor Testing Station (NRTS), Idaho; and a reduction in the SNAP and sodium graphite work at Atomics International. Weapons modification activities at the Medina Facility, San Antonio, Tex., operated by Mason & Hanger-Silas Mason Co., will be phased out by mid-1966. In addition, the plutonium weapons parts fabrication at the Hanford, Wash., plant was closed out in late 1965.

The largest net employment reductions during 1965 were:

Contractor	*Location*	*Approximate employment reduction*
ACF Industries, Inc	South Albuquerque, N. Mex.	195
Aerojet-General Corp	NRTS and San Ramon, Calif.	160
Atomics International	Canoga Park, Calif	1, 020
Bendix Corp	Kansas City, Mo	2, 030
Dow Chemical Co	Rocky Flats, Colo	200
General Electric Co	Richland, Wash	1, 050
Mason & Hanger-Silas Mason.	Clarksville, Tenn., and	220
	San Antonio, Tex	170
Pratt & Whitney	Middletown, Conn	1, 250
Union Carbide Corp. (Y–12).	Oak Ridge, Tenn	740

Employees affected by these reductions were largely concentrated in production, maintenance and clerical classifications. Relatively few hires of these surplus personnel in other contractor establishments were possible since the employment increases in AEC multiprogram and weapons laboratories occurred among scientific and technical categories.

Placement Assistance

Efforts were made to assist personnel in finding new employment and to minimize the impact of the cutbacks on the communities involved. The AEC compiled and distributed monthly lists of occupations of surplus personnel and of vacant positions among contractors throughout the program. AEC contractors assisted employees in preparing résumés; made contacts with other employers to identify vacancies; invited other firms into the plants to interview employees; informed employees of all available information on job possibilities; encouraged early retirements, where feasible; and permitted employees to terminate before scheduled layoff dates in order to accept positions immediately available, including positions in contractors' private establishments. The various State employment agencies provided their usual services and frequently made special arrangements to assist in larger layoffs.

While complete data on the results of placement assistance is not available, these efforts at most installations minimized periods of unemployment. Also, the reductions occurred during a period in which the national economy was expanding and the rate of unemployment, in October 1965, reached the lowest level since 1957.

CONTRACTOR EMPLOYEE WORKING CONDITIONS

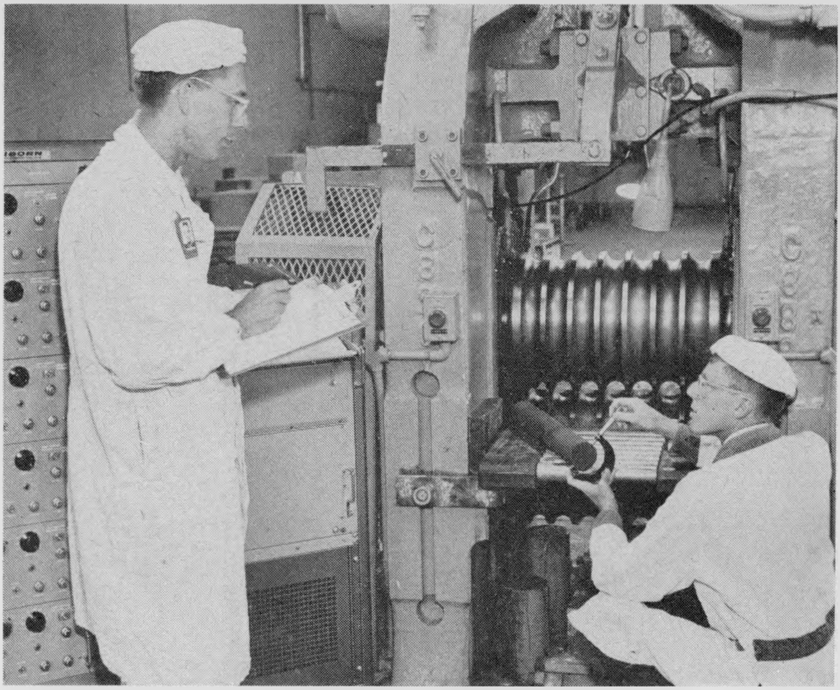
Earnings

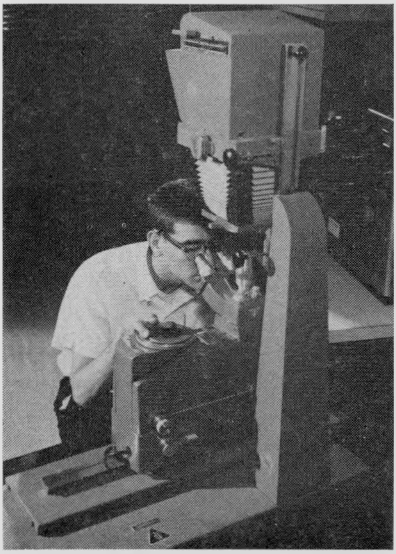
Average earnings of employees of 36 AEC prime contractors increased at about the same rate in 1965 as in 1964. About 34,300 employees of the 36 contractors are exempt from the Fair Labor Standards Act provision for overtime payments. In November, these exempt employees averaged $1,018 per month reflecting an increase of 4.7 percent over the 1964 figure. Within this group the nonsupervisory scientific and engineering staff averaged $1,001 per month and all other "exempts" averaged $1,039 per month. In the "nonexempt" group, approximately 42,200 manual production and related employees averaged $3.35 per hour in November, an increase of 4.5 percent over 1964, and approximately 24,400 clerical and related employees averaged $3.06 per hour, an increase of 2.8 percent over 1964.

Collective Bargaining

During November 1965, 36 cost-type contractors (excluding construction contractors) employed about 66,600 nonexempt employees. Approximately 45 percent of these employees were represented by labor organizations as follows:

Union organization	Approximate representation	Percent
Metal Trades Council (AFL–CIO)	9, 990	33. 5
International Association of Machinists (AFL–CIO)	6, 330	21. 2
Oil, Chemical and Atomic Workers International Union (AFL–CIO)	3, 370	11. 3
Miscellaneous Unions (Excluding Guards, but including Crafts)	6, 776	22. 7
Miscellaneous Guard Unions (Independent)	1, 485	5. 0
Office Employees International Union (AFL–CIO)	1, 850	6. 2
Total	29, 801	99. 9





Summer Trainees. The AEC and its prime contractors offer summer employment to students who are looking toward careers in the nuclear energy field. In photo *above*, a student from the University of Cincinnati (*right*) gains valuable experience in the rolling of dilute uranium-base alloys under the supervision of a senior engineer at the AEC's Feed Materials Production Center, Fernald, Ohio, which is operated by the National Lead Co. of Ohio. At *left*, a senior from New Mexico Institute of Mining and Technology, who was a summer employee at the South Albuquerque Works, which is operated for the AEC by ACF Industries, Inc., is shown at a dynazoom metallograph, one of several pieces of laboratory equipment upon which he received training and practical experience.

795-958—66——5

Through November 1965, 39 labor agreements have been involved in negotiations of contract renewals or modifications under reopening provisions. The Atomic Energy Labor-Management Relations Panel had intervened in four instances where negotiations reached an impasse. These were:

Mason & Hanger-Silas Mason, Inc., Amarillo, Tex., and the Metal Trades Council;

Dow Chemical Co., Rocky Flats, Colo., and District 50, United Mine Workers of America;

Reynolds Electrical and Engineering Co., Nevada Test Site, and the International Brotherhood of Teamsters representing a unit of registered nurses;

Reynolds Electrical and Engineering Co. and Catalytic Construction Co., Nevada Test Site, and International Brotherhood of Teamsters representing truck drivers and warehousemen.

Work Stoppages

From January through December, over 770,000 man-hours were lost in work stoppages—compared to about 727,000 man-hours in 1964. The lost time was approximately 0.3 percent of the total scheduled work time.

Of the 770,000 man-hours lost, 96 percent resulted from strikes at the Nevada Test Site (NTS) and primarily from a strike of 5-weeks' duration in September and October. The strike ended following negotiation of new construction project labor agreements between Reynolds Electrical and Engineering Co., Inc., and Catalytic Construction Co. and a group of construction craft unions. These agreements, which run for a period of five years, contain procedures for settlement of disputes and provide a basis for improved labor-management relations on construction work at NTS. Earlier in the year, three-year labor agreements applicable to maintenance and operations work performed by the Reynolds Co. were negotiated. These, too, provide procedures for dispute settlement and avoidance of work stoppages. At year's end, consideration was being given to the establishment of a preventive mediation program as a further step in assuring stability in NTS operations.

CONTRACTOR EQUAL EMPLOYMENT OPPORTUNITY PROGRAM

The tempo of AEC's program for assuring Government contractor compliance with Executive Order 11246 and affirmative action to assure equal employment opportunity to minority group members increased during the year. The AEC had responsibility for nearly 450 employers with about 1,300 establishments in which periodic compliance reviews, in accordance with Government-wide criteria, are required. Since the start of this Compliance Review Program in July 1963, the AEC has conducted reviews at more than 1,200 facilities, 565 of these in the 11-month period ending November 30, 1965. Impetus to the equal employment opportunity program was given by performance of corporate compliance reviews of certain multi-facility employers; 12 such reviews were conducted with corporate officials. Concentration of the major compliance review workload in five offices (Albuquerque, Chicago, New York, Oak Ridge, and San Francisco) as of July 1, 1965, contributed to increased effectiveness.

WORKMEN'S COMPENSATION STANDARDS

Although the atomic energy program historically is one of the safest industries in the nation and few of the injuries in the program have involved radiation (see Chapter 4—Operational Safety), there is a need to assure adequate workmen's compensation coverage for those radiation injuries which do occur. Three studies aimed at finding means to achieve improvements in workmen's compensation systems, in the area of radiation injury, were completed in 1965. The studies were jointly sponsored by the AEC and the U.S. Department of Labor. The Commission also took action on a set of recommendations made by its Labor-Management Advisory Committee.

COMPENSATION STUDIES [1]

Legislation Study

The first study, "Federal-State Cooperation in Improvement of Workmen's Compensation Legislation," was conducted by contract with the University of Wisconsin. The study proposed amendments to state laws generally, based upon federal grants-in-aid to (*a*) improve administration, (*b*) increase permanent disability benefits, (*c*) provide physical rehabilitation, (*d*) broaden coverage of second injury funds to facilitate employment of workers with known prior disability, and (*e*) provide full medical benefits. The report was reviewed by the Atomic Energy Labor-Management Advisory Committee and was the subject of a workshop conference on workmen's compensation, held in Washington, D.C., on January 25 and 26, 1965.

[1] The first and second studies, under their indicated titles, are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. The first study (including the proceedings of the 2-day workshop) is $1.25; the second is $0.35; the third is not yet available in printed form.

Compensation Claims Study

The second study, "The Incidence, Nature and Adjudication of Workmen's Compensation Claims Involving Radiation Exposure and Delayed Injury," was made by the Georgetown University Law Center, Washington, D.C. The study covered experience in establishing causal relation in radiation injury claims filed with workmen's compensation commissions and disclosed considerable inadequacies in workmen's compensation coding systems and uncertainty as to the frequency with which radiation injury has occurred. The study proposed, among other things, a Federal-State cooperative program under which State radiation cases could be reported to the AEC and later analyzed by the State following the disposition of the case.

Record-Keeping Study

The third study, "Report on Ionizing Radiation Record Keeping," was prepared by Woodward and Fondiller, Inc., consulting actuaries of New York City. The study emphasized the need for exposure records in workmen's compensation cases. The recommendations in the report deal with the question of which records ought to be retained by the employer, by the State, and by the Federal Government.

ADVISORY COMMITTEE RECOMMENDATIONS

In May, the AEC's Atomic Energy Labor-Management Advisory Committee recommended the adoption by the Commission of 11 standards for inclusion in State workmen's compensation laws for the protection of the radiation worker.

Standards

The standards recommended by the committee cover such matters as the need for compulsory workmen's compensation laws, elimination of numerical exemptions, extra-territoriality, second injury funds, adequate time limits for filing claims, coverage for radiation injury, full coverage of medical expenses and physical rehabilitation, vocational rehabilitation, authority to review medical care, and lump sum settlements.

In October, at a conference on Workmen's Compensation and Rehabilitation held in Oklahoma City, Okla., AEC Commissioner James T. Ramey stated that the time is appropriate for a new degree of Federal-State cooperation in the field of workmen's compensation for radiation injury. Consistent with the Atomic Energy Labor-

Management Advisory Committee's recommendations, the Commission approved in late October a program of action to assist in accomplishing the improvements needed to meet the above described standards for radiation workers.

The Program to Date

A task force, under the Assistant General Manager for Operations, was appointed to implement the program. Its work in developing objectives and preparing detailed proposals for carrying out the Atomic Energy Labor-Management Advisory Committee's recommendations was well underway at the end of the year.

During December, the AEC announced that, in conjunction with the Department of Labor, it is soliciting State cooperation in a program to improve State workmen's compensation laws for employees involved in radiation work. The States are being asked to study their workmen's compensation laws, provide information to the AEC on radiation injuries, and cooperate in keeping standard records.

The studies of State workmen's compensation laws will determine the extent to which the laws meet standards adopted by the AEC and what changes are needed to meet those standards. The AEC plans to enter into contracts with the States for such studies.

Under another phase of the proposed program, the cooperating States would furnish the AEC with copies of radiation exposure reports filed by employers and radiation claims filed by employees. This information would be used by the AEC as part of its study of the processing of compensation claims by State agencies. In addition, certain of the information will be used by the AEC in its biomedical research program.

Administrative expenses incurred by the States in setting up a reporting procedure will be reimbursed by the AEC. Also, the AEC will contract with States for an analysis of all radiation claims which have been settled by State workmen's compensation authorities. These analyses will be used, among other things, to study the standard of proof of causation in effect in the several States.

In addition, the AEC is studying the feasibility of developing a cooperative, uniform employer-State-Federal record-keeping system and the desirability of furnishing the States with some form of financial assistance for the installation and maintenance of such a system. The system would not only provide a source of information for statistical, evaluative and other type studies, but also would provide useful information to the States in their review and adjudication of workmen's compensation claims and in furthering their radiation safety programs.

NUCLEAR MANPOWER THROUGH CONTRACTOR TRAINING

It is AEC policy to encourage and support programs of its cost-type contractors that are directed toward developing disciplines and skills needed to increase the supply of competent personnel for atomic energy development. Some 35 AEC operating and research and development contractors conducted such programs in 1965. These programs provide part-time and temporary employment for students and faculty as a supplement to their study and teaching activities, as well as work experience for employees of private firms and institutions engaged in the civilian applications of atomic energy.

AEC contractors also conduct extensive training programs for their regular employees. These include a wide variety of in-plant training and development activities, and assistance in outside education. In 1965, 12 AEC contractors assigned regular employees to colleges and universities on a full-time basis for advanced education or research projects. (See also, Chapter 16—Nuclear Education and Information.)

The table on the opposite page shows a two-year comparison of the types of training activities under these programs.

	Number of participants		
	Fiscal year 1965	Fiscal year 1964	Percent change
Temporary and part-time use of students and faculty:			
A. Cooperative education participation (Students taking similar courses alternate between school and work and normally provide continuous position coverage.)	283	292	−3.1
B. Research and engineering participation (Students or teachers combining part-time university attendance or teaching with part-time laboratory assignments or alternate periods of AEC research with university attendance or teaching.)	1,140	1,039	+9.7
C. Guest appointments (Temporary employees appointed to gain experience through performance of research projects which are part of the contractor's mission.)	699	312	+124.0
D. Summer technical (Vacation employment of university and secondary school students and faculty.)	2,008	1,812	+10.8
Work experience training (Employees sponsored by other organizations who participate to meet the demonstrated needs of their sponsor where such training is determined to be in the best interest of overall atomic energy development.)	329	479	−31.3
Job related activity (College level training courses and research assignments for regular contractor employees. Only training courses or research assignments of more than 168 hours' duration are reported.)	194	206	−5.8

Chapter 4

OPERATIONAL SAFETY

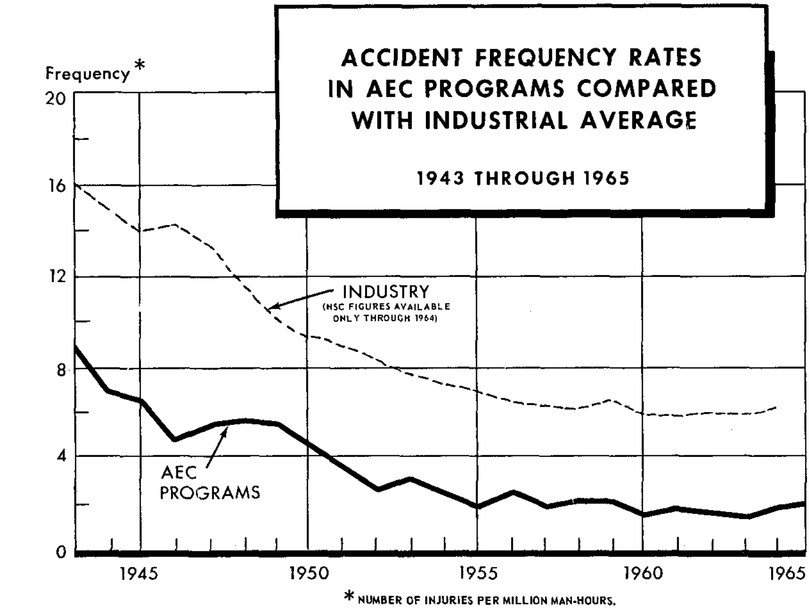
Contributing to the Nation's atomic energy effort during 1965 were approximately 7,000 AEC employees and 126,000 AEC-contractor employees conducting a $2.5-billion-a-year program in facilities valued at more than $8 billion. This imposed an obligation upon the AEC, paralleling its responsibilities in the past, to so conduct its affairs that these people could work under conditions conducive to the guarding of their general health and to freedom from the potential hazards of radiation as well as the normal hazards of industrial employment. Likewise, it was necessary that the physical properties represented in the figure given be protected, insofar as possible, from damage by fire, explosion, and other means of destruction. Hence, the nature of the AEC's safety program involved a wide spectrum of activities—industrial safety, fire protection, health physics, industrial hygiene, industrial medicine, reactor safety, materials processing, and nuclear explosives safety—all requiring unique technical competence to conduct safe operations. The effectiveness of the AEC's health and safety program is best evaluated by its record in the three categories of In-Plant Operations, Off-Site Activities, and Associated Activities.

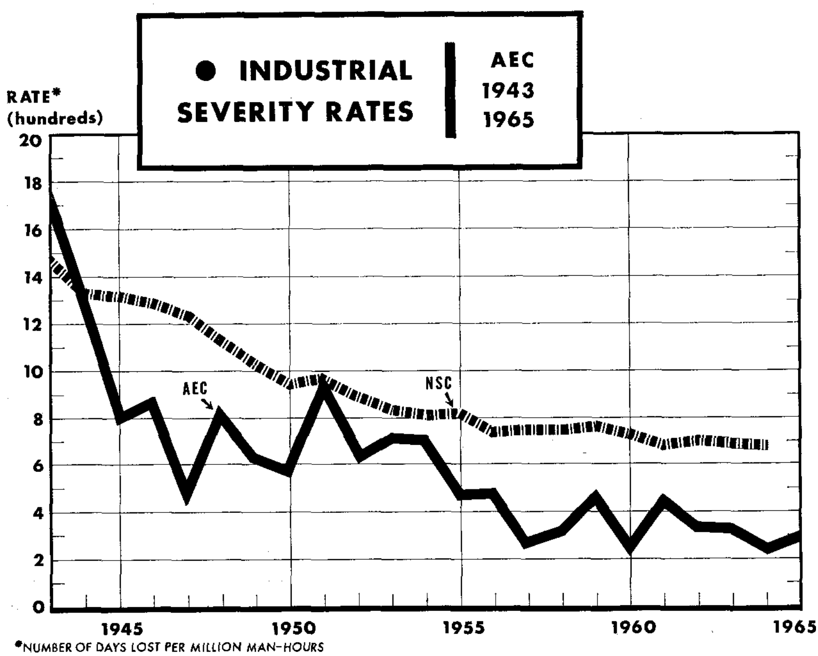
IN-PLANT OPERATIONS

Occupational Injuries

During the past 23 years there have been 16,265 lost-time accidents of all types.[1] This gives an overall frequency rate of 3.32 injuries for each million man-hours of work. An average calculated from National Safety Council (NSC) figures covering the experience of 42 industries over the 1943–64 period shows an "all-industry" rate of 8.17.

[1] During 1965, a publication was prepared by the AEC's Division of Operational Safety entitled "Operational Accidents and Radiation Exposure Experience Within the United States Atomic Energy Commission, 1943–64," available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, $0.40. This publication includes the results of a comprehensive compilation of accidents statistics in the AEC's operational activities and brings together available information, descriptions, and statistics regarding disabling injuries, radiation exposures, contaminations, criticalities, fatalities, and property damage accidents. A similar compilation for 1965 is being prepared and will be available about the middle of 1966.


ACCIDENT FREQUENCY RATES
IN AEC PROGRAMS COMPARED
WITH INDUSTRIAL AVERAGE
1943 THROUGH 1965
Frequency *
20
16
12
8
4
0
INDUSTRY
(NSC FIGURES AVAILABLE ONLY THROUGH 1964)
AEC
PROGRAMS
1945
1950
1955
1960
1965
* NUMBER OF INJURIES PER MILLION MAN-HOURS.


● INDUSTRIAL
SEVERITY RATES
AEC
1943
1965
RATE*
(hundreds)
20
18
16
14
12
10
8
6
4
2
0
AEC
NSC
1945
1950
1955
1960
1965
*NUMBER OF DAYS LOST PER MILLION MAN-HOURS

Thus, the AEC's gross rate, which includes construction, is less than half the industrial average. (See Chart—Accident Frequency Rates in AEC Programs Compared With Industrial Average—1943–65).

The year 1965 was one of the more accident-free years the AEC has experienced. There was a total of 475 lost-time accidents during 1965; only two of these injuries were due to radiation. Both of these resulted from X-ray exposures to fingers, one occurring at Lawrence Radiation Laboratory, Livermore, Calif., and the other at the AEC's Hanford plant.

Radiation has been a minor factor in injuries in AEC operations; in fact, during the past 23 years, only one-half of one percent of the lost-time injuries were due to radiation.

The severity rate of occupational injuries per million man-hours of work in the atomic energy program showed a substantial decline from 1943 to 1965, particularly after 1951. (See Chart—Industrial Severity Rates.) The severity rate peaked in 1946, 1948, and 1951, a reflection of heavy construction activity. The 1964 AEC severity rate was 283 which compared favorably to the NSC rate of 693.

During 23 years, there were 257 fatalities from all causes. These included 156 in construction; 90 in production, research, and service activities; and 11 in direct Government operations.[2] For the 1943–65 period, this gives an average calculated death rate per 23 years of 11 per 100,000 employees which is less than half of the NSC rate. There were six fatalities in AEC operations during 1965, none due to radiation.

Accidental Property Damage

Other measures of safety in the AEC's program include the amount of property damage resulting from accidents and fires.

Accidents. Over the 23 years, accidents caused property damage totaling $26 million. About 45 percent of this loss resulted from fire, 34 percent from reactor-associated accidents, and the remaining 21 percent from acts of nature, explosions,[3] and various miscellaneous causes.

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[2] Six deaths have been attributable to nuclear causes. Three of these occurred at Los Alamos (Aug. 21, 1945, May 21, 1946, Dec. 30, 1958) and were a direct result of exposure to a massive dose of nuclear radiation. The immediate causes of death of the three additional fatalities were the physical effects (*i.e.*, blast, flying debris, etc.) associated with the SL–1 nuclear accident of Jan. 3, 1961 at the National Reactor Testing Station in Idaho; however, the radiation levels associated with that accident were extremely high and probably would have been fatal. (See p. 330, "Annual Report to Congress for 1964" regarding licensee fatality.)

[3] ERRATUM: The opening sentence of the fourth paragraph, p. 153 of the AEC's "Annual Report to Congress for 1963" erroneously showed the word "tons" where the word "pounds" should have appeared. The sentence should have correctly read "A chemical explosion (approximately 120,000 pounds of high explosives) occurred in an igloo at the Medina Facility, near San Antonio, Tex., on November 13, 1963 . . ."

Eight major accidents caused more than half of the total property damage losses during the 23-year period. During this period, the AEC's average property damage and loss from all causes amounted to about two cents a year per $100 of property.

Fires. The 23-year fire loss rate experience was less than one cent a year per $100 of property. In industry, companies in the "improved-risk" category have annual fire losses approximating 2.8 cents per $100 of property. Thus, the AEC's fire loss rate is only about one-third that of the "improved-risk" industrial firms.

1965 Industrial Property Losses

The AEC industrial property loss of approximately $3.6 million during 1965 resulted in a 2.6-cent loss per $100 of AEC-owned property. Most of the AEC damage and loss during 1965 resulted from the two incidents described below:

A flash fire, followed by explosion and a second fire, caused more than $1.4 million worth of property damage and injured eight employees (one fatally) on July 5 at the Cambridge Electron Accelerator, Cambridge, Mass.

An accident during operation of the Plutonium Recycle Test Reactor at the Pacific Northwest Laboratory on September 29 resulted in leakage of contaminated light-water coolant into the heavy-water (D_2O) moderator systems and other auxiliary systems and general contamination of all surfaces within the reactor containment vessel. Of the $895,000 loss suffered, about half resulted from decontamination costs and the remainder from loss of heavy water which was degraded to a degree precluding economic recovery.

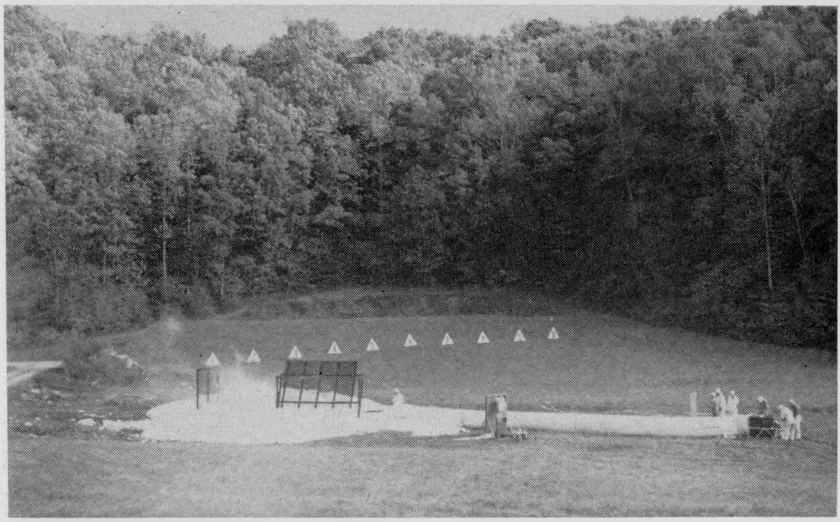
Radiation Exposures

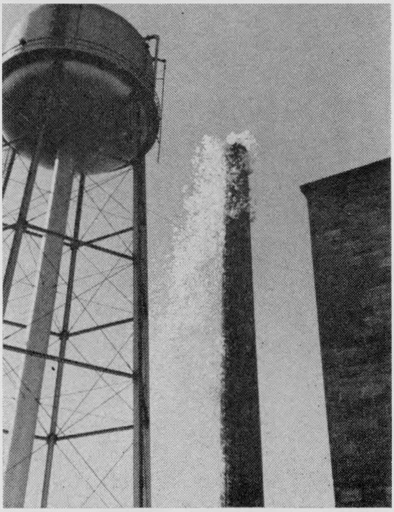
AEC and AEC-contractor employee whole-body exposure experience for the past 18 years shows over 99.8 percent of the employees monitored received an annual dose of less than 5 *rem*, and that over 94.6 percent received 1 *rem* or less.

1965 exposures. There were 37 employees who received radiation exposures exceeding normal operating criteria in 1965[4]: 11 were internal exposures (3 were thyroid exposures and 8 were lung exposures), 5 exposures were to hands, and there were 21 whole-body exposures.

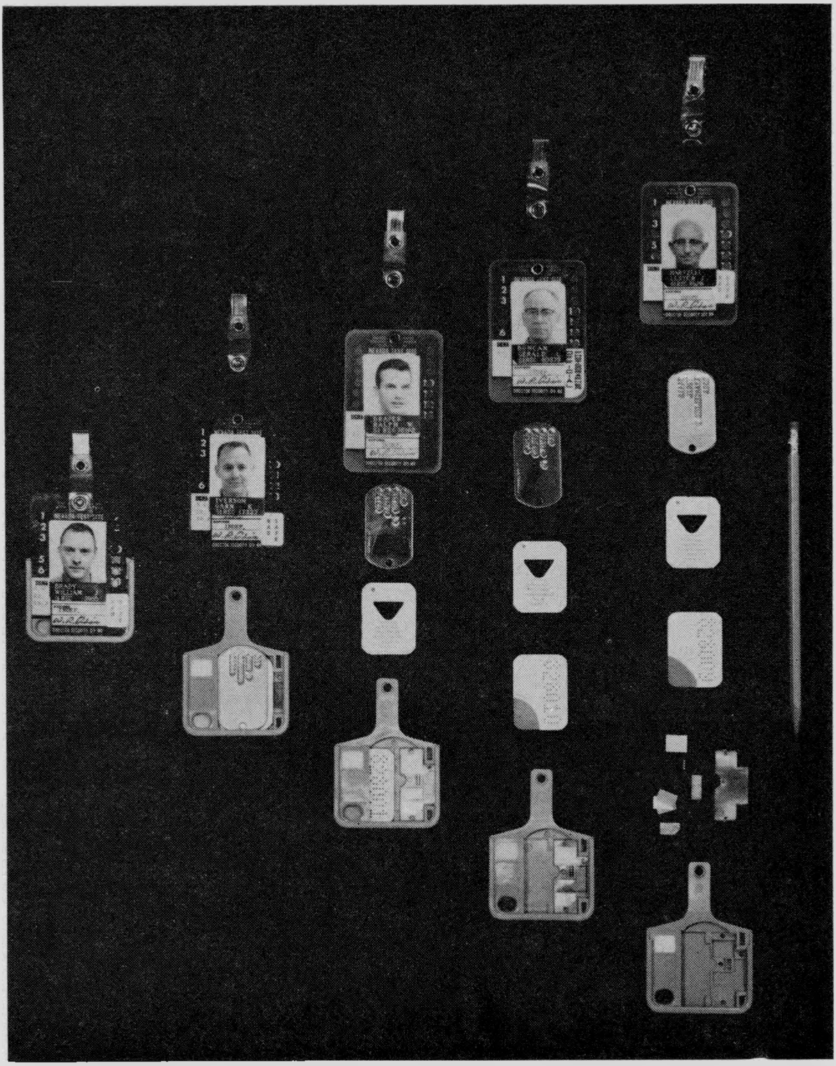
The three highest exposures in 1965, estimated at 80,000, 3,500, and 1,000 *rem*, occurred to the fingers and were the result of X-ray

[4] See p. 403, "Annual Report to Congress for 1962," for reporting criteria.





Versatile Foam. A recent innovation in fire control methods is the use of a high-expansion foam—a water-detergent solution dispersed as bubbles—which is particularly useful for indoor fires. As a reverse "technology spinoff," the AEC is finding a variety of uses for the commercially developed foam. During the year, AEC offices and contractors conducted tests involving imaginative applications ranging from fighting brush fires, to containment of radiation releases where no fire is involved, to suppression of fire in records in storage. Photo *above* shows an Oak Ridge Gaseous Diffusion Plant test that demonstrated the effectiveness of the foam in extinguishing open air fires in wind velocities up to 15 miles per hour. A large diesel oil fire was controlled in less than 3 minutes. Photo *at left* shows a test at Hanford to determine the effectiveness of high-expansion firefighting foam as a containment aid. One hundred curies of argon 41 were released within the "F" production reactor building. (The reactor had previously been shut down as a part of the production cutback.) The building air containing the argon 41 was converted to foam by a foam generator as it left the building through the 200-foot air-exhaust stack. The photo shows the foam being forced out of the stack and floating to the ground below. Monitoring of the plume emitted from the stack during the test indicated that the foam was successful in bringing the argon 41 to the ground. With use of a long-lasting foam, the release of the gas to the atmosphere could be spread over a period of several days.



Combination Badge. The combination security-credential and film-badge holder now used at the Nevada Test Site was designed and developed to replace a cumbersome arrangement where photograph, film badge, and metal charge-a-plate hung loose from a clip. The compact unit, encasing all components, makes security inspection easier and refines radiation dosimetry capacity. The film badge measures thermal neutron, beta, and gamma radiation; fast neutron doses can be measured if another film is included under the charge-a-plate. Other dosimetric devices, for high-range gamma and neutron dosage determinations, are accommodated in the holder when needed. At *left* is the new combination badge; to the *right*, in progressive order, the components of the badge are broken out.

radiation on three different occasions and were not due to reactor produced material. The 80,000 *rem* finger exposure occurred at Hanford in September when an individual wiped moisture from the shutter area of an X-ray machine, not realizing it was operating. The low-energy X-rays which produced this high exposure had a low penetrating power and affected primarily the superficial tissues of the fingers.

OFF-SITE MONITORING ACTIVITIES

Environmental monitoring is conducted around every major AEC installation. Summaries of the data obtained are printed in the U.S. Public Health Service monthly publication Radiological Health Data.[5] The Nevada Test Site (NTS) is mentioned here due to the continuing public interest regarding any radioactivity released to the off-site environment by effluents from tests.

NEVADA TEST SITE

Operational and long-term safety programs are essential to safe conduct of current nuclear test operations and to provide knowledge for better understanding of fallout and other effects. There is no sharp dividing line between the two programs but, in general, operational safety programs concern themselves with current activities while the long-term safety studies aid in foreseeing future requirements and provide needed basic information.

Pre-Test Studies

Before any nuclear test is conducted, detailed evaluations are made of such possible hazards as radiological, biological, hydrological, and seismological effects. For these studies, the AEC solicits the advice of several Federal agencies and recognized authorities. The agencies cooperating are the U.S. Public Health Service, the Environmental Science Services Administration (which includes the U.S. Weather Bureau and the U.S. Coast and Geodetic Survey), the U.S. Geological Survey, and the U.S. Bureau of Mines. Commercial contractors include Roland F. Beers, Inc., Alexandria, Va.; Reynolds Electrical and Engineering Co., Inc., Las Vegas, Nev.; Hazleton-Nuclear Science Corp., Palo Alto, Calif.; John A. Blume and Associates, Los Angeles,

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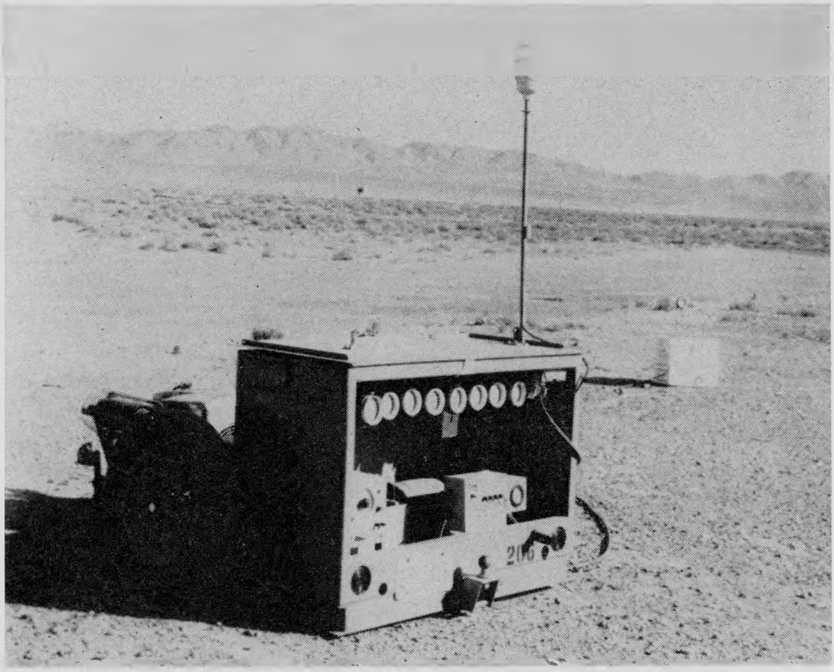
[5] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, $0.50 for single copies, $5.00 per year by subscription (foreign: $6.50).



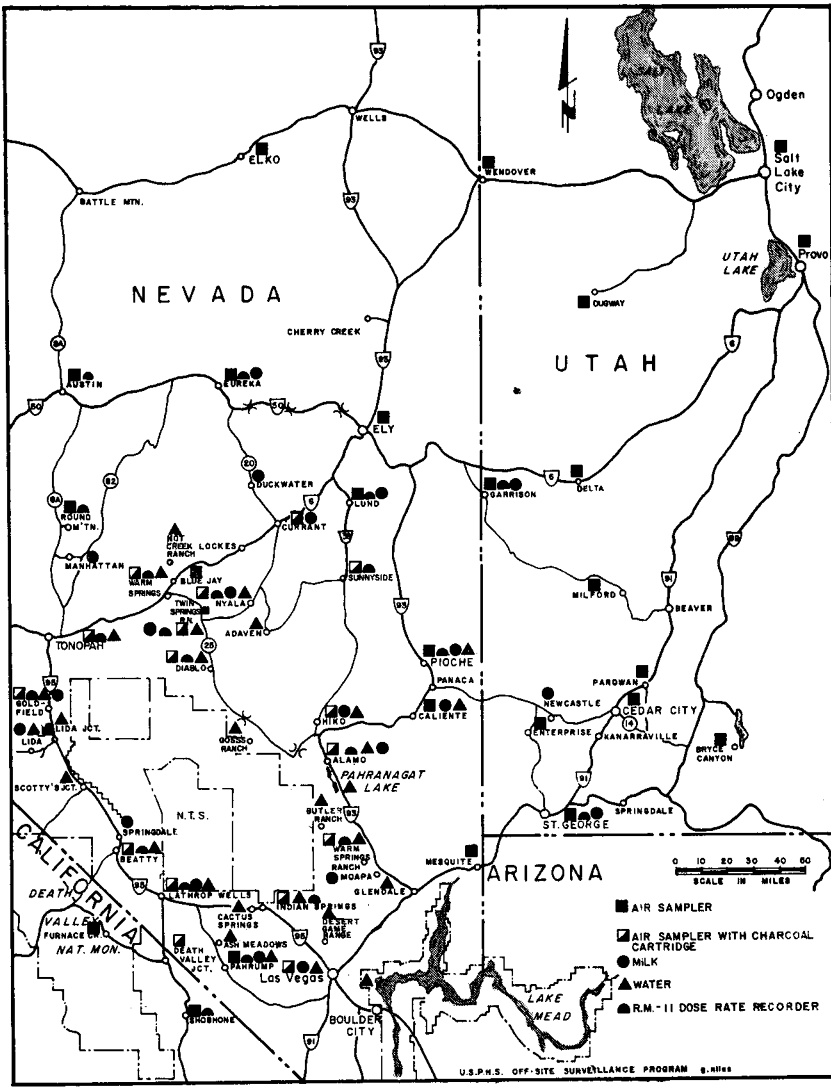
Ground Sampler. Photo shows one of the inexpensive mobile air sampling units (right of photo) used at the Nevada Test Site by Reynolds Electrical & Engineering Co., Inc. (prime support contractor at the AEC's site) which has proved to be highly reliable and efficient in monitoring airborne radioactivity. Individual sampling units are operated remotely by a power supply mounted on the trailer unit, making it possible for three separate points over a span of 1,000 feet to be sampled simultaneously during operation. A retractable wheel design permits the trailer to rest solidly, greatly reducing the possibility of damage from ground motion in underground detonations.

Calif.; and Holmes and Narver, Inc., Los Angeles, Calif. As necessary, the specialized services of various laboratories and scientific and technical consultants are obtained.

Off-Site Monitoring

During 1965 there were 25 announced underground weapons development and/or Department of Defense tests, one underground Plowshare experiment, and five nuclear reactor tests conducted at the Nevada Test Site. In addition, the underground Long Shot event was conducted on Amchitka Island, Alaska, on October 29.

Off-site radiological monitoring near NTS and other test sites is conducted for the AEC by the U.S. Public Health Service. The map



indicates the permanent radiological monitoring stations around NTS. Many additional points can be monitored if there appears a need to do so.

Detectable levels of radioactivity were measured off-site by ground monitors from only three of the underground nuclear detonations: Palanquin (a Plowshare excavation experiment), April 14; Tee, May 7; and Diluted Waters, June 16. Of these, only the first resulted in readings at populated areas (the highest at Stone Cabin Ranch,

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Nev., a ranch about 20 miles north of the test site). This reading was only 3 milliroentgens per hour at the peak. It dropped to about 1 milliroentgen per hour in 4 hours and to less than 0.1 milliroentgen per hour the following day.

Film Badges

Approximately 1,800 film badges were issued to the off-site population surrounding the Nevada Test Site during the year. Of all these film badges which were related to off-site exposures associated with NTS events, none showed exposures above 20 milliroentgens monthly which is the lower detectable limit for these films.

Milk Monitoring

During 1965, about 285 routine milk samples were collected at 21 different routine milk sampling stations. In addition to the routine milk samples, over 1,600 special samples were collected for the Plowshare event, 129 special samples for reactor activities, and 23 special samples for weapons events.

The highest radioiodine content found in milk during the year was at Martin Ranch, Eureka, Nev., where a peak level of 11 nanocuries [6] per liter of milk was recorded on April 18. However, the highest value found at a farm where children were living was at Pasquale-Richards Ranch, Paradise Valley, Nev., where the peak level of 5.5 nanocuries per liter of milk was recorded on April 20. This is about one-fortieth of the Protective Action Guide of the Federal Radiation Council.

Water Monitoring

Domestic water supplies are monitored for gross beta contamination in the off-site area around the Nevada Test Site. During the year, samples of water were collected at 40 different locations. Of the more than 100 samples collected, only seven demonstrated positive results for fresh fission products. The highest level of radioactivity found was 160 picocuries [7] of iodine 131 per liter in samples collected at Caliente,

[6] A nanocurie is equal in activity to one-thousandth of a millionth of a gram of radium.
[7] A picocurie is equal in activity to one-millionth of a millionth of a gram of radium.

Nev., on June 28, and at Blue Jay Maintenance Station on July 7. It is most likely that the iodine 131 in the water came from the Chinese atmospheric test conducted on May 14, the nuclear rocket engine test at the NRDS on June 25 or possibly from the Diluted Waters event on June 16, or a combination of these events. The highest value attributable to operations at NTS was 70 picocuries of iodine 131 per liter on April 18.

Gross beta radiation in air. There were from 36 to 94 air sampling stations located in the area surrounding the NTS operating 24 hours per day each month. In addition, up to 20 supplementary sampling units were employed during specific events.

The highest gross beta activity in air in a populated area was measured at Clark Station, Nev., on April 14, 1965, with a value of 23,000 picocuries per cubic meter averaged over the time period of about 12 hours during which the high concentration occurred.

While the gross beta activity in the air has little value in determining radiation doses to persons, the data obtained by air samplers are used by the off-site monitoring group as an indication of presence of airborne radioactivity in a specific area and to determine the areas where milk, water and vegetation samples should be collected.

ASSOCIATED ACTIVITIES

Radiological Assistance Program

The AEC maintains radiological assistance teams at 39 installations to provide emergency assistance in the event of incidents involving radioactive materials. Assistance is available in response to requests from AEC contractors, Federal and State licensees, agencies of Federal, State, and local government, private industry, and private organizations or responsible individuals. Since June 1958, when the teams were organized, the AEC has responded to 572 requests for assistance from transportation companies, State agencies, local police and fire departments, the military, licensees, Federal agencies, AEC installations, and others. In 284 of these incidents, assistance was dispatched to the incident scene; in the remaining 288 incidents, verbal advice on procedures to be followed was all that was necessary During 1965, none of the incidents to which teams were dispatched in response to requests for assistance proved to be of any significant hazard to the public. The following table shows the number of responses on a calendar year basis through 1965:

Year	Total requests	Assistance sent	Advice adequate
1958–59 [1]	92	67	25
1960	79	37	42
1961	139	41	[2] 98
1962	68	37	31
1963	57	28	29
1964	59	38	21
1965	78	36	42
Total	572	284	288

[1] The data on responses during this 1½-year period could not be fully separated into the last 6 months of 1958 and the year 1959.

[2] Large increase believed due to including requests for information that should not have been defined as radiological incident assistance.

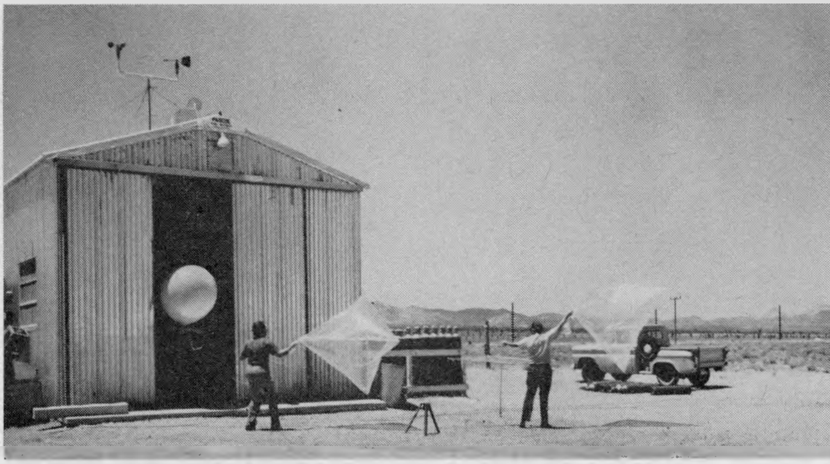
Safety of AEC-Owned Reactors

At the end of 1965, 26 AEC prime contractors were operating 81 stationary reactors, 4 propulsion reactor test stands, and 39 critical facility test cells that are owned by the AEC. There are 11 new reactors, and one test stand under construction.

The AEC staff devoted approximately 60 man-years of safety effort during the year to functions aimed at assuring safe operation of these 124 facilities. These functions have included developing and enforcing operating limits, inspecting facilities, and reviewing reactor proposals. As a result of these efforts, more than 100 reactor-years of operation were accumulated in the past 12 months, involving operations by about 1,700 individual reactor operating personnel, with no reactor-induced injury to contractor personnel, AEC personnel, or the public at large. Further, no significant releases of radioactivity have occurred.

Epidemiological Study of Contractor Employees

A long-range study to determine if mortality might be related with occupational radiation exposure has been initiated by the University of Pittsburgh School of Public Health. Test runs have been initiated using employee records from selected AEC contractors to see if such personnel, employment, medical, and radiation records can be used to establish the relationship, if any, between mortality patterns and levels of occupational radiation exposure. This project will provide information indicating the presence or absence of an accumulated effect on healthy humans of small doses of radiation received over a long period of time.



Weather Study. The U.S. Weather Bureau is conducting a "Long Range Trajectory Project" at the AEC's Nevada Test Site which is serving a double purpose. For the Weather Bureau, it is providing new data on the movement over great distances of air masses in the lower atmosphere; for the AEC, it is providing information for predicting, and tracking when necessary, the movement of any off-site radioactivity release. Photo *above* shows helium-filled, constant-volume balloons (tetroons) being launched at the Yucca Weather Station. Tracking of the constant-volume balloons on the Nevada Test Site is accomplished with M–33 radar, as shown *below*. Offsite tracking of the balloons uses radar scopes at the various Federal Aviation Agency (FAA) centers. During this project, the 72-inch tetroons have been tracked up to 53 hours and for distances up to 1,400 miles.

Accelerator Safety Panel

An Advisory Panel on Accelerator Safety was established in July 1965 to review unique safety problems which may arise in AEC operations (see Appendix 2). Such characteristics as the high energy, the pulse nature, and the complex spectrum of the radiation immediately adjacent to the accelerators have made the measurement of radiation and the estimation of radiation dose to personnel difficult. The specialized skills of the Advisory Panel will be available to all AEC offices to assist in carrying out surveillance and provide advice on these scientific tools.

Chapter 5

SOURCE AND SPECIAL NUCLEAR MATERIALS PRODUCTION

During the year, negotiations for stretching out uranium procurement deliveries were completed. The AEC's production of enriched uranium and plutonium continued to be cut back consistent with previous announcements and, when the planned reductions are completed in 1969, annual savings in excess of $125 million will accrue. The AEC began implementation of the 1964-enacted law which provides for private ownership of plutonium and enriched uranium.

RAW MATERIALS

Uranium Procurement

The procurement of uranium concentrate (U_3O_8) in 1965 was approximately 4,000 tons of U_3O_8 less than in 1964. The following table shows the sources and quantities for the 2 years:

	Tons of U_3O_8	
	1964	*1965*
USA	11, 850	10, 490
Canada	1, 760	720
South Africa	3, 530	1, 930
Total	17, 140	13, 140

The Canadian and South African contracts, with uncompleted balances of approximately 720 and 1,330 tons respectively, expire in 1966.

Domestic Procurement Program

Negotiations to implement the domestic stretch-out program announced in November 1962 were completed, with signing of the last contract amendment in November 1965. Eleven contracts with 10 companies have been modified, covering the operation of 11 uranium mills through 1970. The total U_3O_8 deferred for delivery in 1967 and 1968 by all producers participating in the stretch-out program is about 15,300 tons, with an equal amount to be delivered during 1969 and 1970. The price for such deferred deliveries through 1968 remains unchanged at $8 per pound of U_3O_8. The price to be paid in 1969 and 1970 will be $1.60 plus 85 percent of the allowable production costs per pound of U_3O_8 during the prior six years, subject to a maximum price of $6.70 per pound. In addition, under the stretch-out program, the AEC will purchase U_3O_8 in concentrates recovered from up to one million pounds of U_3O_8 in ore per year supplied from small mining properties. Subject to the million-pound ceiling, such a small property may produce up to 10,000 pounds in a six-month period. The price per pound of the U_3O_8 obtained from this source will be $8 through 1968 and $6.70 in 1969 and 1970. For all U_3O_8 delivered in 1969–70 the average price is expected to lie between $5.50 and $6.00 per pound.

Table 1 shows the companies participating in the stretch-out program whose contracts have been extended through 1970 as well as those whose contracts expire in fiscal year 1967.

TABLE 1.—STRETCH-OUT PROGRAM

Company	Mill location	Estimated tons U_3O_8 to be delivered under contracts from January 1, 1966
Contracts extended through 1970		
Anaconda	Bluewater, N. Mex	3, 720
Atlas Corp	Moab, Utah	4, 740
Federal-Radorock-Gas Hills Partners.	Fremont County, Wyo	1, 810
Homestake-Sapin Partners	Grants, N. Mex	5, 390
Kerr-McGee Corp	do	7, 590
Union Carbide Corp	Natrona County, Wyo	1, 000
Do	Rifle & Uravan, Colo	4, 800
United Nuclear Corp	(Ores treated in Homestake-Sapin mill).	4, 770
Utah Construction & Mining Co	Fremont County, Wyo	2, 620
Vanadium Corp. of America	Shiprock, N. Mex	1, 560
Western Nuclear, Inc	Jeffrey City, Wyo	2, 680
Contracts expiring in fiscal year 1967		
American Metal Climax, Inc	Grand Junction, Colo	460
Dawn Mining Co.[1]	Ford, Wash	260
El Paso Natural Gas Co	Tuba City, Ariz	230
Mines Development, Inc	Edgemont, S. Dak	310
Petrotomics Co	Carbon County, Wyo	280
Susquehanna-Western, Inc	Falls City, Tex	50
Total		42, 270

[1] Dawn Mining Co. will complete deliveries under its AEC contract from concentrates already produced.

The following four mills discontinued operations during the year: Atlas Corp., Mexican Hat, Utah; Vitro Chemical Co., Salt Lake City, Utah; Cotter Corp., Canon City, Colo.; and Dawn Mining Co., Ford, Wash.

Reserves

Ore reserves at the beginning and end of 1965 are shown in the tabulation below:

	Tons of ore	*Percent* U_3O_8	*Contained tons* U_3O_8
Estimated reserves Jan. 1, 1965	63, 000, 000	. 24	152, 000
Estimated reserves Jan. 1, 1966	61, 600, 000	. 235	145, 000
Decrease in estimated reserves	1, 400, 000	--	7, 000
Shipments to mills in 1965	4, 400, 000	. 24	10, 600

At year's end, there were at the mills approximately 2,860 tons of U_3O_8 in ore stockpiles, and 2,580 in process and finished product, making a total inventory at the mills of 5,440 tons.

Net additions to reserves during the year were approximately 3,600 tons of contained U_3O_8, partially offsetting production and delivery to mills of about 10,600 tons. Although withdrawals in 1965 again exceeded net additions to reserves, the uranium industry is showing an increased interest in exploration, and prospects for a step-up in the discovery of new ore appear favorable.

Table 2 shows reasonably-assured resources and geologic estimates of future discoveries for the United States and the non-Communist

TABLE 2.—URANIUM RESOURCES[1]

Price range per lb. U_3O_8	Short tons of U_3O_8	
	United States[2]	World total[3]
$5 to $10:		
Reasonably assured	195, 000	640, 000
Possible additional[4]	325, 000	680, 000
$10 to $15:		
Reasonably assured	150, 000	680, 000
Possible additional[4]	200, 000	500, 000
$15 to $30:		
Reasonably assured	170, 000	430, 000
Possible additional[4]	440, 000	1, 100, 000
Totals: Reasonably assured	515, 000	1, 750, 000
Possible additional[4]	965, 000	2, 280, 000

[1] Adopted from European Nuclear Energy Agency publication of August 1965.
[2] U.S. figures supplied to ENEA by USAEC. Reasonably assured figures include 152,000 tons at $8 per pound of U_3O_8 as of Jan. 1, 1965.
[3] Including United States, but excluding U.S.S.R., China, and Eastern Europe.
[4] *The figures for possible additional resources refer to geologic estimates of future discoveries for those regions in which important efforts have been made in the field of prospecting or evaluation.*

world at various price ranges, which should be taken into account in assessing availability of supplies of nuclear fuels to meet expected future demands.

Thorium

Thorium, as a possible source of nuclear fuel supplementary to uranium, continues to be of interest; and, although there has been only relatively small demand for thorium to date for both nonnuclear and nuclear purposes, the belief is that a gradually increasing market will develop in time. However, total thorium requirements for nuclear use in the next 15 years probably will be measured only in hundreds of tons, with annual requirements of less than 100 tons during most of that period.

Preliminary investigation indicates that the reasonably assured resources of the United States are more than ample to meet foreseeable requirements. Thorium resources, on the basis of up to $10 per pound of thoria ($ThO_2$), are:

	Short tons of ThO_2	
	United States	*World total* [1]
Reasonably assured	100, 000	565, 000
Possible additional [2]	500, 000	975, 000

[1] Taken from European Nuclear Energy Agency publication of August 1965. Excludes U.S.S.R., China, and Eastern Europe.

[2] The figures for possible additional resources refer to geologic estimates of future discoveries for those regions in which important efforts have been made in the field of prospecting or evaluation.

NUCLEAR MATERIALS PRODUCTION

During 1965, although AEC production of enriched uranium and plutonium decreased substantially as planned, national defense and civilian use needs were met successfully.

CUTBACKS IN PRODUCTION

Gaseous Diffusion Plants

Power reduction. In February, a third reduction in the future production of enriched uranium was announced under which the total power [1] requirements of the AEC's three gaseous diffusion plants will drop to two million electrical kilowatts (ekw) by January 1, 1969; the previous reduction announced in April 1964,[2] was to reduce the level to 2,970,000 ekw, some 40 percent below the previously planned schedule.

This latest reduction in enriched uranium production at the AEC's three gaseous diffusion plants—at Oak Ridge, Tenn.; Paducah, Ky.; and Portsmouth, Ohio—was the result of a continuous reassessment by the AEC of the production level necessary to meet projected military and civilian requirements. The 1965 power cutback of 970,000 electrical kilowatts is made up of the following components: 205,000 ekw of Tennessee Valley Authority (TVA) power at Oak Ridge; 240,000 ekw of TVA power at Paducah; 325,000 ekw of Electric Energy, Inc., power at Paducah; 200,000 ekw at Portsmouth supplied by Ohio Valley Electric Corp. When the power reductions that were announced in 1964 and 1965 are completed on a step-by-step basis by January 1969, the diffusion plant operating power level will be about 60 percent below the 4,850,000 ekw level planned prior to the 1964 cutbacks. When fully effected, these reductions will save the Government about $100 million in annual power costs.

Process development. Even though the production cutbacks are taking place on schedule, a continued aggressive development program directed toward further advances in gaseous diffusion technology has

[1] The power is used to pump uranium, in a gaseous state, through a series of porous membranes; the uranium passing through the porous membranes becomes enriched with the fissionable uranium 235 isotope.

[2] The first reduction was announced in the President's State of the Union Message on January 8, 1964; see p. 17–18, 44–45, "Annual Report to Congress for 1964."

been approved by the Commission. Long range goals have been set in view of the probability, within the next decade, of sharply increased demand for enriched uranium primarily for use in commercial nuclear power reactors.

Reactor Operations

Reactor shutdowns. The "F" reactor at the Hanford Works in Washington was shut down on June 25, 1965, completing the series of production reactor shutdowns announced by the President in January 1964. Previously, the "DR" and "H" reactors at Hanford were shut down in December 1964 and April 1965, respectively. The "R" reactor at Savannah River was shut down in June 1964. These shutdowns will save about $25 million annually.

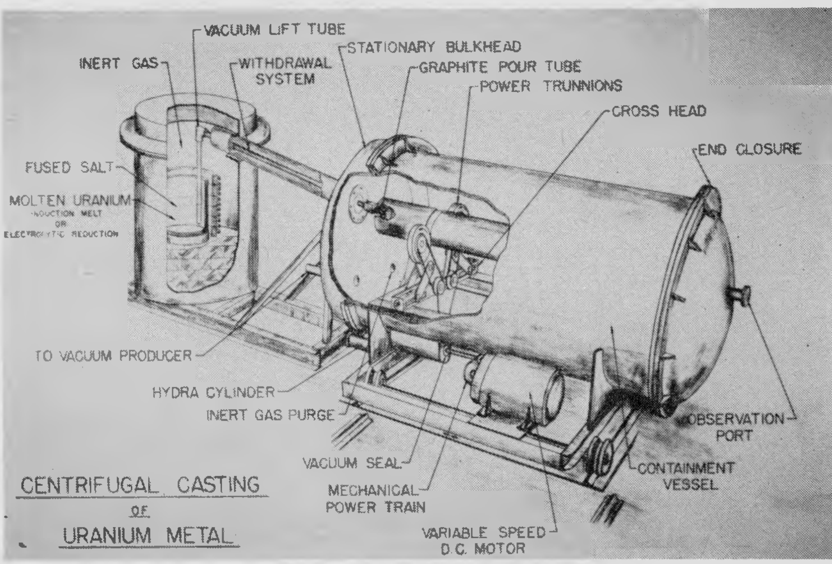
On-Line Computer. Operating safety and efficiency of a large production reactor at the Savannah River Plant were improved during the year by use of an on-line digital computer which scans 3,200 instrument sensors every 5 minutes and compares calculated performance data with operating limits. Photo shows supervisor examining computer printout in reactor control room. Computer results are used with existing written procedures for control of reactor operation; specific applications of direct control by the computer are being developed. The Savannah River Plant is operated for the AEC by the E. I. du Pont de Nemours Co.

"R" reactor conversion study. A year-long study on the possible conversion of Savannah River's shutdown "R" reactor to a nuclear powerplant by the Savannah River Nuclear Study Group (consisting of 11 Southeast utilities [3]) concluded that the cost of electricity from the converted plant would exceed that from a new nuclear powerplant. The study was made at no cost to the Government.

PRODUCTION OPERATIONS

Feed Materials

Operations in the feed materials plants at Fernald, Ohio, and Weldon Spring, Mo., continued to show a slight decline in the production output. Employment was reduced, reflecting not only the decrease in net requirements, but also improved scrap management and recovery



Centrifugal Casting Pilot Plant. The centrifugal casting of nuclear fuel element tube blanks, or billets, directly from an induction furnace or electrolytic cell will be accomplished in the facility shown in the above sketch. This pilot-plant unit is operated by the Mallinckrodt Chemical Works for the AEC at the Weldon Spring, Mo., Feed Material Plant. In addition to producing 83-inch-long tube blanks, castings of hollow billets up to 8 inches in diameter will be made. The molten uranium can be cast close to the final desired dimensions, thus reducing the machining losses to a minimum.

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[3] Utilities comprising the Savannah River Nuclear Study Group were: Alabama Power Co., Carolina Power and Light Co., Duke Power Co., Florida Power Co., Georgia Power Co., Gulf Power Co., Mississippi Power Co., Savannah Electric Power Co., South Carolina Electric and Gas Co., Tampa Electric Co., and Virginia Electric and Power Co.

techniques and improved use of manpower in these plants. There was an increased demand for thorium for the production of uranium 233 with a low uranium 232 content.

Commercial Cold Uranium Scrap Processing

During 1965, cold (nonirradiated) enriched scrap continued to be made available to private industrial firms to recover the contained enriched uranium. Twenty-eight contracts having a total cost of about $831,500 were awarded to Nuclear Fuel Services, Inc., Erwin, Tenn.; Nuclear Materials and Equipment Corp (NUMEC), Apollo, Pa.; Kerr-McGee Corp., Guthrie, Okla.; and General Atomic Division of General Dynamics Corp., La Jolla, Calif.

Boron 10 Production

The AEC-owned plant at Model City, N.Y., for separation of boron isotopes, has been reactivated by the operating contractor, Nuclear Materials and Equipment Corp. Production of boron 10 was resumed in July at product purities comparable to, or slightly better than, those achieved before the plant was shut down in 1958. The boron 10 produced from this plant will be used to satisfy Government-wide needs, and to supply the small commercial demand for this product since there is no privately owned boron isotope separation facility in the United States. Boron 10 sales to industry are handled by the Isotope Sales Department of the Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tenn.

Heavy Water Production

Heavy water (D_2O) sales to U.S. customers totaled 8,292 pounds in 1965—a slight increase over 1964 sales. Foreign sales during the year totaled approximately 27.4 tons and leases, principally to Canada for the first Candu reactor at Douglas Point in Ontario, totaled 186 tons. Heavy water requirements in the next decade may increase substantially because of increased emphasis in advanced converter reactors such as the heavy water-moderated, organic-cooled reactors which are under development in the United States.

Hanford Dual-Purpose Reactor ("N" Reactor)

Reactor operation. Full design power of 4,000 megawatts (thermal) was atained in the "N" reactor at Hanford in December 1965. Equipment malfunctions, normal to any new plant, were encountered early in 1965 during the power ascension and run-in phases of operation; these difficulties were experienced in facilities peripheral to the reactor itself. The resulting shutdown periods were used for routine maintenance and for tie-ins with the new electrical generating plant. At year's end, the "N" reactor had reached a normal level of operation.

Power generation project. Construction of the 800,000 electrical kilowatt (ekw) power plant by the Washington Public Power Supply System (WPPSS) was essentially completed in 1965. Initial power generation, using steam produced in the "N" reactor is expected in February 1966. Full power generation of 800,000 ekw is expected during the summer of 1966.

Dual-Purpose Plant. The world's largest nuclear powerplant was nearing completion at Hanford, Wash., at the end of the year. The AEC's "N" production reactor, housed in building on *left*, became operational for plutonium production during the year. At year's end, turbines were being installed in the integrated 800,000 electrical kilowatt (ekw) generating plant, on *right*, being built by the Washington Public Power Supply System. Steam generated by plutonium production will be piped (center of photo) to the turbines for production of electricity. Power is expected to be delivered from the first of two 400,000 ekw units in early 1966. The dual-purpose facility's claim to fame as the "world's largest" will be short lived since other plants presently under construction or planned, both in the United States and abroad, will have equal or larger electrical kilowatt ratings.

SPECIAL REACTOR PRODUCTS

The production reactors of the AEC were built specifically to provide fissionable material for the Nation's defense. Historically, certain small amounts of products for other purposes had been made and recently an increaing interest has been evidenced for these other products. The products fall into three main classes (*a*) other fissionable materials, (*b*) those having unique scientific interest, and (*c*) heat-producing isotopes.

Other Fissionable Materials

High exposure plutonium. The operation of power reactors will produce plutonium having high percentages of the istopes plutonium 240 (20 to 30 percent) and plutonium 241 (2 to 8 percent). A long-range goal is to burn the plutonium made in power reactors in subsequent fuel cycles of the same reactors or in breeder reactors. The presence of significant quantities of plutonium 240 and 241 in such fuels will make their performance in the reactors different from that of the relatively pure plutonium 239 hitherto available for experimental purposes. Both Hanford and Savannah River demonstrated their ability to manufacture plutonium containing 25 to 40 percent plutonium 240 during 1965. Although such materials are more expensive, a considerable interest has been shown in obtaining them so that experimental programs may proceed expeditiously in advance of the time major quantities are produced in power reactors.

U-233. Production of uranium 233 was increased during the year as reactor and fuel cycle development needs for this material continued. Production by irradiation of thoria (ThO_2) was carried out at both Hanford and Savannah River. For research and development purposes, high-purity "clean" uranium 233 is specified because of its low radioactivity so that direct handling and fabrication are possible without the use of heavy shielding. The uranium 232 content of such "clean" uranium 233 is approximately five parts-per-million (ppm). Production of this special material is expected to continue in 1966.

Scientific Interest

High flux demonstration. The ability to operate a large nuclear reactor at high neutron thermal flux offers significant advantages for the generation of special isotopes, especially where short half-lives, low cross-sections, or many neutron captures are involved in the production chain. The possibility of such an operation at one of the

Savannah River plant production reactors was raised in 1964 by the E. I. du Pont de Nemours Co., the AEC's operating-contractor at Savannah River. A demonstration program was authorized by the Commission for several purposes, one of which was to pilot reactor

High Flux Fuel Assembly. The use of one of the Savannah River Plant's production reactors to generate special isotopes, such as curium 244, not only required special operational procedures but also modifications to components of the reactor. Photo shows W. P. Overbeck (*right*), Director of the AEC's Savannah River Laboratory, being briefed on design innovations in a reactor fuel assembly by a design group leader. With this type of fuel assembly, a Savannah River reactor was operated at the highest thermal neutron flux ever achieved in a reactor, 5×10^{15} neutrons per cm^2-sec.

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conditions needed for more efficient production of curium 244. In addition to this, other benefits are: (*a*) production of californium 252 for possible use in the cancer program; (*b*) advancement of reactor technology and world leadership in this field; (*c*) new production techniques to decrease costs on other neutron produced products such as polonium 210, curium 244, and high-intensity cobalt 60; (*d*) provides a test bed for use in the fast reactor program; (*e*) contributes to the higher isotope program.

The high flux demonstration began in February 1965, and will continue into 1966. At year's end, a record high flux level, 5.4×10^{15} (five quadrillion) neutrons per square centimeter per second ($n/cm^2/sec$) had been attained. This is the highest sustained flux ever attained in any reactor in the world. The average flux level for the entire reactor is about 20 percent below the peak level and the flux in the target material used for isotope production is about 5 to 10 percent below the peak level. The average flux is available over a volume of 165 cubic feet.

During the high flux demonstration, a large number of research samples were irradiated for the various AEC national laboratories. One of the unique experiments is a series of irradiation tests being performed by Lawrence Radiation Laboratory scientists from Livermore and Berkeley in an attempt to measure the half-life of fermium 258—thought to be very short. These experiments were performed at the reactor site and involved the use of a rapid-discharge device known as a "rabbit," by which the samples were removed from the reactor directly into an identification device. Such means of rapid handling were made necessary by the extremely short half-life of the isotopes of interest. Results from this particular experiment are inconclusive to date, and additional irradiation experiments are planned for early 1966.

Heat-Producing Isotopes

A number of heat-producing isotopes of major interest for space and terrestrial applications are produced in the production reactor complex. The more important of the isotopes produced directly by neutron addition reactions in nuclear reactors are plutonium 238, curium 242 and 244, cobalt 60, and polonium 210. (Some of the aspects of production and characterization of these materials as isotopic power fuels are discussed in Chapter 13—Isotopes and Radiation Development. In addition, the fission product isotopes, Sr^{90}, Cs^{137}, Pm^{147}, and Ce^{144} have important uses and Chapter 9—Auxiliary Electrical Power for Land and Sea, provides a discussion of isotope characteristics which are significant to their applications. The direct use of heat from these isotopes is covered in Chapter 8—Nuclear Power for Space Applications, and in Chapter 13. Space applications involving the conversion of isotopic heat to electricity are also discussed in Chapters 8 and 9.)

Fission products production. In February, the AEC selected a joint proposal by the Martin-Marietta Corp., and the U.S. Rubber Co., to operate the irradiated fuel processing facilities at Hanford and to undertake a large-scale fission product recovery fabrication program at Hanford as a private commercial enterprise. The two organizations subsequently established a jointly owned corporation, Isochem, Inc., which has negotiated a contract with the AEC to construct, own, and commercially operate within the Hanford reservation a Fission Products Conversion and Encapsulation (FPCE) plant. Isochem will develop and expand markets for the plant's products.

The FPCE plant, which will cost about $8 million and is scheduled for operation in 1968, will be capable of processing each of the four fission products—strontium 90, cesium 137, cerium 144 and promethium 147—into appropriate chemical and physical forms and of encapsulating them into heat and radiation sources. Feed material for the FPCE plant will be obtained from Hanford's waste management operations. Long-lived fission products are to be removed from both stored and current high-level radioactive wastes so as to permit solidification of those processed wastes to salt cakes for safe long-term storage.

In the meantime, as has been done since early 1961, Hanford is treating portions of its current high-level wastes in available facilities to recover selected fission product radioisotopes which are required by AEC programs.[4] During 1965, the following deliveries of these products were made:

Fission products	*Kilo-curies*	*To*
Strontium 90	1,200	Oak Ridge National Laboratory.
	250	Martin Co., Quehanna, Pa.
Cesium 137	546	Oak Ridge National Laboratory.
Cerium 144	420	Oak Ridge National Laboratory.
Promethium 147	180	Pacific Northwest Laboratory.

PLUTONIUM SCRAP RECOVERY

Plutonium contaminated materials and scrap, generated during the production operations, can constitute significant losses of plutonium to the weapons program unless they are treated for plutonium recovery. The recovery process results in a discardable residue and a

[4] See p. 55, "Annual Report to Congress for 1964."

plutonium product that can be returned to the production operations.

At Hanford, the plutonium bearing waste solutions and leachable plutonium scraps are processed in the Plutonium Reclamation Facility (PRF).[5] In conjunction with the PRF operations, 197 grams of americium 241, a decay product of plutonium 241, were recovered for use in AEC research programs.

At Savannah River, the plutonium scrap is recycled for plutonium recovery at appropriate places within the plant's plutonium production operations. In addition, Savannah River employs a chemical fusing process [6] to reduce the plutonium in refractory oxides to a soluble form. At times, Savannah River also processes some plutonium scrap from the AEC's Rocky Flats plant in Colorado.

Prior to 1965, the Richland Operations Office (Hanford) had the responsibility for the disposition and/or treatment of all plutonium scrap generated by AEC contractors and laboratories, except where the plutonium in the scrap was recovered by the generating organization. Starting in June 1964, all AEC plutonium scrap—other than that generated from the AEC's plutonium production and weapons fabrication programs—was held in storage pending determinations of actions to be taken to encourage development of private plutonium capabilities. In March of 1965, the AEC announced steps to give further encouragement to the growth of competitive plutonium processing and fabrication, indicating that it would procure commercial services of most of the nonweapons plutonium processing, including plutonium scrap processing services.

In December 6, 1965, a contract was signed between Nuclear Fuel Services, Inc. (NFS), and the AEC for NFS to recover an estimated 16.5 kilograms of plutonium from approximately 820 kilograms of uranium-contaminated plutonium scrap being stored at Hanford. This is the first such scrap processing contract to be awarded to private industry by the AEC. NFS provided the most favorable response to the Invitation for Proposals, which was sent to seven firms in November 1964, and plans to do the scrap processing at its Erwin, Tenn., facilities.

FUEL REPROCESSING

Up to now, the reprocessing of "spent" fuels from operating reactors to recover the still fissionable (burnable) materials has been done only at the AEC's Hanford, Idaho, and Savannah River facilities. Now, with one privately owned reprocessing plant ready to begin operations during early 1966, there is evidence of growing commercial interest in reprocessing operations.

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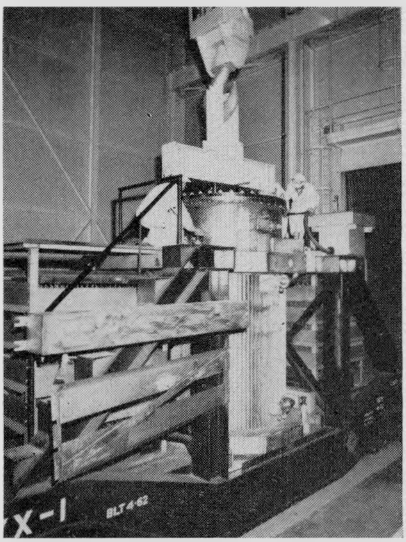
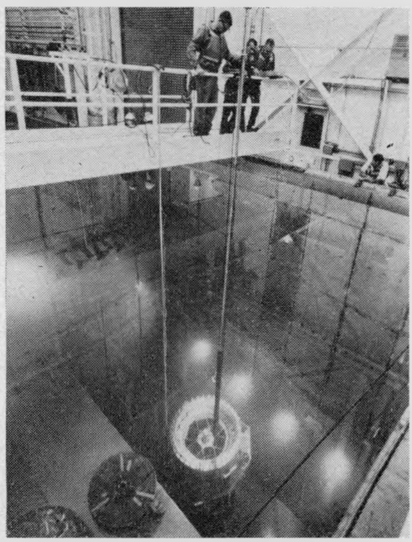
[5] See pp. 50–51, "Annual Report to Congress for 1964."
[6] See p. 51, "Annual Report to Congress for 1964."

Privately Owned Fuel Processing Plants

Status of NFS plant. On May 27, 1965, Nuclear Fuel Services, Inc. (NFS), was granted a license to receive and store "spent" fuel in the basin at its reprocessing facility located in West Valley, N.Y. The first irradiated fuel (from the Yankee reactor) was placed in storage in the NFS basin on June 5. Since then, fuel receipts by NFS have consisted of both private- and Government-generated fuels. As of year's end, startup operations were nearing completion and it is expected that the plant will be available for spent fuel processing on a full-scale commercial basis early in 1966.





Private Processing Capability. Private industry's capability to reprocess reactor fuels to recover the unspent fissionable materials will become a reality early in 1966 when the Nuclear Fuel Services, Inc. (NFS), plant at West Valley, N.Y., goes into operation. Heretofore, fuel reprocessing has been done only at the AEC's plants in Idaho, South Carolina, and Washington. Photo on *left* shows the nuclear fuel shipping cask and specially designed railroad carrier used by NFS to transport the highly radioactive fuel elements arriving at the reprocessing plant. After its removal from the rail car, the 72-ton cask was placed in the unloading pool. Photo at *right* shows underwater removal of a nuclear fuel assembly from its shipping cask. The assembly is one of 24 contained in the first multiple-fuel element to arrive at the plant site. This shipment, from the Dresden Power Station of the Commonwealth Edison Co., Chicago, Ill., was placed in the fuel storage pool adjacent to the single-fuel element from the Yankee reactor which had arrived 10 days earlier during June. It represents the first rail transport of nuclear fuel ever made to a privately owned reprocessing plant.

Activities by others. During February, the General Electric Co. announced that it had awarded a contract to Fluor Corp., Ltd., for design and construction of a nuclear fuel reprocessing plant tentatively planned to be located on the West Coast. Detailed engineering and construction of the plant with a yearly capacity of 300-metric-tons of spent low-enriched fuel is scheduled to begin in 1967. At year's end, General Electric had not made public its choice of a plant site.

In March, the Dow Chemical Co. advised the AEC that, after thoroughly reviewing its activities, potential contribution, and opportunities in the application of chemical technology to the processing of nuclear fuels, the firm had decided that continuation of its programs related to spent fuel processing was not justified. Previously, in August 1964, Dow and Westinghouse had announced plans for a joint research and development program on nuclear fuel reprocessing.[7]

The responses to a March AEC press release indicated that other domestic companies are considering having private fuel reprocessing plants in operation in the early 1970's. In April, Allied Chemical Corp. announced an extensive nuclear fuels development program. The initial step will consist of a "cold" (nonradioactive material) pilot plant to provide chemical engineering technology for a commercial fuel processing plant using fluoride volatility technology. The pilot plant, to be located in Metropolis, Ill., will have a daily capacity of 2.5 tons of unirradiated fuel and is scheduled to be in operation by the end of 1966.

AEC Fuel Reprocessing

During 1965, the AEC received "spent" fuels from five domestic and four foreign reactors for chemical reprocessing, at its own and the NFS plant, to recover plutonium and uranium. The deliveries are summarized in Table 3.

RADIOACTIVE WASTE MANAGEMENT

At the AEC's three chemical processing facilities at Hanford, Savannah River, and National Reactor Testing Station (NRTS), Idaho, highly radioactive waste solutions, resulting from the reprocessing of spent nuclear fuels, are concentrated and stored in large underground tanks.[8] To conserve valuable tank space (ranging in cost between

[7] See p. 59, "Annual Report to Congress for 1964."
[8] See p. 56, "Annual Report to Congress for 1964."

$0.40 to $1.10 per gallon for carbon steel tanks to over $3 per gallon for stainless steel tanks) all three sites have been developing methods to further concentrate the stored waste solutions (liquors). The concentrations that can be achieved are limited by the ability to dissipate the heat from radio-decay of the fission products in the concentrate.

TABLE 3.—IRRADIATED FUEL DELIVERED DURING 1965 TO AEC FOR REPROCESSING

Contracting party	Reactor	AEC office	Type of fuel	As received			
				Total contained uranium Kgs	Percent U-235	Total contained plutonium Kgs [1]	Total contained U-233 Kgs [1]
General Electric	GETR	ID [2]	U-Al Alloy	41.7	84.3		
Do	VBWR	SR [3]	UO_2-SS	573	2.7	1.3	
			UO_2-Zr	756	2.8	0.9	
Yankee Atomic Electric	Rowe, Mass	SR [4]	UO_2-SS	31,000	2.3	195.0	
Commonwealth Edison	Dresden	SR [4]	UO_2-Zr	20,100	0.6	92.2	
Do	do	SR [4]	UO_2-SS	8,900	1.7	29.9	
Do	do	SR	ThO_2-UO_2-SS	43	56.0		13.6
Government of Sweden	R-2	SR	U-Al Alloy	17.9	82.1		
Government of France	Triton Melusine.	SR	U-Al Alloy	174.2	17.0		
NASA	Plumbrook	SR	U-Al Alloy	22.0	85.0		

[1] Purchased by AEC under 30 F.R. 3886 which guarantees purchase prices for plutonium and uranium enriched in the isotope U^{233}.
[2] National Reactor Testing Station, Idaho.
[3] Savannah River Plant, S.C.
[4] Fuel stored at reactor sites for delivery to Nuclear Fuel Services, Inc., plant by the AEC.

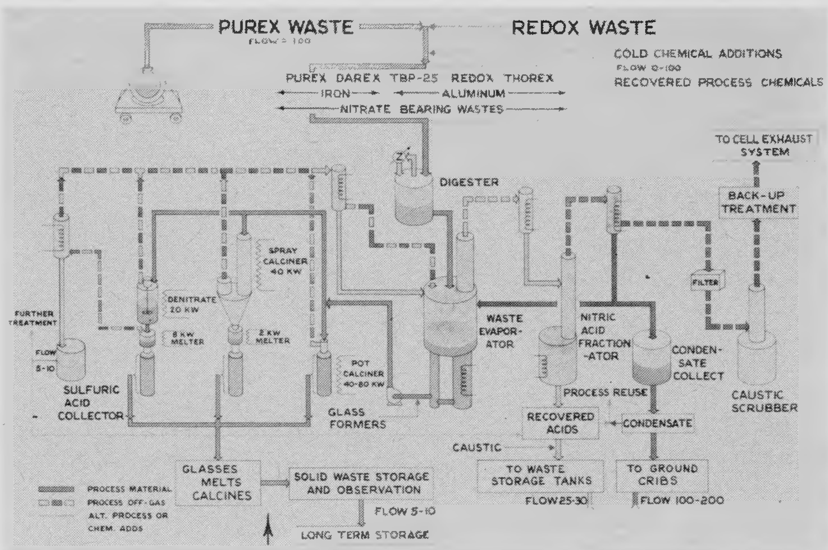
Waste Calcining Facility

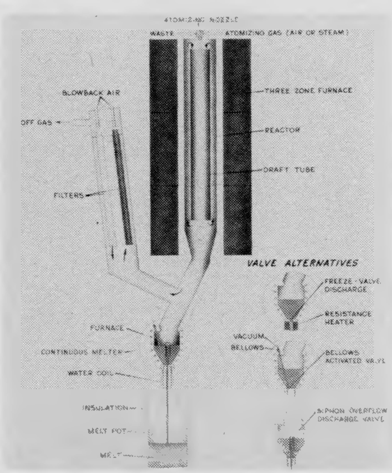
The NRTS has a prototype Waste Calcining Facility (WCF) which uses a fluidized bed principle to evaporate and convert the stored liquid wastes to granular calcine product, having about one-ninth of the original solution volume.[8] The calcined product is sent to underground bins, especially designed for heat dissipation, for long-term storage. The WCF was not operated during 1965 since the available bin space was filled in October 1964. New bins, now being constructed, will be ready for filling early in 1966.

Salt Cake Concentration

Techniques to evaporate the liquid wastes to very concentrated salt solutions and slurries which will solidify to moist salt cakes as the liquors cool are being developed at Hanford and Savannah River.

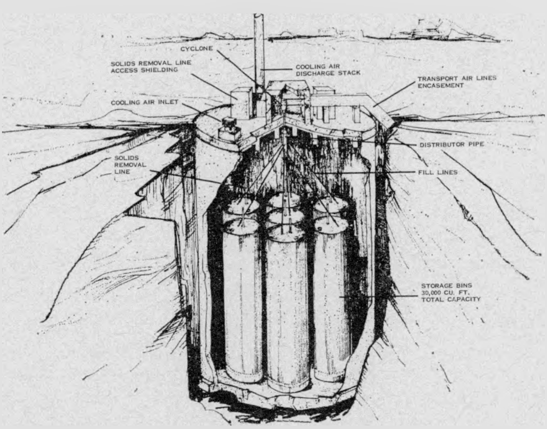
Concentration to a moist salt cake is possible only for those liquid wastes with a low fission product content such as would result from (*a*) aging for decay of the fission products to permissible levels, or (*b*) processing the liquid wastes to remove and segregate the fission products, or (*c*) a combination of (*a*) and (*b*). While methods to remove and segregate the fission products from the liquid wastes are being considered, both Hanford and Savannah River already have large quantities of waste suitable for concentrating to moist salt cakes. Savannah River is circulating the liquors in the waste tanks through large pot evaporators with the evaporator bottoms being returned to the tanks for cooling and crystallizing, and the condensates being de-





Waste Solidification. Drawing *above* is a schematic of the process to be used in the waste solidification engineering prototype (WSEP) plant at Hanford. Construction of the plant was completed during the year. Drawing *at left* shows the engineering-scale spray calciner and continuous melter. (These components are located above the unconnected arrow at bottom of schematic of process.)

Waste Calcining Facility. At the end of 1965, new dry-storage bins were nearing completion at the AEC's Waste Calcining Facility (WCF) at the Idaho Chemical Processing Plant. In photo *above*, the partially-completed 69-foot-deep dry-storage vault is shown at extreme *right*. The tank will contain seven 12-foot diameter by 42-foot long stainless steel bins which will store the solids resulting from the fluidized bed calcining of highly radioactive liquid wastes. Drawing *below* is a schematic of the storage unit. The WCF did not operate during 1965 because the WCF's original storage bins, marked by the small black stack in photo, were filled in 1964 after the plant had completed 312 consecutive days of operation with a 99.3 percent on-stream time. During this period, 510,000 gallons (68,200 cubic feet) of high-level liquid wastes were converted to 7,500 cubic feet of granulated solids at an average rate of 68 gallons per hour—13 percent above design capacity. Operation of the WCF in 1966 is pending completion of the new storage bins.



contaminated by ion-exchange treatment prior to discharge to seepage basins. During 1965, this technique was used at Savannah River to evaporate 3,000,000 gallons of water from its stored waste. Hanford is developing an in-tank solidification (ITS) scheme involving evaporation by using either heated air blown through the liquors or electrical heater elements immersed in the liquors; the moisture in the off-gases leaving the tank is condensed. The condensate would be sent to an underground crib (a porous, graveled-bottomed structure) where the relatively small amounts of radionuclides in the condensates would be retained by the ion-exchange properties of the soil. During 1965, operations of a prototype ITS unit[9] evaporated approximately 1,490,000 gallons of water from stored wastes, thereby recovering this volume of tank space for further use.

NUCLEAR MATERIALS MANAGEMENT

Availability of Special Nuclear Materials

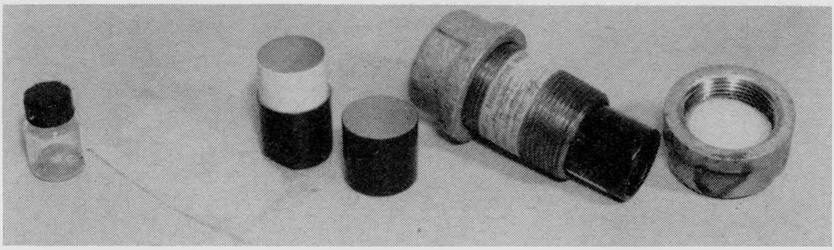
Section 41b. of the Atomic Energy Act of 1954, as amended, provides for Presidential determination of the quantities of special nuclear materials available for distribution to U.S. licensed users and to nations having Agreements for Cooperation with the United States. During 1965, AEC commitments for uranium 235 increased by 36,000 kilograms for domestic licensees. The status, in kilograms, of the determinations for 1965 was:

	U^{235}	Pu	U^{233}
Domestic licensees			
Presidential determination of availability	200, 000	207. 5	53. 6
AEC commitments	110, 400	115. 0	0. 6
Actual distribution	15, 450	107. 0	0. 6
Foreign nations			
Presidential determination of availability	150, 000	543. 0	45. 0
AEC commitments	105, 000	527. 0	32. 3
Actual distribution	8, 850	265. 0	1. 7

[9] See p. 58, "Annual Report to Congress for 1964."

Standard Reference Materials

During 1965, major emphasis was placed on improving plutonium chemical and isotopic standards. Work was begun to compare the plutonium isotopic standard with synthetic blends of high purity plutonium isotopes, prior to final certification by the National Bureau of Standards. A third batch of plutonium metal was encapsulated for use as a chemical standard, the first two batches being nearly exhausted. Efforts were continued to find a stable plutonium compound for use as a primary standard. Negotiations and sample exchanges were initiated with the United Kingdom Atomic Energy Authority for joint acceptance of a natural uranium isotopic standard. Preparations were begun for two new uranium isotopic standards, one at 97.7 percent uranium 235, and one at 0.016 percent uranium 235.



Plutonium Standard. Photo shows the multiple containment (*left to right*) used for protecting plutonium isotopic standard samples (powder in bottom of bottle on left). The plutonium metal standard is similarly packaged, except that a sealed glass ampoule replaces the glass bottle, to reduce atmospheric corrosion. These standards are used by both domestic and foreign laboratories as a basic "benchmark" in high-precision plutonium analysis.

International Symposium on Nuclear Materials Management

The First International Symposium on Nuclear Materials Management was sponsored by the International Atomic Energy Agency (IAEA) at Vienna, Austria, August 30–September 3. Nineteen IAEA member governments, including the U.S.S.R. and Czechoslovakia, and two supranational groups were represented. The United States supported this symposium by the presentation of 31 papers (21 from AEC and 10 from private industry), dealing with methods applicable to the management of both irradiated and unirradiated nuclear materials. It is noteworthy that the Soviet bloc representatives, in addition to presenting a paper, participated freely in this symposium and indicated there would be even greater contributions at future meetings.

Research Toward Improved Materials Management

A study by Combustion Engineering, Inc., Windsor, Conn., to evaluate the calculations of fuel consumption in nuclear reactors indicated the best precision that can be obtained at the present time is ±2 percent for uranium 235 depletion, and ±4 to 5 percent for plutonium production for a large batch of fuel assemblies.[10] These calculations will provide basic data which will help all nuclear reactor operators improve their knowledge of nuclear material burnup and plutonium production.

A nondestructive assay technique using gamma ray spectrometry has been developed by the AEC New York Operations Office for determining the uranium content of absolute air filters. Field experience has demonstrated that this technique (precision of ±10 percent) can be useful to most atomic energy installations in determining the economical recoverability of the contained uranium in air filters.[11]

An investigation by the Stanford Research Institute (SRI), Menlo Park, Calif., of the application of modern mathematical statistics to management and control systems for nuclear materials is nearing completion. SRI is presently constructing and evaluating mathematical models. This work will simplify and improve nuclear materials management and control within both the AEC and private industry.

An Oak Ridge (Y–12 Plant) fundamental study of mixing parameters in critically safe tanks in long cylindrical geometrics (4″–6″ diameter, 10′–60′ length) is nearing completion. The study will permit the design of critically safe processing and storage for uranium solution systems in which homogeneity of process solutions can be assured.[12]

A bibliography of published information related to the management and control of nuclear materials has been prepared.[13] The bibliography contains over 800 references selected from Nuclear Science Abstracts covering such nuclear materials subjects as techni-

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[10] "Analytical and Experimental Methods of Determining Heavy Isotope Content of Operating Fuel Elements," USAEC Report CEND–540 (in publication) to be available from Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va., 22151, for about $5.00.

[11] "Non-Destructive Measurement of U-235 Retained in Absolute Air Filters," USAEC Report NYO–10726; available from Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va., 22151, for $0.50.

[12] "Mixing and Sampling of Enriched U–235 Fluids in Cylindrical Storage Containers," USAEC Report Y–1502 (in publication); to be available from Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va., 22151.

[13] "Nuclear Materials Management, An Annotated Bibliography of Selected Literature," USAEC Report TID–3315 (August 1965); available from Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va., 22151, for $5.00.

cal measurement methods, waste management and recovery, inventory, accounting and auditing, and internal control procedures.

Use of Laboratories as Measurement Umpires

Because of the complexities of measuring special nuclear materials, qualified umpires are needed to settle differences when parties to a transfer cannot agree on the quantity transferred. To answer this need, the AEC has initiated a program to evaluate various industrial and private commercial laboratories, both in the United States and abroad, as potential uranium and plutonium measurement umpires. Preliminary screening of about 40 domestic laboratories and 10 foreign laboratories was in process at the year's end. Preparation of samples of known constitutents for use in the program was also underway at several AEC laboratories.

PRIVATE OWNERSHIP ACT IMPLEMENTATION

New Purchase Prices Established

During the year, the Commission began implementation of the Private Ownership of Special Nuclear Materials Act [14] of 1964 by establishing new guaranteed purchase prices for uranium 233 and plutonium and by developing proposed criteria under which AEC facilities could be used for enriching privately owned uranium after December 31, 1968. Under the 1964 law, domestic private ownership of special nuclear materials for all licensed uses became permissive; after June 30, 1973, it will be mandatory for power reactor fuels.

Guaranteed prices at which the AEC will purchase privately owned plutonium and uranium enriched in the uranium 233 isotope were established during March. The price set for plutonium, $10 per gram for the isotopes Pu^{239} and Pu^{241}, applies to material delivered to the AEC before January 1, 1971, provided it was produced in a domestic reactor under conditions stipulated in section 56 of the Atomic Energy Act of 1954, as amended. The price set for uranium enriched in the isotope U^{233} of $14 per gram of isotope U^{233} is subject to the same production criterion as that for plutonium and is also subject to adjustment for the presence of other uranium isotopes. The uranium 233 price also applies until January 1, 1971, but the Commission may establish a guaranteed purchase price beyond that date if deemed appropriate. The plutonium purchase price may not be guaranteed after that date. Both the plutonium and uranium 233 prices are subject to change if the AEC revises the schedule of charges for uranium enriched in the isotope U^{235}.

[14] See pp. 12–15, "Annual Report to Congress for 1964."

Criteria for Enrichment Services

The 1964 private ownership revision of the Atomic Energy Act authorized the AEC to enter into contracts to provide, after December 31, 1968, "enrichment services" for privately owned uranium. A draft of proposed criteria under which these services would be offered was published in the *Federal Register* on October 1, 1965, for public comment. Ninety days were allowed for the receipt of comments. After incorporation of any appropriate changes resulting from public comments, the criteria will be submitted to the Joint Committee on Atomic Energy pursuant to the private ownership act.

Chapter 6

THE NUCLEAR DEFENSE EFFORT

Working with the Department of Defense, the AEC continued to provide the Nation a strong nuclear military posture and during 1965 gave a high priority to the maintenance of the four safeguards[1] stated to Congress in 1963 in connection with the ratification of the limited nuclear test ban treaty.

WEAPONS DEVELOPMENT, PRODUCTION, AND TESTS

WEAPONS DEVELOPMENT

During the year, the AEC continued the progressive effort necessary to meet the limited nuclear test ban treaty safeguards requirements and continued the development of weapons designed to meet Department of Defense (DOD) military requirements. The AEC, through its laboratories, continued to participate with the DOD in the research and development of nuclear detonation detection techniques (Vela Program).

Warhead Advances

A major weapons development objective has been the improvement of the penetration capability of strategic missile warheads by further decreasing warhead vulnerability to advanced enemy antiballistic missile countermeasures. Laboratory computations and experiments have identified several possible designs toward achieving these im-

[1] Prior to ratification of the test ban treaty in 1963, the late President Kennedy had announced as U.S. National Policy, four safeguards which would be maintained to provide the Nation with a national defense nuclear readiness posture. The four safeguards were: (1) continuation of an aggressive underground nuclear weapons test program; (2) maintenance of a progressive laboratory program; (3) a readiness capability to resume atmospheric tests if the treaty should be broken by other signatories; and (4) the improvement of our capability, within feasible and practical limits, to monitor the terms of the treaty and to detect violations. The four safeguards were reaffirmed in April 1964 by President Johnson. See p. 55, "Annual Report to Congress for 1963"; pp. 66, 70–71, and 74 of "Annual Report to Congress for 1964."

provements. The designs are under further study, with the purpose of producing—within any given set of limitations in size, weight, and yield—a system with hardness balanced against all possible threats. Field tests to demonstrate the durability of hardened devices have been made and further tests are in preparation.

Significant weapons tests in the areas of nuclear safety and efficiency were also conducted. In addition, the laboratories continued their investigations of advanced concepts and technologies to assure continued U.S. technical supremacy in the nuclear defense field. Efforts to simplify and miniaturize nonnuclear components as well as to reduce weight have been continued.

Progressive Laboratory Programs

The three AEC weapons laboratories—Lawrence Radiation Laboratory, Livermore; Los Alamos Scientific Laboratory, and Sandia Laboratory, Albuquerque and Livermore—continue to function in a healthy and modern condition. The fiscal year 1966 budget (July 1, 1965 through June 30, 1966) provides for continuing progressive laboratory programs in basic nuclear weapons technology, and applied nuclear research and development directed toward stated military requirements. It also provides for continuation of programs to simulate various weapons phenomenology in laboratory environments. The improvement in facilities, the maintenance of challenging research and development programs, and the continuing underground testing program have enabled the laboratories to continue expanding the "state of the art" as well as to retain and recruit the necessary technical staff to conduct the assigned programs.

Included in the laboratory research and development objectives were the design and fabrication of more sophisticated test devices which were used in the continuing underground test program at the Nevada Test Site. In addition, the laboratories maintained and improved their readiness capability to resume atmospheric testing in the event of an abrogation of the limited nuclear test ban treaty by another nation and a subsequent decision by the United States to resume testing in the atmosphere.

The fiscal year 1966 appropriation included almost $13 million for nine major construction projects for the three laboratories (three for Livermore, five for Los Alamos, one for Sandia) with an additional $2.2 million for three support projects at the Nevada Test Site. In addition, equipment and minor construction funds were provided at a level consistent with laboratory needs. This has included upgrading, and additions to, the scientific computer complexes which are considered vital to the development programs at the laboratories.

Neutron Physics Research Using Nuclear Detonations

Two successful neutron physics research experiments in which neutrons from underground nuclear detonations were used as the source for cross-section measurements—utilizing the neutron flight time to define neutron energy—were carried out by the Los Alamos Scientific Laboratory at the Nevada Test Site in conjunction with weapons test events. The technique for these measurements, as it was developed in the past year, permits: (*a*) many experiments requiring high-energy neutrons to be conducted simultaneously; (*b*) high energy resolution, comparable to that available using modern laboratory accelerators; (*c*) recovery of electronic equipment and samples of rare isotopes located near the neutron flight path; (*d*) observations on isotopes too short-lived for conventional laboratory experiments; and (*e*) observations to be made on microgram quantities of materials. Intensity levels in the underground weapon experiments were so great that hundreds of years would be required for acquisition of the same data using laboratory accelerators as neutron sources.

Efforts were directed toward measurements of immediate interest in connection with design and development of weapons and reactors; however, new fission cross-section data were also acquired for the uranium isotopes 233, 235, and 238, and plutonium 239, 240, and 241. Numerous capture cross-sections were also measured. It is anticipated that, as these methods become more highly refined, other unique experiments requiring intense neutron sources will be conducted.

WEAPONS PRODUCTION

Under Presidential authorization, the production of nuclear weapons in 1965 continued to meet the Department of Defense military requirements. Weapon production activities, including fabrication and assembly of new weapons and factory and field modifications of existing weapons, continued during the year with no major problems.

Stockpile Improvement

Weapon production during the year incorporated several design and technological improvements which contribute materially to improved reliability, safety, and efficiency. Efforts to simplify and miniaturize nonnuclear components as well as to reduce weight and increase operational reliability have continued. An additional portion of the stockpile was modified to incorporate devices for prevention of unauthorized use. Improved demolition munitions were introduced into stockpile during the year.

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The retirement of obsolete weapons continued on a planned, orderly basis with emphasis placed on re-use and maximum salvage of both nuclear and nonnuclear components and materials for use in current production, research and development, and training programs.

Consolidation of Facilities

The weapons modification centers at Medina Base, San Antonio, Tex., and at Clarksville, Tenn., were scheduled for closure by July 1966 with their functions transferred to the Burlington AEC Plant, Iowa, and the Pantex Plant at Amarillo, Tex.[2] The Clarksville facility (the smaller of the modification centers) was closed in late September 1965 and the facilities made available to the Department of Defense. AEC operations at Medina will be terminated by July 1966 and the facilities will either be transferred to another Federal agency or disposed of by GSA. The termination of these two AEC operations will result in an estimated annual savings of about $3.1 million.

Consolidation of Development Work

In mid-September, a decision was made to consolidate neutron generator development work conducted for the AEC by the General Electric Co. in the GE-Milwaukee Plant, with closely related work at the GE-operated AEC Pinellas Plant in Florida. Savings of over $900,000 annually are estimated when the transition is completed about September 1966.

Transfer of Uranium 235 Fabrication

In late January, the AEC announced the transfer of certain uranium 235 fabrication work from the Rocky Flats Plant, Colo., to the Oak Ridge, Tenn., Y-12 Plant where other similar work was performed. The transfer was accomplished by the end of June 1965; this action is estimated to save up to $1.5 million in future annual operating costs. The Rocky Flats Plant is operated for the AEC by the Dow Chemical Co., and the Y-12 Plant by Union Carbide Nuclear Corp.

Termination of Parts Fabrication at Hanford

In mid-November, the AEC announced the termination of plutonium weapons parts fabrication at the Hanford, Wash., Works by the

[2] See pp. 18–19, 73–74 of "Annual Report to Congress for 1964."

end of 1965. The net savings from this action will amount to over $1 million annually.

Studies of Weapons Production Capacity

In the interest of economy and efficiency, the AEC is continuing an over-all review of the capacity of plants in the weapons production system. The basic objective of this review is to determine the operating structure and capacity that will most economically assure a capability to meet all foreseeable nuclear weapons needs.

Reduction of Contractor Production Personnel

Employment levels at the AEC's contractor-operated weapons production plants were reduced by approximately 13 percent during 1965. A major reduction occurred at the Bendix Corp., Kansas City, Mo., plant. Early in 1965, it was announced that a reduction from 8,100 employees at the beginning of the year to about 6,700 by yearend would be effected. At mid-year, it was announced that the employment level by year end would be further reduced, to about 6,300. The net reduction was slightly more than 2,000. Other reductions were about 740 positions in the Y–12 Plant at Oak Ridge, about 200 at the Rocky Flats plant, and about 195 at the South Albuquerque, N. Mex., Works.

UNDERGROUND NUCLEAR TESTS

The AEC has continued to conduct an underground nuclear test program at the Nevada Test Site under the terms of the limited test ban treaty since its signing on August 5, 1963, by the United States, United Kingdom, and U.S.S.R. representatives. Through a comprehensive series of underground tests, a sophisticated capability has been developed to support a wide range of full-scale underground experiments. Along with advanced laboratory techniques, new and improved methods continue to be developed for conducting experiments that were not previously considered feasible in the underground test environment (see previous "Neutron Physics Research Using Nuclear Detonations" item).

"*Bigger and Bigger*". The "technology spinoff" from the AEC-Department of Defense underground test program continues to add new equipment and techniques useful to the drilling industry. Laboratory requirements for larger and deeper cased holes during 1965 made it necessary for the Nevada Test Site architectural and engineering services contractor for drilling and mining operations (Fenix & Scisson, Inc., and Petroleum Consultants) to design new equipment and methods and for suppliers to fabricate special equipment. Hugh B. Williams Co. fabricated this 160-inch drill-hit assembly for drilling a hole which required a 144-inch inside diameter casing that had walls 2¼-inch thick. Larger and deeper holes make it possible to conduct underground tests that previously were thought possible only through atmospheric detonations. Under the 1963 limited nuclear test ban treaty, atmospheric detonations are prohibited.

1965 TEST PROGRAM

Whetstone-Flintlock Series

The current test series, Operation Flintlock (commencing July 1, 1965 and ending June 30, 1966), will help to meet the objectives of the major programs of the AEC and DOD through underground tests conducted at the Nevada Test Site. Operation Whetstone was the name of the preceding underground series which ended June 30, 1965.

The planned events of Operation Flintlock, as approved in principle by the President, are grouped into four broad categories: (*a*) weapons and/or device development events, (*b*) Plowshare experiments (peaceful uses of nuclear explosives), (*c*) Department of Defense effects events, and (*d*) joint AEC–DOD tests designed for research and development on improved detection methods and systems to enhance the U.S. detection capability (Vela Program). Included in the first category are events to further weapons and device development, investigate advanced concepts and technologies, assure the reliability and safety of nuclear weapons, and investigate nuclear outputs and detonation effects on weapons materials and components. Events, with increasing magnitudes of yield on a step-by-step basis, are planned for the higher-elevation area of Pahute Mesa which was added to NTS in 1964. The Plowshare experiments (see Chapter 12—The Plowshare Program) are planned to develop "clean" (less radioactive fallout) excavation explosives, and to carry out studies of nuclear explosives designed to produce very high fluxes and with them special isotopes such as those of the transplutonium elements. The DOD effects events are designed to extend knowledge of weapon-generated effects. The joint Vela Program events are planned to improve the capability to detect, identify, and locate underground nuclear explosions.

As has been true in preceding test series, each event was reviewed and approved in accordance with Commission-developed procedures. The events are executed only with the expectation that they can be conducted within the requirements and constraints of the limited test ban treaty.

Test Event Summary

Sixteen events, including four DOD effects events and one Plowshare event, were publicly announced in 1965 as being conducted under Whetstone and 11 events (including a United Kingdom event) have been announced as being conducted under Flintlock through December 31, 1965. Two of the Whetstone announced events were conducted in the Pahute Mesa area of the NTS. One event was a weapons development event and the other a Plowshare experiment.

Table 1 summarizes the announced 1965 test events.

TABLE 1.—ANNOUNCED UNDERGROUND NUCLEAR DETONATIONS
(January 1–December 31, 1965)

Event name	Date	Type of event [1]
Wool	January 14	Low yield.
Cashmere	February 4	Do.
Merlin	February 16	Do.
Wish Bone [2]	February 18	Do.
Wagtail	March 3	Low intermediate yield.
Cup	March 26	Do.
Kestrel	April 5	Low yield.
Palanquin [3]	April 14	Do.
Gum Drop [2]	April 21	Do.
Tee	May 7	Do.
Buteo	May 12	Do.
Scaup	May 14	Do.
Tweed	May 21	Do.
Petrel	June 11	Do.
Diluted Waters [2]	June 16	Do.
Tiny Tot [2]	June 17	Do.
Bronze	July 23	Low intermediate yield.
Mauve	August 6	Low yield.
Centaur	August 27	Do
Screamer	September 1	Do.
Charcoal [4]	September 10	Low intermediate yield.
Elkhart	September 17	Low yield.
Long Shot [5]	October 29	Low intermediate yield.
Sepia	November 12	Low yield.
Corduroy	December 3	Intermediate yield.
Emerson	December 16	Low yield.
Buff	December 16	Low intermediate yield.

[1] Low yield—less than 20 kt; low intermediate yield, 20 kt to 200 kt, intermediate yield, 200 kt to one megaton.

[2] Department of Defense events conducted with AEC laboratory assistance.

[3] Plowshare (Peaceful Uses of Nuclear Explosives) event.

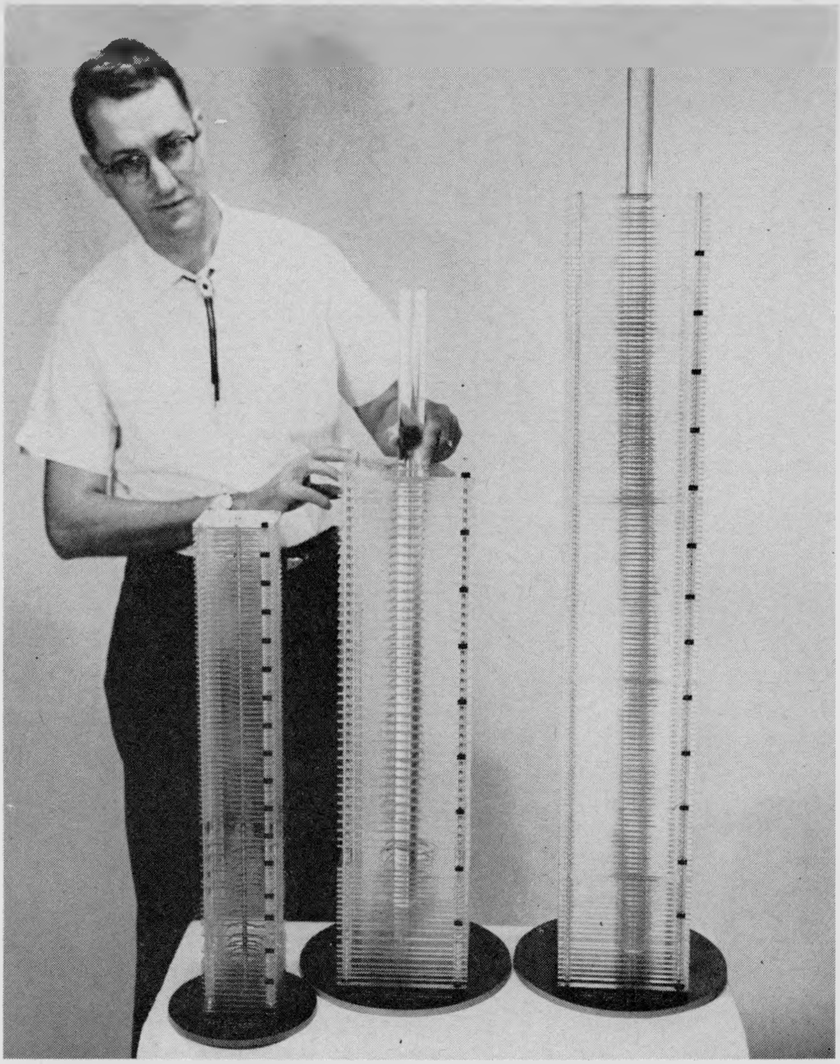
[4] Jointly with the United Kingdom.

[5] Joint AEC-DOD Vela Uniform event conducted in Aleutian Islands.

"TECHNOLOGY SPINOFF"

Commercial drilling and mining techniques continue to be enhanced[3] by innovations being made at the Nevada Test Site for conducting nuclear detonations deep underground. Some of the new developments that can be adapted by industry are illustrated by photos in this report; another is cited on page 102.

[3] See p. 68, "Annual Report to Congress for 1963"; pp. 11, 67–68, "Annual Report to Congress for 1964."



Important Drilling Advance. The Dowell sonar caliper survey tool developed at Nevada Test Site during 1965 provides drilling engineers with a much more accurate representation of large-diameter drilled holes than was possible with conventional caliper logs. By revealing potential areas of difficulty the system enables engineers to carry out remedial work when it is most economical—before casing operations commence. The tool is an adaptation of the familiar type of sonar gear used in submarine detection. A rotating sonar beam scans the walls of the hole and transmits a trace of its findings to a photographic film. From this film the scale models of the hole shown in the above picture are constructed. These provide a pictorial representation of the drilled holes, showing any irregularities or deviations and enable scale models of the casing string (the clear plastic tubes shown in the picture) to be run in the hole. This pinpoints areas where remedial work is needed. The tallest of the three models shown is that of a 4,200-foot-deep hole drilled and cased on Pahute Mesa.

"Lost" Equipment Recovery

An additional new technique, developed during 1965 and of interest to the drilling industry, is an integrated television circuit and remote manipulator for down-hole equipment recovery.

The television-manipulator system provides a means of recovering drill bits, drill pipe, and other equipment or material which have broken loose in down-hole drilling operations. The system includes a closed television circuit (previously developed at NTS for down-hole use) to provide a view of conditions in a hole whether in dry soil or underwater, and to facilitate operation of the remote manipulators which can lift up to 26,000 pounds.

When a drill bit, cutter, drill pipe, or other piece of equipment breaks loose during down-hole drilling, it is necessary to "fish" for the equipment with various mechanical devices. For the most part, "fishing" operations are conducted blindly. Frequently, they take long periods of time and occasionally it has become necessary to cease drilling entirely because of the inability to clear the hole. Drilling technicians believe development of a means for "seeing" conditions down-hole and for moving, gripping, and lifting "lost" equipment with sensitive manipulators will be more efficient and more economical (both as to time and cost) than the "fishing" techniques ordinarily used by the drilling industry.

ATMOSPHERIC TEST READINESS CAPABILITY

As directed by the late President Kennedy and reaffirmed in April 1964 by President Johnson, the AEC continued to maintain and improve the capability for resumption of nuclear testing in the test ban treaty prohibited environments (atmosphere, underwater, and in space) should it be directed to do so in the event of an abrogation of the treaty or in the interest of national security, within a minimum reaction period. This capability was attained on January 1, 1965.

Summary of Major Readiness Accomplishments

The following major projects have been accomplished and are being maintained in a state of readiness: (*a*) substantial upgrading of facilities at Johnston Atoll, the base of operations for the majority of any planned tests; (*b*) construction of scientific and support facilities throughout the Hawaiian area and at Johnston Atoll; (*c*) modification and instrumentation of three C–135 aircraft to permit basic measurements of device diagnostic data and phenomena for the AEC; (*d*) modification and instrumentation of RB–57 aircraft for debris sampling purposes; (*e*) availability of additional B–57 aircraft for launching airborne rocket samplers; (*f*) availability of B–52 aircraft for use as device drop aircraft; (*g*) development, fabrication, and stockpiling of special ballistic cases for nuclear devices; (*h*) establishment of the capability for a high altitude program by development of booster vehicles as device carriers, and small instrumentation rockets; (*i*) comprehensive instrumentation development to establish advanced equipment designs which can perform reliable and accurate measurements of device outputs and weapons effects; and (*j*) identification of operational systems tests as well as nuclear tactical exercises of prime interest to the services and the development of plans and safety studies required to place them in readiness.

In addition, full-scale and abbreviated air-array exercises of a nonnuclear nature to check the diagnostic capability, based on Johnston Atoll and in the United States, respectively, have been conducted and are planned. These help to maintain a state of readiness by increasing the technical proficiencies of both air crews and civilian technicians, as well as to test and exercise the diagnostic aircraft and the instrumentation.

AEC/DOD Agreement on Johnston Atoll

The Commission and the Department of Defense, in February 1965, entered into an agreement regarding contractual arrangements at Johnston Atoll. The principal points are:

(*1*) A single contractor, operating under one contract, will provide engineering, construction, maintenance and operations support services at the Atoll.

(*2*) Except for contract administration, which remains an AEC responsibility, the Commander of DOD's JTF–8 (Joint Task Force No. 8) will exercise operational control.

The DOD assumed base construction, maintenance, and operations costs on July 1, 1965. Through appropriate delegation of authority and coordination, the operational requirements were merged with the contract administration which is being accomplished by the AEC.

Establishment of Honolulu Area Office

The AEC's Honolulu Area Office was established on May 1, 1965, to increase the efficiency and economy of operations in connection with the administration of Pacific operations. These activities, previously carried out both in Honolulu and Las Vegas, Nev., involve administration of contracts for engineering, construction, and operations support services related to test readiness in the Pacific Area.

Participation in Solar Eclipse Expedition

Los Alamos and Sandia diagnostic aircraft participated in a National Science Foundation expedition (based on American Samoa) to the South Pacific Ocean area to make observations of the exceptionally long-duration total solar eclipse on May 30, 1965. The participation was preceded by an AEC determination that no adverse effect would result to the readiness posture and that such an experiment would provide additional valuable training for both the flight crews and civilian technicians. Solar and astrophysical phenomena are areas of interest to the AEC in view of their special connection with both the Vela satellite and surface-based detection programs. In addition to aircraft participation, during the eclipse, Sandia launched several rockets, from a base on the island of Rarotonga in the Cook Group, carrying LASL-developed X-ray detectors to observe X-ray fluxes from the partially-obscured sun.

The scientific commander of the Los Alamos-Sandia expedition reported that about 85 to 95 percent of the possible total data was obtained and that essentially all equipment operated satisfactorily. Shortly after the eclipse, the two diagnostic aircraft flew to Australia, from where missions were flown to obtain cosmic ray data in the vicinity of the south magnetic pole. The aircraft returned to their home base in the United States in early June.

DETECTION OF NUCLEAR EXPLOSIONS

The AEC continued in 1965 to participate in studies on ways and means to improve detection techniques and systems (Vela program) for both underground and space nuclear explosions. The Vela program is supervised by the Advanced Research Projects Agency (ARPA) of the Department of Defense and is a research and development effort conducted to improve capabilities of detecting, locating, and identifying nuclear detonations. The ultimate objective is development of a system, or systems, capable of adequately monitoring a comprehensive nuclear test ban by (*a*) detection of underground detonations; (*b*) detection, by means of satellites, of nuclear explosions in space; and (*c*) detection of nuclear explosions in space through ground detection equipment.

VELA UNIFORM PROGRAM

During 1965, measurements of ground shock accelerations and other effects, and the operation of both short- and long-range seismic recording stations continued, in conjunction with underground test events at the NTS as a part of the Vela Uniform program (underground test detection). The DOD has the administrative, funding, and technical responsibility for the program, and the AEC is responsible in connection with certain nuclear events, for: (*a*) conducting the experiment within the provisions of the limited test ban treaty; (*b*) assuring public safety; (*c*) constructing emplacement facilities and firing; (*d*) determining the yield and conducting post-shot drilling; and (*e*) instrumenting for close-in measurements.

Three underground events have been conducted under the Vela Uniform program. The first was Project Shoal, a nuclear detonation of about 12 kilotons (kt) in granite, conducted on October 26, 1963, near Fallon, Nev.,[4] to record seismic signals from a nuclear detonation for comparison with signals generated by a naturally occurring earthquake. The second was the October 22, 1964, Salmon event of Project Dribble,[5] in salt at the Tatum Salt Dome, near Hattiesburg, Miss., directed at exploring decoupling[6] techniques. The third event was Long Shot conducted on October 29, 1965, on Amchitka Island in the Aleutian Chain.

Project Dribble

The primary technical objectives of Project Dribble were to obtain data which can be extrapolated to indicate the significance of decoupling at the five kiloton level and to study seismic wave propagation in the southeastern United States.

During 1965, following investigation of the Salmon cavity, the Dribble site was placed on a standby-ready status. Currently, there is a DOD-approved program for re-entry into the Salmon cavity through the emplacement casing. The purpose of this project is to determine whether the Salmon emplacement hole can be used again in the event that a decision is made to request permission for another

[4] See p. 70, "Annual Report to Congress for 1963"; p. 75, "Annual Report to Congress for 1964."

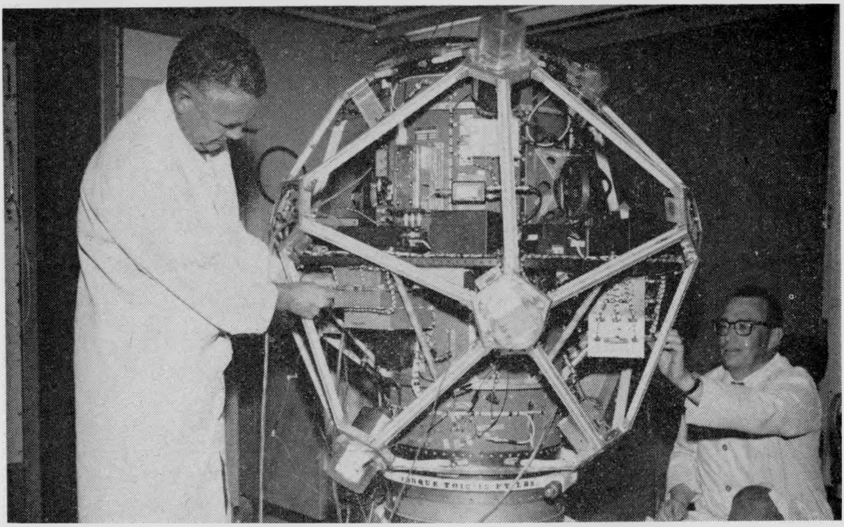
[5] See pp. 75–76, "Annual Report to Congress for 1964."

[6] "Tamped" is the placing of an explosive device underground in direct contact with the medium in which it will be fired so that the shock and earth movement generated by the explosion will be directly transferred by close physical coupling to the medium.

"Decoupled" is the use of an underground cavity as an explosion site to reduce the transference of the explosive energy and hence the amount of shock and earth movement imparted to the surrounding medium, thus possibly concealing the true magnitude of the explosion or reducing the effects of the explosion below the detection capabilities of a detection system.

DOD experiment. Real estate lease agreements on the Dribble site are being maintained.

Salmon post-shot investigation. Following the 1964 detonation of the 5-kt Salmon event in a 2,700-foot hole, a 2-month waiting period was requested by the Advanced Research Projects Agency to allow unhampered surface investigations. Postshot drilling was started in early January 1965 and the cavity was penetrated in early March. The cavity was about 112 feet in diameter with the bottom 24 feet filled with solidified melt and with a void volume of about 690,000 cubic feet. The temperature was 400° F., about 280° hotter than before



Space Detonation Detector. Vela research satellites use Sandia Laboratory-designed logic systems and Los Alamos Scientific Laboratory-designed detectors for the detection of nuclear devices detonated in space. The third set of Vela satellites was placed into orbit some 60,000 miles in space during July. A world-wide tracking network tapes data from the satellites. The tapes are processed by Sandia Laboratory and the reduced data are sent to Los Alamos Scientific Laboratory for final analysis. Photo *above* shows a satellite being readied for testing at Sandia Laboratory before being encased in its sheath and shipped to Cape Kennedy, Fla., for boosting into space. The satellites measure 54 inches in diameter, weigh about 500 pounds, and are icosahedron (20 sides) shaped. Each of the triangular sides is covered with solar cells which draw energy from the sun for operation of all internal electronic equipment. A central cylinder houses the orbit injection rocket and provides structural rigidity. X-ray detectors are at the corners of the spacecraft. Neutron and gamma radiation detectors are located inside the satellites. It is believed that the sensors will allow detection of nuclear tests conducted in space more than ten million miles from earth. In photo *opposite page* S. P. Schwartz, Sandia Corp. president, shows a satellite model to representatives of the All-Pueblo Council, Mescalero and Jicarilla Apache Tribes and Navajo Tribe, who visited the AEC's Sandia Laboratory in May. The purpose of the program was to brief the Indian officials on the nature of Sandia's work and employment opportunities and practices at the Laboratory.

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the shot. Livermore scientists responsible for the technical programs believe the temperature will decline slowly. At the time penetration was made into the cavity, radioactivity had declined to about one-tenth of a roentgen per hour, and the cavity gases were under a vacuum of 20 inches of mercury.

Salmon claims. The AEC, as part of its responsibilities in connection with conduct of the Salmon event, handles investigation and settlement of claims pursuant to the provisions of paragraph 167 of the Atomic Energy Act (reimbursable to the AEC by the Department of Defense). In early 1965, payments of claims beyond 12 miles from ground zero of the Salmon event were deferred until detailed studies by technical consultants could be made of the ground structure and seismic propagation. The studies were completed in mid-1965 with a conclusion that the previously stated thresholds of damage criteria (based on chemical explosions) were not applicable in the case of Salmon. A number of factors such as local geological features, energy propagation phenomena, orientation of buildings, and preshot stress conditions were recognized as significant in specified individual cases. The studies did not identify any single cause for damage. Claims of $5,000 or less are now being settled when supporting evidence shows that the damage claimed had directly resulted from the Salmon detonation.

Long Shot

Long Shot was the third joint AEC–DOD Vela Uniform nuclear event and was executed on October 29, 1965. The experiment was con-

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ducted deep underground on Amchitka Island in the Aleutian Chain and was fully contained. Preliminary results indicate that a seismic magnitude of about 5.75 (moderate) was achieved. The event had worldwide seismic coverage. News media representatives were present on Amchitka before and after the detonation. The objective was to obtain a new set of seismic travel-time curves from an underground disturbance in a high-incidence earthquake area. The AEC participated by: (*a*) furnishing, timing, and firing the nuclear device; (*b*) constructing emplacement facilities; (*c*) supervising emplacement of the device and stemming the hole; (*d*) developing and directing the public safety program; and (*e*) assuring that the experiment was carried out in accordance with the provisions of the limited nuclear test ban treaty.

Unmanned Seismic Observatory (*USO*)

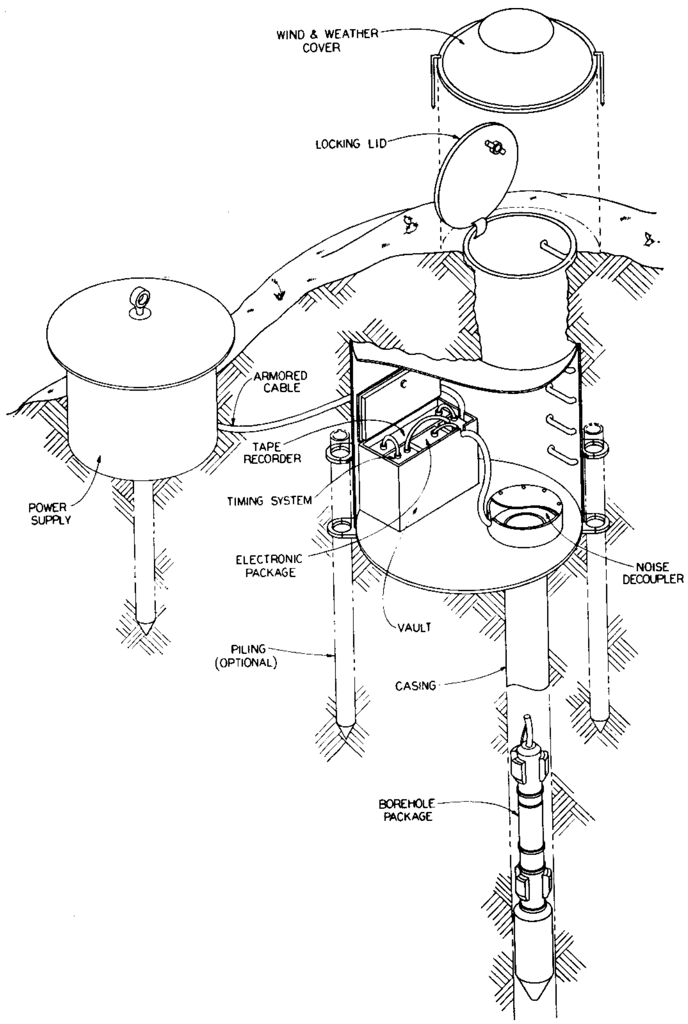
A prototype model of an unmanned seismic observatory is being developed for the Advanced Research Projects Agency by the AEC's Sandia Laboratory. Initial field test of a prototype unit is expected to begin in February 1966 near Albuquerque, N. Mex., with field tests of production units in Alaska (Arctic environment) beginning in April, and in Utah (Uinta Basin Seismological Observatory to correlate data with that from a well-instrumented site) beginning about July 1966.

The project, which was authorized in 1964, calls for development of a compact, reliable system capable of operating unattended for a minimum of 90 days (120 days now appears feasible). For a given station, the planned timing accuracy is 0.1 second or better over the operational period. The system is to continuously record three components of short- and long-period seismometer outputs and is planned for operation under the extremes of normal terrestrial environments.

The present design concept envisions a USO in three equipment units—to provide flexibility—consisting of: (*a*) down-hole unit consisting of three short-period seismometers and three long-period seismometers; (*b*) an electronic package including electronic logics, tape recorder, timing system, etc.; and (*c*) a thermoelectric power supply.

VELA SATELLITE DETECTORS

The AEC continued to participate in the Vela satellite program, a research and development effort to develop satellite-based instruments and detection systems for the detection of nuclear explosions conducted in space.



Unmanned Seismic Observatory. The schematic drawing shows how an unmanned seismic observatory, now under development for the Department of Defense by the AEC's Sandia Laboratory, would appear in a typical underground installation. The borehold package is positioned inside the pipe by a gyro unit and mechanically locked in place. The center section of the package rotates to aline short-period seismometers to compass points; long-period seismometers are in lower section with stabilizing weight. The first prototype unit is scheduled to undergo field testing near Albuquerque, N. Mex., early in 1966.

Third Pair Orbited

Another successful Atlas-Agena launch on July 20, 1965, placed the third pair of tandem AEC-instrumented satellites into widely-spaced positions on a near circular orbit with average radius of about

60,000 nautical miles. The newest pair of nuclear test detection satellites joined the four satellites placed in similar orbits by two earlier launches in October 1963 and July 1964. Improved types of detectors designed by Los Alamos Scientific Laboratory, and new integrated circuits for the logic systems developed by Sandia Corp., are aboard the twin detection satellites. The six spacecraft contain radiation detectors for neutrons, gamma rays, and X-rays. The second and third launch satellite contained instrumentation for measuring characteristics of the "solar wind" in interplanetary space, charged particle fluxes as seen in the "magnetosphere" and "transition" regions of space, and solar X-rays so that the effects of these background radiations can be evaluated and understood. In addition, the third launch satellites were also instrumented to obtain data on lower energy solar X-rays.

All spacecraft are performing their nuclear test monitoring functions as intended. Although there have been failures of some components in certain detection systems, these have not appreciably affected the detection capabilities of the spacecraft because of the electronic circuit and sensor redundancies incorporated into the payloads. A fourth Vela satellite launch is scheduled for late 1966 to place two additional AEC-instrumented satellites into orbit with further improvements and augmented capabilities. In addition to the currently authorized satellite launches, AEC-developed instruments to measure solar X-ray emision were flown on low-altitude rocket probes.

VELA GROUND DETECTORS

The AEC continued to participate in the program for the ground-based detection of nuclear explosions in space. The primary effort was on the air fluorescence method. The fluorescence system is based on the detection of the fluorescent light produced when nitrogen is bombarded by X-rays.

Efforts were directed toward five general areas: (*a*) analysis of air fluorescence data obtained from the Dominic atmospheric weapons test series[7] of April-November 1962, (*b*) studies of the energy partition into various frequency bands, (*c*) calculations on the effects of atmospheric attenuation on air fluorescence signals received on the ground, (*d*) investigation of the charge transfer processes that occur under high altitude conditions, and (*e*) conduct of a joint AEC–DOD summer lighting study to investigate lightning backgrounds as they

[7] See pp. 62–68, "Annual Report to Congress for 1963."

may relate to air fluorescence detection; the experimental phase of this study was conducted during the summer at Los Alamos and data analyses are underway.

MUTUAL DEFENSE AGREEMENTS

Under the provisions of the Atomic Energy Act of 1954, as amended, the President may authorize the United States to cooperate with another nation or regional defense organization to which the United States is a party and to communicate certain classified data as is determined necessary for mutual defense purposes.[8] During 1965, exchanges of information for mutual defense purposes continued under 11 such agreements with Australia, Canada, Belgium, France, the Federal Republic of Germany, Greece, The Netherlands, Turkey, Italy, the North Atlantic Treaty Organization (NATO), and the United Kingdom. The agreement with the United Kingdom is much broader than the other 10, and includes the exchange of weapons design information through visits and reports and the exchange of nuclear materials. A revision of the agreement with NATO, submitted to the Congress on June 30, 1964, became effective during March 1965 upon approval by all member nations of NATO.

[8] See pp. 77 and 79, "Annual Report to Congress for 1964."

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Chapter 7

CIVILIAN NUCLEAR POWER

During 1965, a growing number of electric utilities moved forward in accepting—or seriously considering the selection of—nuclear powerplants for installation on their systems.

CENTRAL STATION NUCLEAR POWER

One of the most important civilian uses of nuclear energy—that of generating electric power—is obtaining an increasing amount of the rapidly expanding power market. Several nuclear power plants ranging in size from 500,000 to 873,000 ekw (electrical kilowatts) are either currently under construction or are firmly planned. When these plants become fully operational, substantial amounts of nuclear power will have been brought to many areas of the United States where fossil fuel costs are relatively high. As Table 1 indicates, the Oyster Creek, Nine Mile Point, Dresden No. 2, Millstone Point, Boston Edison, Florida Power & Light, and Indian Point No. 2 plants all fall within this size range. Also, the San Onofre and Connecticut Yankee plants under construction, and the planned Malibu, Colorado High Temperature Gas-Cooled Reactor, and Brookwood plants all will have capacities greater than any nuclear powerplant in operation today. In addition, when the Washington Public Power Supply System (WPPSS) facility, which will draw its heat from the "N" Reactor at Hanford, goes "on the line" in early 1966, it will be the largest operating nuclear power facility in the Nation. (See Chapter 5—Source and Special Nuclear Materials Production.)

NUCLEAR POWERPLANTS BEING CONSIDERED

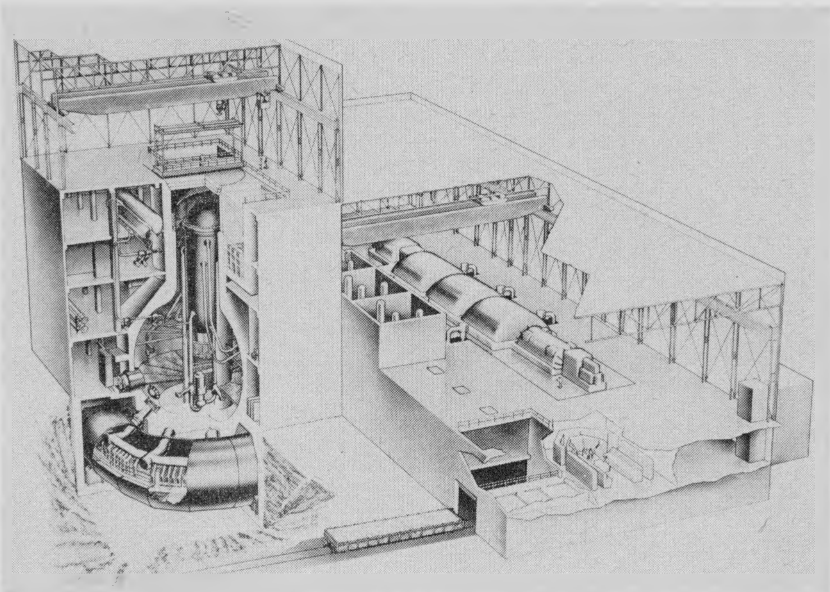
In addition to the projects listed in Table 1, page 114, numerous other utility organizations, through public announcements or in discussions with the AEC, have expressed serious interest in the installation of nuclear power generating units on their systems. Among those whose evaluations have reached an advanced stage are the Florida Power & Light Co. for a second approximately 760,000 ekw unit to be in opera-

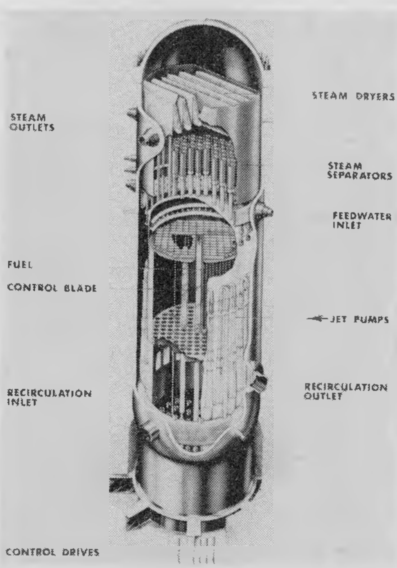
TABLE 1.—CENTRAL STATION-TYPE NUCLEAR POWERPLANTS[1]

Nuclear powerplant	Location	Plant capacity (net ekw)
Operable		
Shippingport Atomic Power Station	Shippingport, Pa	90, 000
Dresden Nuclear Power Station, Unit 1	Morris, Ill	200, 000
Yankee Nuclear Power Station	Rowe, Mass	175, 000
Big Rock Point Nuclear Power Plant	Big Rock Point, Mich	70, 400
Elk River Reactor	Elk River, Minn	22, 000
Indian Point Station	Indian Point, N.Y	270, 000
Carolinas-Virginia Tube Reactor	Parr, S.C	17, 000
Enrico Fermi Atomic Power Plant	Lagoona Beach, Mich	60, 900
Humboldt Bay Power Plant	Eureka, Calif	68, 500
Piqua Nuclear Power Facility	Piqua, Ohio	11, 400
Boiling Nuclear Superheat Reactor (BONUS).	Punta Higuera, Puerto Rico.	16, 500
Pathfinder Atomic Power Plant	Sioux Falls, S. Dak	58, 500
		1, 060, 200
Under Construction		
Peach Bottom Atomic Power Station	Peach Bottom, Pa	40, 000
LaCrosse Boiling Water Reactor	Genoa, Wis	50, 000
San Onofre Nuclear Generating Station	San Clemente, Calif	375, 000
Connecticut Yankee Atomic Power Plant.	Haddam Neck, Conn	462, 000
Oyster Creek Nuclear Power Plant	Toms River, N.J	515, 000
Nine Mile Point Nuclear Station	Scriba, N.Y	500, 000
		1, 942, 000
"N" Reactor (WPPSS power takeoff)	Hanford, Wash	800, 000
		2, 742, 000
Planned		
Malibu Nuclear Plant	Coral Canyon, Calif	462, 000
Colorado High Temperature Gas-Cooled Reactor (PSC-HTGR).	Platteville, Colo	330, 000
Dresden Nuclear Power Station, Unit 2	Morris, Ill	715, 000
Millstone Point Nuclear Plant	Waterford, Conn	549, 000
Boston Edison Plant		600, 000
Brookwood Power Plant	Ontario, N.Y	420, 000
Florida Power & Light	Turkey Point, Fla	652, 000
Indian Point No. 2	Indian Point, N.Y	873, 000
		4, 601, 000
Grand total		8, 403, 200

[1] Condensed from "Nuclear Reactors Built, Being Built, or Planned in the United States" (TID-8200) available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va., 22151, for $0.50. Single copies may be obtained free of charge from the Division of Technical Information Extension, U.S. Atomic Engery Commission, P.O. Box 62, Oak Ridge, Tenn., 37831.

tion by about 1971; Carolina Power & Light Co. for a 650,000 ekw unit to go into operation in 1970; Pacific Gas & Electric Co. for an approximately 750,000 ekw unit to go into operation in 1971 or 1972; Consumers Power Co. for a 600,000 ekw unit for 1970 operation; Central Vermont Public Service Corp. for a 450,000 ekw unit to be ready for full power operation by the early 1970's; Tennessee Valley Authority for a one million ekw nuclear powerplant at Browns Ferry near





Dresden No. 2. Cutaway drawing *above* shows the general layout planned for the second nuclear power unit the General Electric Co. will build for Commonwealth Edison at its Dresden, Ill., site. The 715,000–793,000 ekw plant is scheduled for 1969 operation, and when operated in conjunction with the present Dresden No. 1 nuclear powerplant (200,000 ekw) will be the largest atomic power station in the world. Drawing at *left* shows the major components of the compact—3½ times greater power than Dresden No. 1, but only 20 percent larger in volume—boiling-water reactor planned for the second unit. One of the new features will be the use of jet pumps (heavy arrow, right of drawing) which will reduce the number of primary recirculating loops from five to two. The plant will be built entirely with private funds.

Decatur, Ala.; and New York State Atomic Space and Development Authority for a 2,500 ekw, one-million-gallon-per-day, power and desalting plant which will also be capable of producing high-energy radioactive isotopes.*

Many other utilities have expressed an intent to install nuclear power during the 1970's, but have not yet made final determinations.

Some utilities made thorough comparative evaluations of fossil fuel power versus nuclear power during the year, but decided on fossil fuel units for their next installations. Among these utilities were Public Service Co. of New Hampshire, Duke Power Co. (Charlotte, N.C.), Virginia Electric Power Co., Union Electric Co. (St. Louis, Mo.), Florida Power Corp., and Puerto Rico Water Resources Authority.

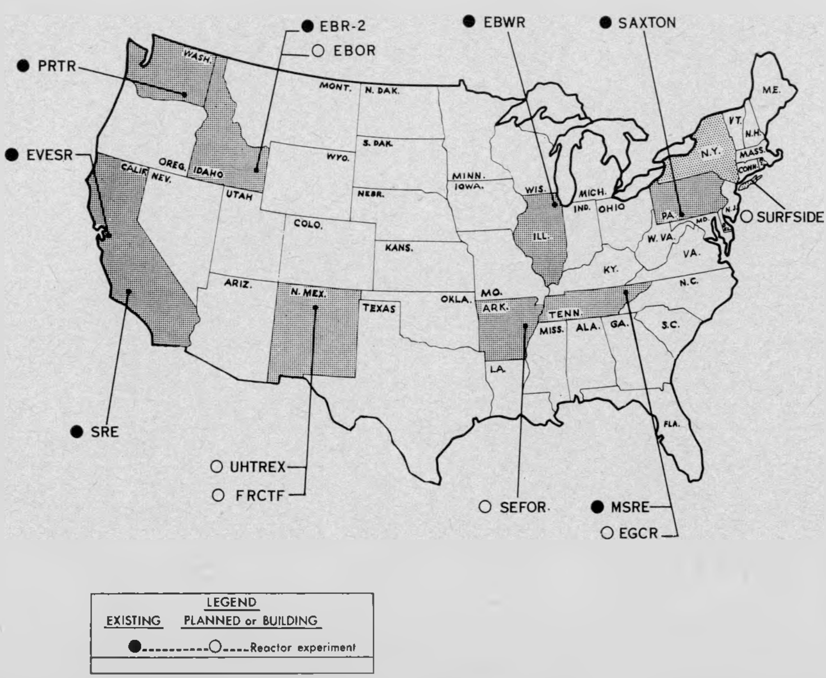
SIGNIFICANT PLANT OPERATIONS

The majority of the 12 operable central station-type nuclear powerplants shown in Table 1 continued to operate routinely throughout 1965. See Part Two, Regulatory Activities, for license actions, surveillance, and significant operating experience and construction status of privately owned nuclear power reactors.

*On January 3, 1966, the Maine Yankee Atomic Power Co. announced its intention to construct a water reactor unit in the 650,000 to 800,000 ekw size range for on-line operation in early 1972.

EXPERIMENTAL CIVILIAN NUCLEAR POWER PROJECTS

AS OF JANUARY 1966



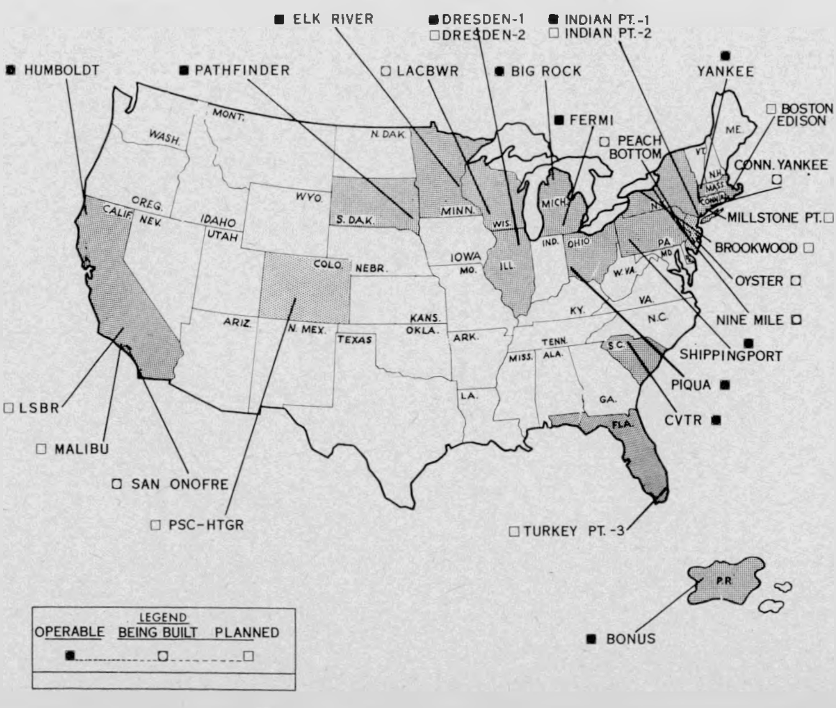
Significant operating experiences of nuclear power reactors owned by the AEC and operated by utility companies under the Power Reactor Demonstration Program (PRDP) are reported in this Part One, as are contractual matters and specific research and development activities on privately owned nuclear reactor powerplants and information on reactors planned or under consideration for which a license application has not yet been filed with the Director of Regulation.

Hallam Nuclear Power Facility

The Hallam Nuclear Power Facility is not listed this year among the presently "operable" plants shown in Table 1. The plant had operated well with only minor technical difficulties until a moderator element problem developed. The purpose of the 17-foot-long, hexagonal-shaped, graphite-filled moderator cans is to "slow down" the neutrons produced by fission and thus increase the probabilty of further fissioning of the uranium. Sodium coolant had leaked into seven of the stainless-steel-clad graphite moderator elements which had cracked during operation, and the reactor was shut down on September 27, 1964.

An examination of the failed moderator cans showed that all but one had failed in about the same area—slightly below the top of the head. The cause of failure was identified as cracking of the stainless

CIVILIAN NUCLEAR POWER PROTOTYPES AS OF JANUARY 1966



steel due to long-time stress rupture of the cladding at operating temperatures.

Because of the technical problems, the AEC in August terminated the contract with Consumers Public Power District (CPPD) of Nebraska under which CPPD had operated the nuclear facility. The failed moderator cans have been disposed of, and the nuclear plant was being maintained in a standby condition at year's end.

Although the AEC is no longer pursuing the sodium-graphite reactor concept, information developed during the design, testing, and operation of the Hallam facility can be applied in improving the reliability and performance of future sodium-cooled reactors.

Shippingport Atomic Power Station

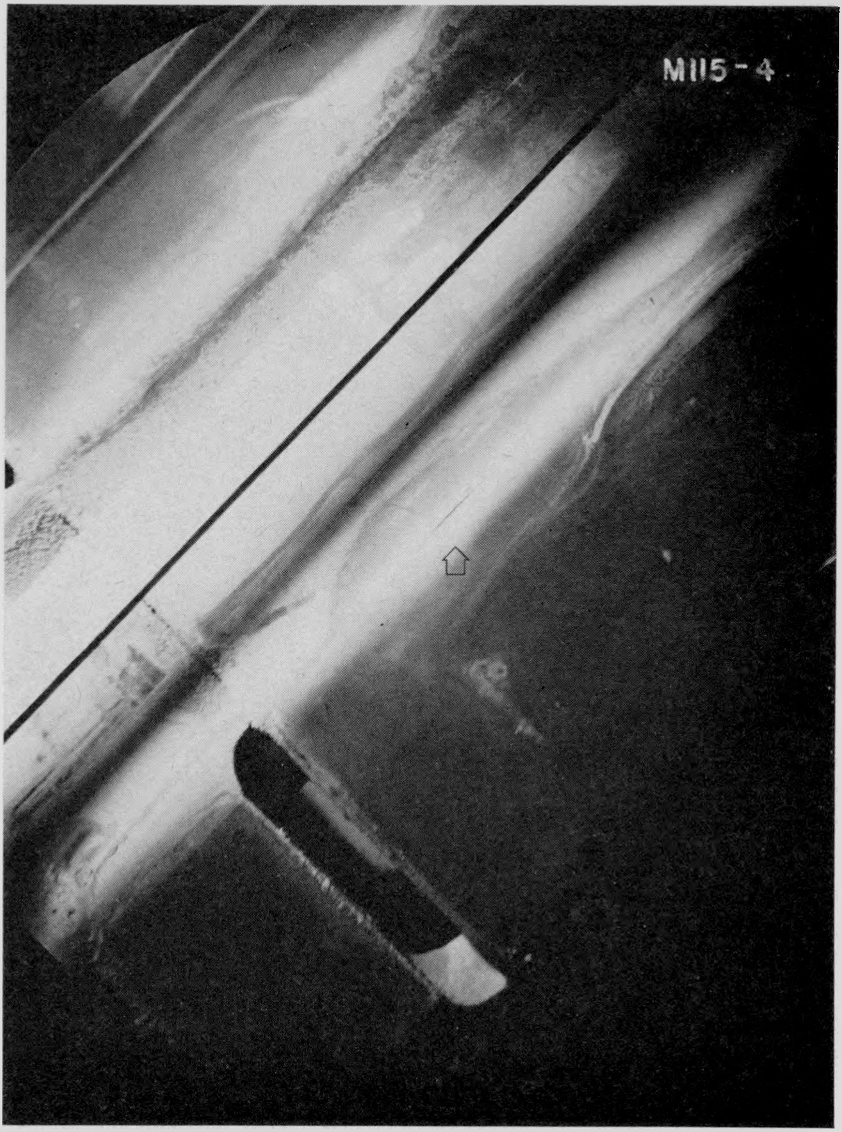
In late April, the Shippingport, Pa., reactor returned to power operation with its second core installed. Operation and testing of the plant up to the maximum reactor rating of 505 thermal megawatts began in early May and continued during the remainder of the year.

Elk River Reactor

On June 4, the Rural Cooperative Power Association (RCPA) assumed control over the operation of the 22,000 net ekw boiling water reactor at Elk River, Minn. The facility, located about 30 miles northwest of the twin cities of Minneapolis-St. Paul, had previously been operated by RCPA personnel under the supervision of Allis-Chalmers Manufacturing Co., builder of the reactor. As of October 31, the reactor had been "on the line" for 61 days without interruption.

Piqua Nuclear Power Facility

In mid-February, the Piqua Nuclear Power Facility (PNPF) in Ohio experienced a sudden loss in power potential. A detailed test program attributed the most probable cause of the loss to an organic-moderator flow restriction which caused local overheating, and possible local boiling, of the moderator in the center region of the fuel elements. Difficulty was also experienced with the control rod drives, due primarily to having an electrical connection submerged in the organic coolant. Minor modifications to the connections were made to resolve this difficulty. The PNPF was operated continually from mid-May through mid-July without any significant difficulties. From July 18 to September 7, the plant was shut down for in-vessel filter replacement and the correction of the electrical feed-through problem mentioned above. The PNPF operated until October 12, when it was



Moderator Can Crack. Photo shows a typical crack (indicated by arrow) of the type found in 19 of the moderator cans of the Hallam, Nebr., sodium-cooled reactor. It was through such cracks in the stainless steel sheaths of the 17-foot-long moderator cans that the molten sodium penetrated and caused the moderating graphite to swell. The contract for operation of the reactor was terminated in mid-1965. The reactor had been shut down in September 1964, when it was believed only seven of the cans had cracks.

shut down for replacement of the six outer control rod fuel elements because of the above-mentioned organic-moderator flow restriction. The reactor went back into operation on October 24, and by the end of November had generated 10,000 megawatt-days of thermal energy. (A megawatt day is the total heat generated in one day at a power level of one megawatt.)

The AEC has determined that the second core for the PNPF will consist of sintered aluminum powder (SAP)-clad uranium carbide fuel assemblies. Inasmuch as this fuel is also the prime fuel candidate for the Heavy Water Organic-Cooled Reactor (HWOCR), its use in Piqua will provide direct technical information in support of the AEC's HWOCR program. Final design of this core, which is expected to significantly reduce fuel cycle costs, is in progress by Atomics International. The detailed design of a catalytic hydrocracker, which reclaims decomposed organic coolant, was initiated in August. By reclaiming the previously unuseable irradiated organic coolant, the hydrocracker could reduce the organic coolant makeup requirements for the Piqua plant by as much as 90 percent, allowing a further improvement in energy cost for organic-cooled reactors. Construction of the hydrocracker is expected to begin in mid-1966.

Boiling Nuclear Superheat Reactor (BONUS)

Conclusions drawn from the examinations made by the Oak Ridge National Laboratory of the BONUS superheater fuel assembly which failed on November 11, 1964, and of an unirradiated spare fuel assembly, are that the superheater fuel difficulties are related to fabrication quality control and inspection procedures, and are not peculiar to the intended application of the fuel.

Several additional defective superheater assemblies were located after the November 11 failure, and the reactor at Punta Higuera, Puerto Rico was shut down while the superheater core was shifted. On February 15, the reactor again achieved criticality, and operational testing proceeded satisfactorily with a 24-superheater-assembly core instead of the 32-assembly-core for which the reactor was designed.

In mid-June, cracks were detected in the stainless steel inlet and outlet steam piping to the steam preheaters-dryers. These units are part of the reactor pressure vessel internals and assure that only dry steam enters the superheater fuel assemblies. This difficulty was corrected, the superheater zone fuel loading was increased to 32 assemblies, and the test program was resumed in August. Operation of the full BONUS core at 50 thermal megawatts was achieved on September 15, and by September 21 an electrical output of 16,500 ekw was reached. Design output of the BONUS plant turbogenerator—17,500 ekw—was achieved on November 9. Plans call for operating the reactor continuously at this power for the next six months.

Pathfinder Atomic Powerplant

A contract was signed in mid-January by Northern States Power Co. and Allis-Chalmers Manufacturing Co. covering the design, testing, and fabrication of a second, advanced core for the Pathfinder superheat reactor at Sioux Falls, S. Dak. In the new core, which is scheduled for delivery in late 1966, both the superheater and boiler fuel elements will be made of low-enriched uranium oxide. The present core consists of low-enriched boiler fuel elements, but full-enriched superheater elements. The new-type core, in addition to being less expensive, will allow the reactor outlet temperature to be increased from 725 to 825° F., thus enabling the plant to generate more electricity than it does with the present core.

NUCLEAR POWERPLANTS UNDER CONSTRUCTION

LaCrosse Boiling Water Reactor

Construction of the 50,000 net ekw Dairyland Power Cooperative nuclear powerplant near Genoa, Wis., was delayed in 1965 by the late delivery of several critical components. Consequently, completion of the LaCrosse Boiling Water Reactor project by Allis-Chalmers Manufacturing Co.—originally scheduled for June 28, 1966—is now expected to be delayed until late 1966 or early 1967.

NUCLEAR POWERPLANTS PLANNED

Large Seed-Blanket Reactor

On January 1, 1965, a Memorandum of Understanding was executed by the AEC and the Department of Water Resources, State of California, which provided for a cooperative arrangement leading to the design, development, and construction of a nuclear central station plant with a capacity of about 525,000 net ekw. Public Law 89–32 authorized the Large Seed-Blanket Reactor (LSBR) project and authorized appropriation of $91.5 million for the AEC's portion of the project cost. In April 1965, before the LSBR project was authorized, the AEC notified the Congress and the State of California that research and development work had identified technical problems which indicated that the design of the LSBR fuel elements might not be adequate for the long life (about nine years between refuelings) planned for the LSBR initial nuclear core which was to be provided by the AEC. Late in December 1965, the AEC announced that it had notified the State of California of its decision not to contract for construction of the planned LSBR nuclear central station because of technical problems encountered in the LSBR research and development program. The AEC plans to reorient the seed-blanket development work to a research and development program directed toward the thermal breeder type design. The objective would be to develop technology in the areas of fuel elements, nuclear physics, and reactor engineering necessary to explore the feasibility of a subsequent demonstration of the breeding potential of the seed-blanket concept in an operating reactor.

Colorado High Temperature Gas-Cooled Reactor

On November 1, the AEC signed a definitive contract with the Public Service Co. of (Denver) Colorado and the General Atomic Division (GA) of General Dynamics Corp., San Diego, Calif. Under its terms, the utility firm is to provide a plant site for, and fund the construction of and own, a 330,000 ekw high temperature gas-cooled reactor (HTGR) prototype powerplant to be ready for operation on the Colorado system no later than March 1972. General Atomic will perform certain required research and development and will design and construct the plant on a 1,600-acre site about 35 miles north of Denver near Platteville, Colo. The AEC, under ceiling cost arrangements, will partially finance the design of the plant, a research and development program, the fabrication of certain specialized first-of-a-kind equipment and the first core, and will waive fuel use charges. The AEC is contributing to the plant because this advanced converter-type reactor is expected to result in more efficient use of fuel, has the potential for economic power production, and will contribute to the development of fast gas breeder reactor technology.

The Colorado-GA proposal was submitted to the AEC after the February 12 announcement by GA and the Rochester Gas & Electric Corp., that they had terminated negotiations on a contract to build a 260,000 ekw HTGR nuclear powerplant on the Rochester, N.Y., system. The termination was caused by the inability of the reactor manufacturer and the utility company to agree on contract terms; the basic concept of the HTGR was not an issue in the termination of negotiations.

Boston Edison Plant

The Boston Edison Co. announced on August 7 that it had awarded a contract to the General Electric Co. to build a boiling water nuclear generating plant of about 600,000 ekw capacity. The utility expects the plant to be in service by mid-1971. At the time of the announcement, a final decision had not been made on the location of the plant. Boston Edison is part owner of the Yankee plant at Rowe, Mass., and the Connecticut Yankee plant under construction at Haddam Neck, Conn.

Florida Power & Light

In mid-November, the Florida Power & Light Co. publicized its award of a contract to Westinghouse Electric Corp. to supply the nuclear reactor and related equipment for a 652,000 net ekw pressurized water reactor nuclear generating plant at Turkey Point, 25 miles south of Miami on Biscayne Bay, Fla. The utility is scheduling its first nuclear plant for construction completion in early 1970.

OTHER CIVILIAN POWER PROGRAM ACTIVITIES

HEAVY WATER POWER REACTOR PROGRAM

On January 8, Combustion Engineering, Inc. (acting through its Nuclear Division at Windsor, Conn.) and North American Aviation, Inc. (acting through its Atomics International Division at Canoga Park, Calif.), signed prime contracts to conduct a heavy water-moderated, organic-cooled reactor (HWOCR) research and development program for the AEC. Subsequently, a single prime contract with the two companies, replacing the two contracts, was negotiated and was expected to be signed in early 1966.

The President of Atomic Energy of Canada Limited (AECL) and the Chairman of the U.S. Atomic Energy Commission signed an agreement on February 24 permitting the AEC to use the U–3 organic-cooled loop in the NRU (natural uranium heavy water moderated) test reactor at AECL's Chalk River Nuclear Laboratory in Ontario and part of the Whiteshell Reactor-1 (WR–1), a heavy water-moderated, organic-cooled test reactor at AECL's Whiteshell Nuclear Research Establishment at Pinawa, Manitoba, for development of the HWOCR concept. The Canadian facilities made available under the terms of this agreement will be used in direct support of the work being performed by the Atomic International-Combustion Engineering (AI–CE) joint venture organization.

HWOCR Development

During 1965, the major development effort in the Heavy Water Organic-Cooled Reactor (HWOCR) program was directed toward the preparation of a conceptual HWOCR design for a 1,000,000 ekw powerplant, and to the initial design, fabrication, and testing of fuel.

The design engineering effort included all aspects of the plant, but emphasized the most critical components and novel features of the concept which are to be demonstrated in a 300,000 to 500,000 ekw prototype.

The significant effort in the fuel development area was the fabrication of sintered aluminum powder (SAP)-clad uranium carbide and zirconium-clad uranium dioxide fuel assemblies for test irradiation in the U–3 loop in the NRU reactor at Chalk River, Ontario. Irradiation of these test assemblies began on July 28, 6½ months after the HWOCR program was initiated. Further efforts have been directed toward designing and fabricating the fuel assemblies to be irradiated in the WR–1 reactor in Manitoba in 1966.

Lower cost processes are being developed for fabricating uranium carbide fuel elements for the HWOCR. A program was initiated at the Oak Ridge National Laboratory, in support of AI–CE effort, to develop a method for producing reproducible SAP for use as both fuel cladding and pressure tubes. Zirconium alloys are also being considered for the same application, but their use is predicated upon a successful solution of the severe hydriding problem in an organic environment. Work includes both fuel element fabrication and out-of-pile and in-pile testing of the material. Out-of-pile loops which will accommodate the testing of both pressure tubes and fuel elements have been designed and are either operating or under construction.

Associated Work

The continued operation of the Piqua Nuclear Power Facility in Ohio is providing information to the HWOCR program on coolant purity control and on coolant and component performance. The data output will increase with the fabrication and operation of Piqua's second core consisting of SAP-clad uranium carbide fuel assemblies. A hydrocracker, which will reduce the organic makeup requirements for the Piqua plant and provide technology needed for the HWOCR program, is being designed (Phillips Petroleum, Bartlesville, Okla., is the principal contractor) and should be in operation by early 1967.

A HWOCR thorium fuel cycle development program is being carried out by the Babcock & Wilcox Co. The results of this development are expected to show the potential of operating an HWOCR as a thorium thermal breeder reactor. This effort is closely coupled with the thorium utilization work in progress at ORNL. The Savannah River Laboratory and Brookhaven National Laboratory assist by performing physics experiments relative to the thorium-heavy water system.

Desalting Potential

All the above work is being done as the result of the Commission's July 1964 action to redirect its heavy water-moderated reactor concept toward the use of an organic coolant. The HWOCR concept has potential not only for very large central station powerplants, but also is a leading candidate for application to large-scale water desalting operations. The development plan for the HWOCR concept initially includes the construction and operation in the early 1970's of a 300,000 to 500,000 ekw HWOCR power-only prototype. Successful development and operation of this prototype plant would then be expected to lead to the construction by the power industry, in the mid- or late-1970's, of successively larger combined electric power-water desalting plants with heat outputs ranging from 3,500 to 10,000 megawatts.

GAS-COOLED REACTOR PROGRAM

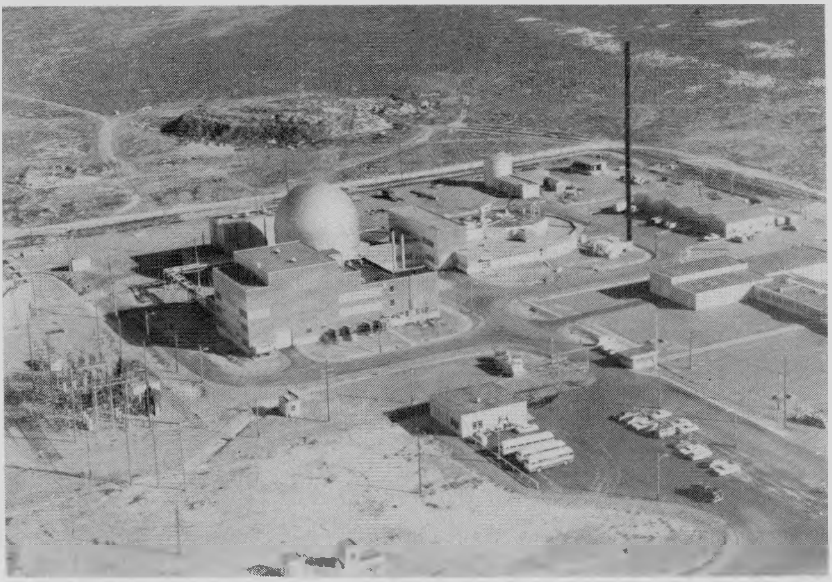
Experimental Gas-Cooled Reactor (EGCR)

Construction of the 21,900 ekw Experimental Gas-Cooled Reactor (EGCR) at Oak Ridge, Tenn., was essentially complete by the end of 1965—about three years behind schedule. On January 7, 1966, the AEC announced it was terminating the project. Factors cited as contributing to this decision were: (*a*) continuing design and engineering difficulties with corresponding delays and rising costs; (*b*) the diminishing potential of timely and significant contributions of the EGCR project to commercial development of high-temperature gas-cooled reactor technology in light of current industrial trends; and (*c*) competing demands for limited funds.

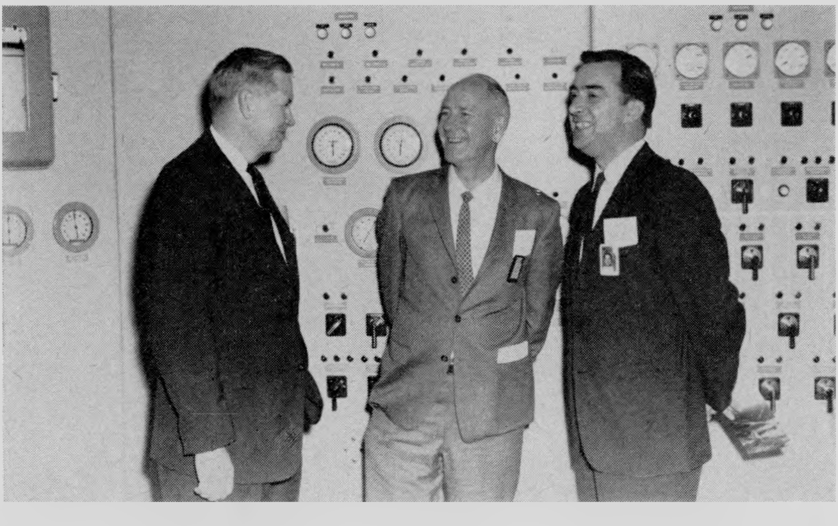
BREEDER REACTOR PROGRAM

Experimental Breeder Reactor No. 2

The control and oscillator rod malfunction which the Experimental Breeder Reactor No. 2 (EBR–2) experienced late in 1964 was corrected in March 1965, and the plant resumed power operation. The



EBR–2 Dedicated. The dome-shaped containment shell (photo *above*) houses the Experimental Breeder Reactor No. 2 which was dedicated September 13, 1965 at the Atomic Energy Commission's National Reactor Testing Station in Idaho. A unique feature of EBR–2 is its integrated Fuel Cycle Facility (circular-ended building to right of dome) where spent fuel from the reactor is melt-processed and refabricated into new fuel pins using slave manipulators and other remotely operated equipment behind concrete and lead glass shielding. In photo *below*, AEC Commissioner Gerald F. Tape (*left*) chats with Dr. George W. Beadle, President of the University of Chicago, and Dr. Albert V. Crewe, Director of Argonne National Laboratory, in one of the EBR–2 control rooms. Dr. Tape was the principal speaker at the dedication.



reactor, located at the National Reactor Testing Station, Idaho, has subsequently been operated routinely at power levels up to 45 thermal megawatts and has generated approximately 14,000 kilowatts of electrical power.

The first recycled fuel subassembly to contain EBR–2-irradiated fuel processed and fabricated in the reactor's adjacent integrated Fuel Cycle Facility was inserted into the reactor early in May, and the first recycled fuel with the initial design-level burnup of one percent was returned to the reactor early in September. The evaluation of fuel performance is being continued by the periodic removal of fuel assemblies for examination at increasing burnup increments.

The initial fuel loading has been safely taken to about one and one-quarter percent burnup (approximately 12,000 megawatt days per ton). This level, which surpasses initial design expectations by 25 percent, has been tentatively established as the burnup level for the Mark I fuel.

Southwest Experimental Fast Oxide Reactor

Construction of the Southwest Experimental Fast Oxide Reactor (SEFOR) was started late in 1965 on a 620-acre site at Cove Creek, about 20 miles southwest of Fayetteville, Ark., and is scheduled to be completed in early 1968. When this 20-thermal-megawatt sodium-cooled reactor facility becomes operational, it will be operated in the conduct of a planned international research and development program aimed at studying the nuclear characteristics—particularly the Doppler effect—of a fast breeder reactor system which uses mixed plutonium oxide-uranium oxide fuel and sodium coolant.

The reactor is being constructed by General Electric for the Southwest Atomic Energy Associates (SAEA), Little Rock, Ark., a group of 17 private power utilities from the Southwest and Midwest. SAEA is associated in the construction of SEFOR with Gesellschaft für Kernforschung, a nonprofit corporation of the Federal Republic of Germany, which will make contributions to the project for itself and for the European Atomic Energy Community (Euratom).

AEC support for the SEFOR project includes reimbursing General Electric, up to a specified ceiling, for research and development needed in support of the reactor design, for operating and maintaining the reactor following completion of its construction, and for performing specified experimental tasks in the reactor that constitute AEC's research objectives. In addition, the AEC is providing, without charge, certain of its facilities, equipment, and materials for use in the supporting research and development program.

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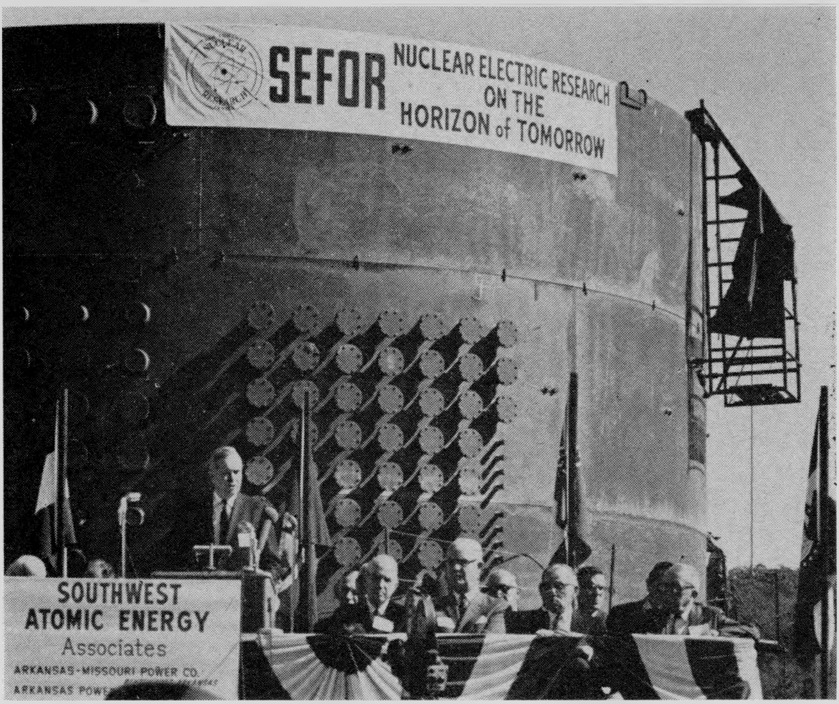

SEFOR Dedication. Construction of the internationally-sponsored SEFOR (Southwest Experimental Fast Oxide Reactor) near Fayetteville, Ark., got underway during 1965. Photo shows AEC Commissioner Gerald F. Tape speaking at the October 27 dedication of the sodium-cooled reactor facility. The project is being jointly supported by the Southwest Atomic Energy Associates—17 private power utilities of the Southwest and Midwest; the West German Government; the European Atomic Energy Community (Euratom); and the AEC. The General Electric Co.-built sodium-cooled reactor, which is scheduled for 1968 completion, will be used for studying the nuclear characteristics of fast breeder reactor systems using mixed plutonium oxide-uranium oxide fuel. No electric power will be produced by the facility.

Fast Flux Test Facility

During the year, the AEC completed an intensive review and evaluation of the facilities it will need in order to develop and test the fuels and materials required for its fast breeder reactor program. As a consequence of this review, the Commission determined late in 1965 that the Fast Reactor Test Facility (FARET) which it had proposed for construction at the National Reactor Testing Station did not have the required testing capability. FARET was consequently terminated prior to the start of construction, and the AEC is proceeding with the design of a Fast Flux Test Facility (FFTF) which will provide the needed capability.

The first phase of conceptual design study for the Fast Flux Test Facility was completed in 1965 by Pacific Northwest Laboratory, with supporting assistance from Argonne National Laboratory, Atomic Power Development Associates, Atomics International, Bechtel Corp., Nuclear Technology Corp., Vitro Engineering Co., and Battelle Memorial Institute of Columbus, Ohio. The interim conceptual design study report described the parameters of the test reactor plant and defined the areas requiring research and development. This report is currently being reviewed by AEC laboratories and industrial contractors. Conceptual design effort will continue, leading to a final design of a facility which will have adequate capability with respect to such factors as fast neutron intensity, space for test specimens, and ability to completely control the test environment in closed loops.

NUCLEAR DESALTING APPLICATIONS

During the year, the AEC accelerated its program—conducted in coordination with the Office of Saline Water, U.S. Department of the Interior—to develop and demonstrate suitable nuclear energy sources for intermediate and large-scale desalting of seawater by: (*a*) designating the Oak Ridge National Laboratory as the primary technical support organization to the AEC in its desalting program; (*b*) completing specific studies of large nuclear power-desalting plants for the Metropolitan Water District (MWD) of Southern California and the Government of Israel; (*c*) participating in a Government task force investigation of the applicability of desalting to the water requirements of the New York-New Jersey metropolitan area; and (*d*) initiating a cooperative study with Mexico of a large nuclear power-desalting plant.

The AEC's desalting program has two major areas of endeavor: the first is to provide appropriate nuclear reactor energy sources to meet desalting needs during the next 5 to 15 years; the other is a longer-term endeavor to provide, by the mid-1970's, demonstrated engineering and economic data for those reactor systems that could be considered as economic energy sources for water desalting in size ranges appropriate for intermediate and large-scale water supply applications beyond 1980.

Specific Application Studies

Metropolitan Water District. The MWD study was performed by the Bechtel Corp. under the joint sponsorship of Interior, the AEC, and the MWD. A preliminary report on the initial phases of the study, submitted by Bechtel in June, indicated that a two-unit nuclear powerplant producing 1,800,000 gross electrical kilowatts (ekw), coupled with a 150 million gallons per day (mgd) water desalting plant, could produce fresh water at about 26 cents per 1,000 gallons delivered to the MWD system. In the final phase of the study, more refined design effort was applied to this plant, and two sites—one a man-made island about 4,000 feet offshore and the other an onshore site—were investigated. The final report of the MWD study [1] indicated that the island site is a practicable location for the plant and is economically preferable to the onshore site. It further indicated that the plant could be operational five years after construction was authorized.

New York-New Jersey. Federal officials met with the Governor of New Jersey and the Deputy Mayor of New York City in August to consider the potential use of large nuclear desalting facilities to help "drought proof" the northeastern metropolitan area in the event of prolonged periods of below average rainfall. As a result of this meeting, a Federal task force was appointed to conduct a preliminary assessment. The task force includes representatives from the Department of the Interior, the Federal Power Commission, the Office of Science and Technology, Council of Economic Advisors, and the AEC. This group, working closely with the State and local officials, and representatives of the water and power utilities serving the area, issued an interim report in November. The interim report indicated that: (*a*) desalting is sufficiently promising to warrant further consideration along with other alternative sources of water; (*b*) large power-desalting plants may provide economical insurance against prolonged drought; (*c*) large nuclear powerplants are the preferred source of new power generation by the electrical utilities participating in the study; (*d*) sites suitable for large nuclear desalting plants are deemed available within the prime load area; (*e*) the electric power produced from the large power-desalting facilities being studied could be beneficially utilized within the New York-New Jersey area; and (*f*) continuing analysis leading toward a detailed engineering feasibility study is warranted. A final report on the task force investigation is expected in February 1966.

Israel. Under the auspices of the Governments of the United States and Israel, a detailed engineering feasibility and economic study was undertaken by Kaiser Industries Inc., Oakland, Calif., with Catalytic Construction Co., Philadelphia, Pa., as subcontractor. This study is

[1] TID-22330, Vols. 1, 2, and 3, will be available in January from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va., 22151; Vol. 1 (Phases 1 and 2) at $4.00; Vol. 2 (Phase 3) at $4.00, and Vol. 3 (Summary) at $1.25.

investigating dual-purpose plants with capacities in the range of 85 to 130 mgd of water and 175,000 to 200,000 electrical kilowatts. A preliminary report on the first phase of the study, submitted in July, recommended that a nuclear plant capable of producing 200,000 net ekw and 100 mgd of desalted water be further investigated in the second phase of the study.

In the second phase of the study, the design of this selected plant was refined, and detailed time schedules and estimates of cost were prepared. Final estimates of the cost of producing water in the plant were 26, 40, and 62 cents per thousand gallons for fixed-charge rates of 5, 7, and 10 percent, respectively, at a fixed value for the saleable electric power of 5.3 mills per kilowatt-hour. The final report was submitted to the Governments of the United States and Israel in December.

Mexico. A technical and economic feasibility study was initiated by the Governments of the United States and Mexico, under the auspices of the International Atomic Energy Agency, of large nuclear power-desalting facilities which could provide power and water to portions of Arizona and California in the United States, and to the states of Sonora and Baja California in Mexico.

GENERAL TECHNICAL PROGRAM

The Oak Ridge National Laboratory has been designated as the primary technical support organization to the AEC in the conduct of its general technical evaluations of the application of nuclear reactors to desalting. General analyses and evaluations were initiated in 1965 to: (*a*) determine the best method of coupling desalting plant systems with nuclear powerplant systems; (*b*) investigate the siting problems of large nuclear dual-purpose installations; (*c*) determine if other process operations could be conducted advantageously in conjunction with large nuclear desalting plants; (*d*) survey reactor concepts producing little or no byproduct electric power to determine their technical feasibility and economic potential for water-only applications; and (*e*) investigate the technical and economic potential of scaling-up to large sizes and combining with desalting plants the reactor concepts being developed under the civilian power program.

Deep Pool-Reactor Study

A preliminary study of a deep-pool reactor for a water-desalting-only application was completed during the year. This investigation, which was initiated on January 6 by the Bechtel Corp., San Francisco, under contract to the AEC, was directed toward refining an AEC-originated (Chicago Operations Office) reactor concept that includes a low capital cost reactor system which uses 270° F. reactor water coolant to heat sea-water. The final report[2] on this study, completed in June, indicated that at reactor sizes appropriate to 10, 50, and 200 million-gallon-per-day (mgd) water plants, energy could be delivered to the water plant at 80, 32 and 24 cents per million Btu, respectively.

New York "SURFSIDE" Proposal

On September 3, the AEC received a proposal from the New York State Atomic and Space Development Authority for AEC participation in project "SURFSIDE" (Small Unified Reactor Facility

Desalting Work Agreement Signing. On April 2, the AEC and the Department of Interior signed an interagency agreement to conduct research, development, and engineering services on water desalting under the general direction of the AEC's Oak Ridge National Laboratory (ORNL). Present at the signing were (*left to right*): S. R. Sapirie, Manager of the AEC's Oak Ridge Operations; AEC Commissioner James T. Ramey; Frank C. Diluzio, Director of the Interior Department's Office of Saline Water; and (behind Commissioner Ramey) R. P. Hammond, Director of ORNL's Nuclear Desalination Program.

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[2] "Deep-Pool Reactor for Water Desalting," available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va., 22151, for $5.

Systems for Isotopes, Desalting, and Electricity). The proposed plant would be located in the town of Riverhead on eastern Long Island, and would produce one million gallons per day of fresh water, 2,500 kilowatts of saleable electricity, and the equivalent of 400,000 curies of radioactive cobalt per year.

Puerto Rico Discussion

U.S. representatives met with the Puerto Rico Water Resources Authority in June to discuss the applicability of desalting to the water needs of southern Puerto Rico. It was mutually agreed that an effective evaluation could not be made until more information on alternative natural water resources was developed.

CIVILIAN NUCLEAR MARITIME PROGRAM

NS Savannah

The world's first nuclear-powered merchant ship, the NS *Savannah*, went into the regular commercial service of American Export-Isbrandtsen Lines (AEIL) in August. Under the terms of a charter pact with the Government, First Atomic Ship Transport Inc. (FAST) of New York City—a wholly owned subsidiary of AEIL—is to operate the *Savannah* for a period of three years as a cargo vessel only; the 60-passenger accommodations have been sealed off and large-scale public visits have been discontinued.

Prior to becoming a commercial freighter, the *Savannah* made trips in 1965 to San Juan, P.R.; Piraeus, Greece; New York-Hoboken; Port Everglades-Miami; and Mobile, Ala., before docking at her maintenance base in Galveston, Tex., on March 10 for annual inspection and overhaul.

In the two years of demonstration voyages conducted under special arrangements between the Government and the AEIL, the atom-powered ship had "opened" 43 foreign and domestic ports to nuclear merchant ships; had been inspected by one million Americans and one-half million foreigners during her "open house" periods; and had traveled more than 90,000 miles under nuclear power—the equivalent of nearly 3½ times around the world. The *Savannah* had consumed only 33 pounds of enriched uranium fuel—which, because of its density, is about as much as could be put into a man's hat—as compared to more than 17,000 tons of fossil fuel which a conventionally-powered ship, traveling the same distance, would have required.

Advanced Maritime Reactors

The AEC has proposed a five-year nuclear merchant ship research and development program with the objective of developing nuclear-propelled ships that, together with improved cargo handling and other nonnuclear innovations, can make possible the superior service necessary to make and keep the U.S. Merchant Marine economically competitive. The program involves a dual approach, one of which entails the construction of an AEC-owned land-based facility for the development and testing of improved components and systems for compact pressurized water reactors, and for the performance of research and development on water and advanced reactor concepts having potential for maritime applications.

The other program approach recognizes the need for shipboard demonstration of civilian nuclear propulsion systems, and to that end the AEC proposes to cooperate with industry in developing the most promising nuclear propulsion plant concepts, at appropriate stages, and in building and operating nuclear propulsion plants in civilian maritime ships.

In mid-October, an AEC-Maritime Administration liaison committee, comprised of four senior staff members from each agency, was established to assure continued coordination between the two agencies in the development of economic nuclear merchant ships. This committee will review all proposed nuclear maritime programs and assure that each agency is kept informed of the other agency's plans for reactor development and nuclear ship construction and operation, including problems, studies, requirements, and progress.

The United Nuclear, General Electric, and Babcock & Wilcox companies, which in 1964 submitted proposals for the construction of land-based prototype maritime nuclear propulsion plants, have been advised that they may submit new bids in line with the newly proposed program, when appropriate.

SUPPORTING REACTOR ENGINEERING TECHNOLOGY

During 1965, a vigorous advanced research and development program was maintained for measuring neutron behavior in reactors and for measuring properties of high-temperature reactor coolants. Major advances in gas-lubricated bearing technology were demonstrated with the first known self-sustained operation of a gas turbine-compressor set operating on self-acting hydrodynamic gas-lubricated bearings. Two-phase flow heat transfer, fluid dynamics, and stability experiments resulted in an improved understanding of the thermal and hydraulic effects in boiling reactors. Heat transfer properties of high-temperature gases and liquid and vapor alkali metal coolants were measured and their behavior in practical energy transfer systems investigated. Development work continued on components and systems configurations for new and improved remotely-operated machines that operate in unique environments. (Additional details concerning the broadly-based programs being conducted in support of the Commission's Civilian Nuclear Power Program will be found in the publications "Fundamental Nuclear Energy Research—1965,"[3] and "Nuclear Fuels and Materials Development."[4]

Plutonium Utilization Program

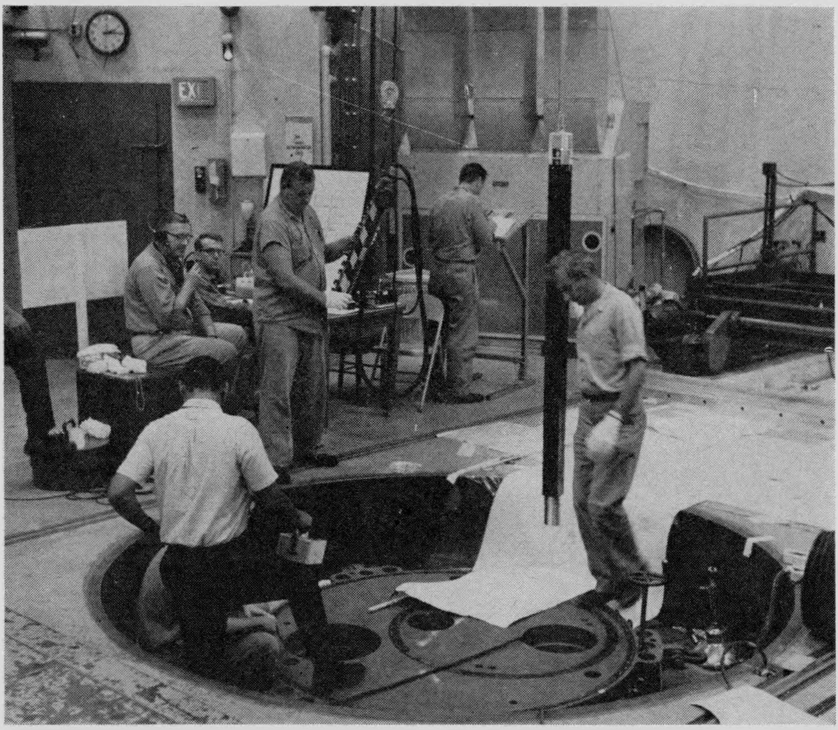
EBWR fuel experiments. A plutonium fuel irradiation demonstration program, using the Experimental Boiling Water Reactor (EBWR) at Argonne, Ill., is being conducted jointly by Argonne National Laboratory and Pacific Northwest Laboratory. The experiment will provide data on the nuclear characteristics of a boiling light water reactor partially fueled with plutonium, and the behavior of the fuel in such an environment. The core will have a central zone of 36 elements containing about 1,300 zircaloy-clad rods of plutonium-enriched fuel, an intermediate zone of 60 slightly enriched uranium oxide (UO_2) fuel elements to maintain system reactivity, and an outer zone of natural UO_2. The plutonium fuel is 1.5 percent plutonium oxide (PuO_2) in depleted UO_2 and was fabricated by the Pacific Northwest Laboratory. Initial criticality with the plutonium assemblies in the EBWR was attained on September 22. Since the main purpose of the experiment is to generate physics information, the reactor will be shut down periodically to conduct appropriate experiments to determine changes in characteristics with exposure.

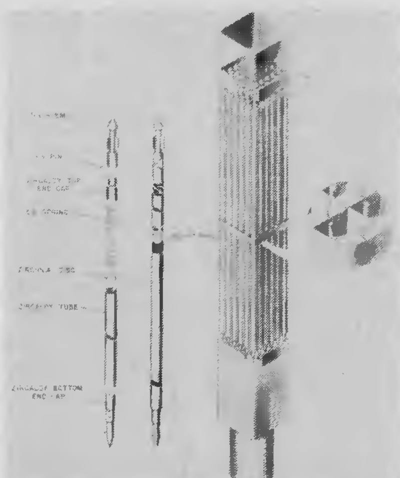
PRTR conversion. Design and development work, started late in 1964, to convert the Plutonium Recycle Test Reactor (PRTR) at the Hanford, Wash., plant to operation with a higher power density core continued in 1965. The purpose of this effort is to shorten the period of time required to achieve significant irradiation exposure of plutonium-enriched fuel and to duplicate more nearly the conditions of fuel temperature and heat flux to be encountered in power reactor cores. The basic core loading for the high power density experiment, which is to begin early in 1966, will be 55 fuel elements similar to the present

[3] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, for $2.25.

[4] TID–11295 (4th ed.) June 1965. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va., 22151, for $7.

19 rod clusters, but with the plutonium enrichment increased from the previous maximum of one to two percent plutonium oxide in natural uranium oxide and the fuel length of the elements decreased from 88 inches to 58 inches. The total power generation from these





Pioneer Reactor's New Role. A plutonium fuel irradiation demonstration program, using the old Experimental Boiling Water Reactor (EBWR) at Argonne National Laboratory, is being conducted jointly by Argonne and the Pacific Northwest Laboratories. The experiment will provide data on the nuclear characteristics of a boiling light water reactor partially fueled with plutonium, and the behavior of the fuel in such an environment. The core has a central zone of 36 elements, one of which is shown being loaded into the reactor in the *above* photo. Drawing at *right* shows the components of the plutonium fuel elements being used in the experiment. The EBWR began operating in late 1956 and was a pioneer in the development of boiling water reactor technology.

elements will be about the same as for the previous 85-element core; however, the total reactor power may be increased from 70 to over 100 thermal megawatts with various experimental fuel elements occupying the 17 positions surrounding the basic core.

During 1965, major efforts were directed toward the necessary development work required to assure the successful operation of the high power density (HPD) core, and toward fabrication of the fuel assemblies. Several prototype assemblies were irradiated in the PRTR "rupture loop" to check the adequacy of the fuel design. During one of these test irradiations on September 29, the in-reactor process tube of the rupture loop in the PRTR failed after having operated routinely for four days, and the reactor was shut down. There was no environmental contamination as a result of the incident, but the heavy water moderator was diluted and contaminated by the light water coolant which was released as a result of the tube rupture. Detailed plans were prepared for the removal of the ruptured tube and fuel element, but at year's end the reactor remained shut down as cleanup of the various systems continued.

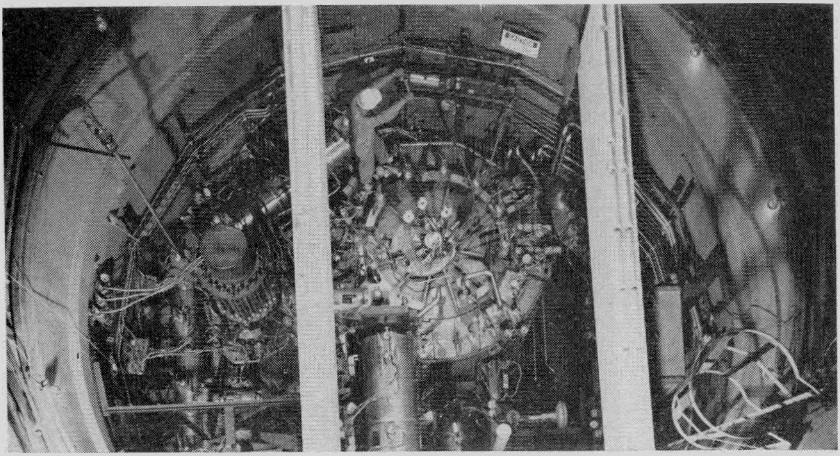
Thorium Utilization Program

Construction of the Thorium-Uranium Fuel Cycle Development Facility (TUFCDF) started during June at the Oak Ridge National Laboratory and was about 31 percent complete by December. On May 6, Blount Brothers Corp., Montgomery, Ala., was awarded a contract to build the facility, which is expected to be completed in mid-1967. The facility will be used to demonstrate remote operation of the entire thorium fuel cycle for a variety of fuel types which will have been subjected to varying degrees of irradiation. It will incorporate improvements in fuel preparation and fuel element fabrication derived from the ORNL Kilorod [5] program experience and from the Cold Microsphere Development Facility which is currently being equipped and tested at ORNL.

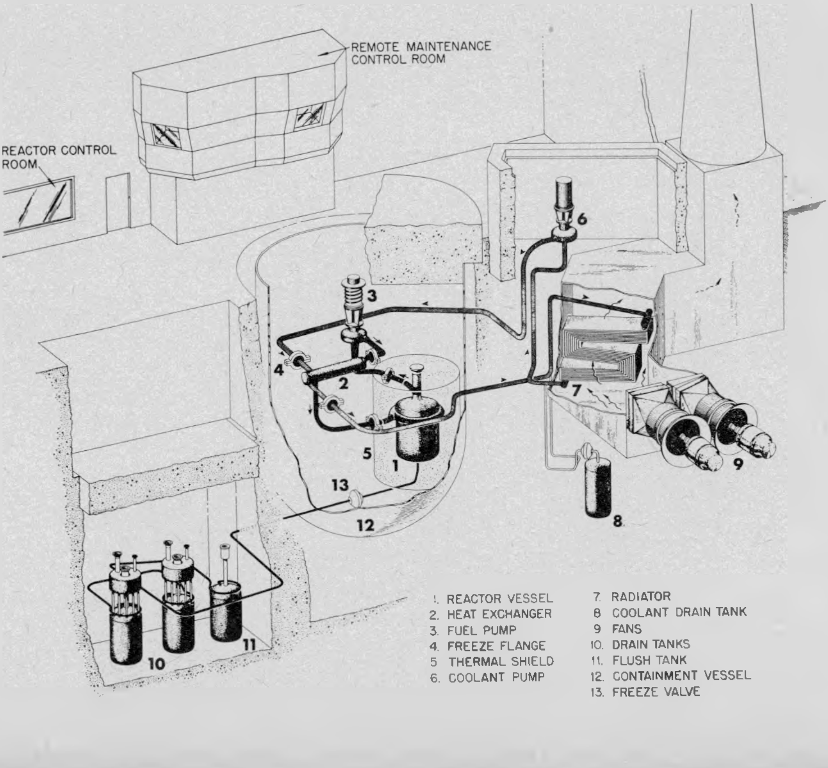
Molten Salt Reactor Experiment

On June 1, the Molten Salt Reactor Experiment (MSRE), which had been under construction for 4 years at the Oak Ridge National Laboratory, achieved initial criticality. A three-month period of nonnuclear testing had preceded this milestone, and the final approach to a self-sustaining chain reaction was smooth and uneventful. During the remainder of the year, the reactor power was gradually increased. Plans call for operating the reactor at the full 10-thermal-megawatt design power during most of 1966.

[5] See pp. 132–133, "Annual Report to Congress for 1964."



First of its kind. The AEC's Molten Salt Reactor Experiment (MSRE) at Oak Ridge National Laboratory became operational on June 1. The MSRE uses as fuel a molten salt solution of fluorides of lithium 7, beryllium, zirconium, and uranium. This first-of-its-kind reactor will be used to demonstrate that the molten salt reactor concept offers a number of advantages over water reactors for large central-station powerplants—such as high temperature and high specific power operation with a low system pressure of 50 pounds per square inch. Use of the thorium-uranium fuel cycle also offers a breeding potential. In the above preoperational photo, the pressure vessel (*top, center*) of the MSRE is shown within its 24-foot-diameter containment cell. Drawing *below* shows the major components of the experiment.



The experimental reactor, which uses a circulating molten salt solution of fluorides of lithium 7, beryllium, zirconium, and uranium as fuel, is one of the advanced converter power reactor concepts which has potential advantages for the production of electric power in large central-station powerplants. The MSRE concept offers potential advantages, when compared with water reactors, of operation at high temperature and high specific power with low system pressure of 50 pounds per square inch, and of breeding by using the thorium-uranium fuel cycle. Also, since its fuel is molten, fuel elements as such are eliminated and fuel processing is somewhat simplified.

During the next two years, main emphasis will be placed on operating the MSRE for periods of approximately six months—each followed by shutdown for maintenance, inspection, and experimental changes—to obtain the data and experience necessary to demonstrate the technical feasibility of the molten salt reactor concept.

Chapter 8

NUCLEAR SPACE APPLICATIONS

Progress continued to be made toward the use of nuclear energy in the Nation's space effort. The year 1965 was marked by the successful launch and operation of the first atomic reactor in space, and the completion of a series of successful ground tests on Rover rocket reactors.

On June 21, 1965, the AEC reorganized its space-related research and development activities, and established a Division of Space Nuclear Systems. All AEC space-oriented work on SNAP reactor and isotope electric power systems was transferred to a newly-created Space Electric Power Office (SEPO) in that division. The isotopic thruster propulsion work,[1] which had been under the jurisdiction of the AEC's Division of Isotopes Development, was transferred to the existing AEC–NASA Space Nuclear Propulsion Office (SNPO), the other element of the Division of Space Nuclear Systems. A major advantage of the new organizational alignment is the improved communication and ease of coordination between AEC and NASA in the power area.

NUCLEAR ROCKET (ROVER) PROGRAM

The nuclear rocket program is a joint National Aeronautics and Space Administration (NASA) and AEC effort, with funding and responsibilities shared by both agencies.

Substantial progress was made in 1965 in advancing the technology for developing nuclear-rocket propulsion systems which will ultimately enable the United States to undertake long and complex space missions possible only with nuclear energy. Throughout 1965, the major emphasis in the program was on development of solid-core graphite-reactor and engine-system technology capable of providing a specific impulse (a measure of rocket propulsion efficiency) substantially higher than that attainable with chemical rocket engines.

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[1] Fuel and capsule development work for the isotopically-powered SNAP electrical and propulsion systems continues to be the responsibility of the Division of Isotopes Development.

The program also continued to support a broad effort in advanced research and technology concerned with investigation of the performance potential of tungsten-core nuclear-rocket engines, development of advanced nonreactor and engine-system technology, and the examination of the feasibility and potential of advanced nuclear-rocket concepts.

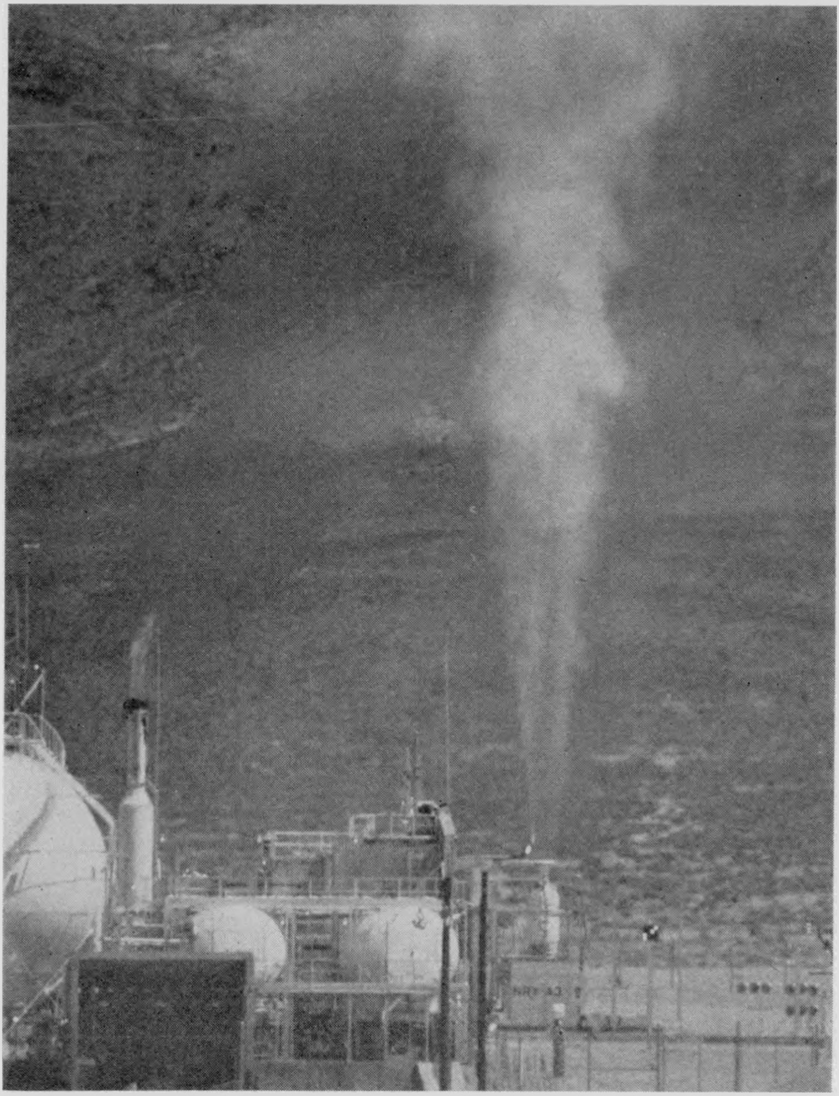
PROJECT NERVA

The NERVA (Nuclear Engine for Rocket Vehicle Application) project is an Aerojet General/Westinghouse contractor team effort to provide the technology for complete nuclear-rocket engines. The plan for achieving this objective has been to continue the development testing of graphite reactors, critical engine components, and ground-based experimental engines until a thorough understanding of equipment, subsystem, and system interactions and behavior is obtained.

Significant NERVA Experiments

During 1965, Aerojet and Westinghouse completed three experiments on an NRX–A reactor designated the NRX–A3, and prepared to conduct the first experiments on an experimental engine system designated the NRX–A4/EST (NRX stands for NERVA Reactor Experiment). In addition, Aerojet completed the first phase of tests on a nonfueled test device called the Cold Flow Development Test System (CFDTS) at its test facility in Sacramento, Calif.

NRX reactor tests. The three experiments with the NRX–A3 reactor were conducted on April 23, May 20, and May 28 at the Nuclear Rocket Development Station (NRDS) in Nevada. In the first two experiments, the reactor was operated for a total test duration of about 25 minutes, 16.5 minutes of which were at full design conditions. Following the two experiments at full power, the reactor was again restarted and used to investigate the characteristics of reactor operation, and the effects of the liquid hydrogen propellant on reactor control in the low-to-medium power region. At the completion of the three experiments, a total of more than 60 minutes of reactor operation had been accumulated. In each of the tests, reactor performance was very good, and excellent operational data were obtained. In addition, the three experiments provided a proof-test of the Aerojet-General stainless-steel U-tube nozzle that will be used, with a hot bleed port, in tests of the NRX/EST.



The NERVA NRX–A3 Experiments. One of the major achievements demonstrated under the Rover program during 1965 was the ability to operate a nuclear rocket reactor at near full design power for a significant run duration. The NRX–A3 reactor shown above in an upward-firing position was operated for more than 60 minutes at power through three power cycles. About 16½ minutes of this operating time was at or near full design power (1,100 megawatts). By way of comparison, the foreseen missions for nuclear rockets will require full power operating times of 15 to 20 minutes in some cases—which has already been demonstrated—and 30 to 40 minutes in other cases. The colorless hot hydrogen heated by a nuclear reactor and rushing from the NRX–A3 nozzle, forms a barely visible plume against the background of Nevada Test Site mountains in the photo. The rush of the heated hydrogen will provide the propulsive thrust for the rockets.

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Engine system tests (EST). In December, preparations were completed for conducting the first NERVA Reactor Engine System Test (NRX/EST) planned in the NERVA technology development program. The NRX/EST comprises a reactor (the NRX–A4, positioned in an up-firing position on a modified reactor test car), a regeneratively cooled nozzle with a bleed port through which hot exhaust gas will be ducted to drive the turbine, and a turbopump located on the test car. These components are connected by a system of valves and piping to simulate as closely as possible the flow characteristics of an actual flight engine. The NRX/EST system will be used to investigate engine startup characteristics, and major component interaction during startup, power operation, and shutdown.

Cold flow development test system experiments. The first phase of tests on the Cold Flow Development Test System (CFDTS) was completed at the Aerojet-General Test Facility in Sacramento on April 20, 1965. "Bootstrap"[2] startups were achieved with liquid hydrogen, and the information obtained will be used in conjunction with data from the NRX/EST to establish the startup conditions for tests of future ground experimental engines (XE's) in Engine Test Stand No. 1.

Phoebus Graphite Reactor Technology Program

The objective of the Phoebus program, conducted by Los Alamos Scientific Laboratory, is to advance the graphite reactor technology provided under project Kiwi[3] and being used under project NERVA, toward higher power and temperatures and longer operating durations. The technical plan for achieving this goal is to (*a*) ground test a series of Kiwi-sized Phoebus–1 reactors to explore the specific technological problem areas associated with the design of large reactors, and (*b*) design, fabricate, and test a series of larger-diameter, higher-powered Phoebus–2 reactors which will ultimately lead to the definition of a high-performance reactor design suitable for inclusion in a high-thrust engine system.

During the year, the Phoebus effort was marked by the completion of the Phoebus–2 preliminary design, and the completion of the first Phoebus–1 reactor experiment.

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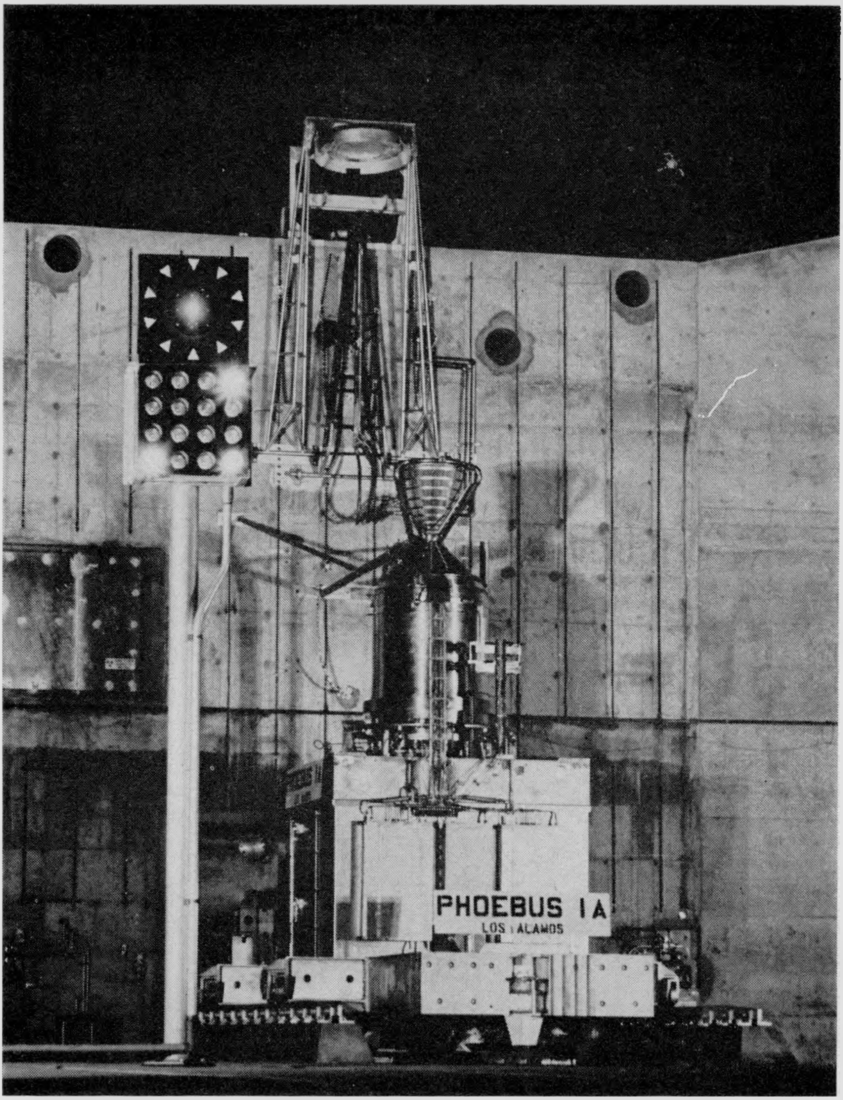
[2] The design of the NERVA engine requires that liquid hydrogen first be forced through the system using hydrogen tank pressure to start the engine turbopump and flow sequence. The turbopump is then brought up to speed by hot hydrogen from a bleed port in the exhaust nozzle. This is what is meant by a "bootstrap" start. Thereafter, propellant flow through the reactor is maintained by the turbopump.

[3] See pp. 110–112, "Annual Report to Congress for 1963"; pp. 109–112, "Annual Report to Congress for 1964."



Phoebus Test Reactor. As a part of the AEC–NASA nuclear rocket program, the first of the Phoebus reactor experiments was conducted at the Nuclear Rocket Development Station on June 25. Photo shows the Los Alamos Scientific Laboratory-developed Phoebus-1A shortly before it was operated for 10½ minutes at full power. The Phoebus series of nuclear rocket reactor experiments are to extend the graphite reactor technology that was developed under the Kiwi series to higher power and temperature and will ultimately lead to a high-thrust nuclear engine system for use in deep-space exploration. In the photo, the reactor, with its rocket nozzle pointing skyward, sits atop the remote-controlled test car.

The first of the Phoebus–1 series of reactor experiments was conducted on June 25 at NRDS. The Phoebus–1A reactor used for these experiments was run at full power and temperature for about 10.5 minutes. Reactor operation was in good agreement with design predictions during the start to full power and the full power hold; however, during shutdown the liquid hydrogen coolant-propellant supply in the facility was unintentionally exhausted, and as a consequence the reactor core was damaged from overheating. This occurrence was not due to a reactor malfunction, but rather to the malfunction of the liquid hydrogen storage tank level gage which indicated a higher than actual content of propellant. Steps have been taken to prevent the recurrence of this problem.

The next Phoebus–1 experiment is scheduled for the summer of 1966.

Rover Program Safety Test

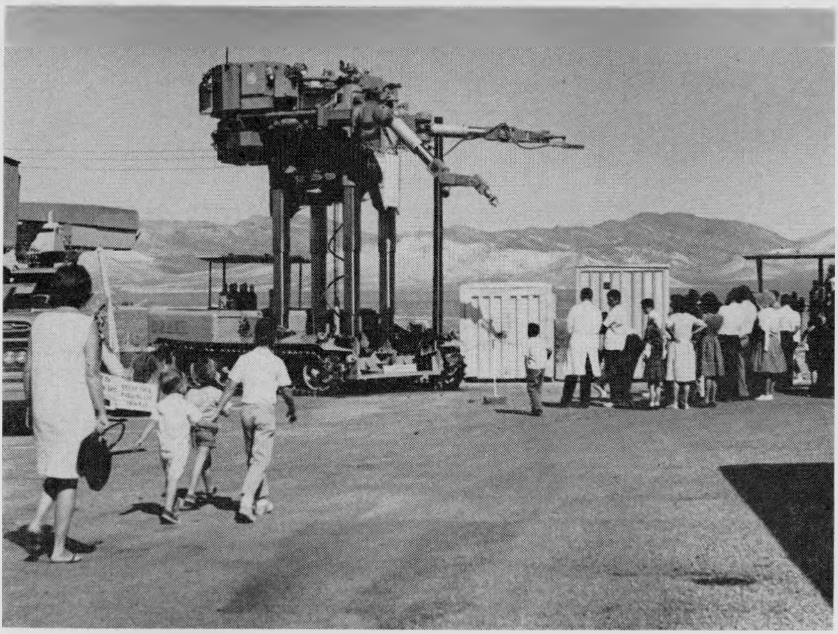
In addition to the reactor experiments conducted during 1965 to advance the state of graphite reactor and engine system technology, a safety experiment known as the Kiwi-Transient-Nuclear-Test also was conducted in January 1965 to determine the accuracy of theoretical techniques developed for predicting the response of a graphite reactor to very large and rapid insertions of reactivity. In the experiment, a Kiwi-sized reactor was deliberately destroyed by subjecting it to a very fast power increase. The results of the test were in good agreement with predictions. The experiment demonstrated that even under launch accident conditions, entailing a maximized power event, the safety of personnel both on and off site could readily be assured. Nevertheless, program plans include incorporation of countermeasures to prevent any such accident.

ADVANCED RESEARCH AND TECHNOLOGY

Tungsten Research

The primary objective of the tungsten research program is to evaluate the feasibility and performance potential of tungsten-core nuclear rocket reactor concepts. In support of this work, the Argonne National Laboratory continued during 1965 to investigate a fast reactor concept, and NASA's Lewis Research Center (Cleveland, Ohio), a thermal water-moderated reactor concept. The potential advantages of such tungsten systems are long operating durations or lighter weight engines in the low thrust range (on the order of 10,000 pounds thrust).

The key to feasibility and performance potential of both tungsten reactor concepts lies in the capability of the fuel elements. During the year, several fuel fabrication processes were developed to produce metallurgically sound fuel elements. The ability of small-scale samples of fuel material to withstand simulated operating cycles was increased from several cycles prior to failure, to 100 cycles prior to failure. In 1966, the effort will be concentrated on improving the sta-



"*The Beetle.*" Looking like something from an old science fiction magazine, "The Beetle" is a piece of equipment used at the Nuclear Rocket Development Station (NRDS) in Nevada. The remote-controlled, self-propelled machine is capable of handling "hot" equipment in connection with nuclear rocket development experiments. Photo *above* shows the General Electric-built machine being demonstrated during a NRDS "Family Day." At *left*, a youngster finds that one of the Beetle's claws can take a pencil from her hand just as gently as her mother could.

bility of the basic fuel materials, and on demonstrating their duration, recycle, and temperature capabilities.

Advanced Nonreactor Technology

The major work on nonreactor and engine system technology development during the year was directed toward the development of feed systems, nozzles, controls, and instrumentation to support the graphite reactor and engine system technology effort. This included basic research to obtain fundamental heat transfer data to improve the performance of conventional components; the development, in selected areas, of new components; and the establishment of improved techniques for systems analysis. The greater portion of this work is conducted either by NASA's Lewis Research Center or by contractors working under the direction of Lewis.

Feed systems and nozzles. Of major importance to the conduct of the Phoebus graphite reactor technology program has been the development work on propellant feed systems and nozzles to support the testing of high-powered reactors. Development of the NFS–3 feed system, at the Rocketdyne Division of North American Aviation, Inc., as a test facility pump is in support of future Phoebus needs. This system, designed to meet the pressure and flow requirements for the Phoebus–2 high power density series of reactor tests, incorporates a pump with a new blade design, and, when coupled to its five stage turbine, is designed to operate at speeds up to 34,000 revolutions per minute (rpm). During 1965, performance mapping of the pump to 30,000 rpm was completed, and system tests with the five-stage turbine to 29,000 rpm were conducted.

In the area of nozzles, hardware developed for the Kiwi/NERVA program appears to be adequate for the support of the Phoebus–1 reactor test program. Testing of the Phoebus–2 reactor, on the other hand, will require a nozzle with larger diameter and with the ability to withstand higher heat fluxes and stresses. The Aerojet-General Corp. was selected in the spring to begin the development of this new hardware. The technology from this effort will be applied to the development of nozzles for the NERVA engine based on Phoebus–2 technology.

Cold-flow engine experiments have been in progress in the Nuclear Rocket Dynamics and Control Facility of NASA's Lewis Research Center to gain a better fundamental understanding of nuclear engine system behavior during the important and critical phases of engine startup. The absence of radiation from these tests allows quick access to the engine and facility for any necessary or experimental modifications. This allows for a wide variety of tests and a very flexible test program.

Engine chilldown. During 1965, 10 experiments were completed by Lewis designed to explore engine chilldown (cooling by the liquid hydrogen propellant) and to determine the range of conditions for which flow oscillations will occur in an engine system. An additional 16 runs were conducted to obtain data on the "bootstrap" starting of a nuclear engine. Analyses of the data from these experiments have indicated that nuclear rocket engines should be able to start smoothly and stably over a wide range of startup conditions.

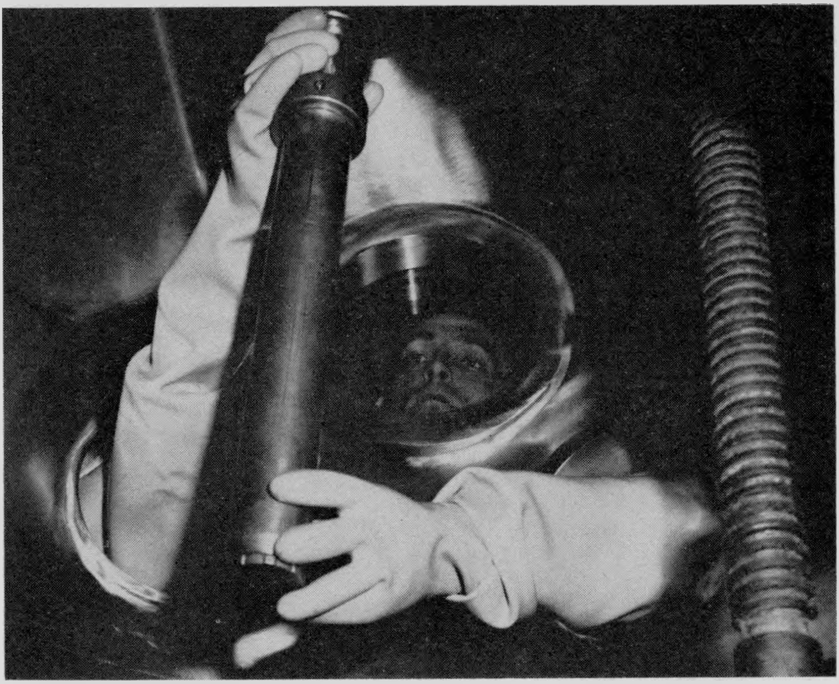
Advanced Nuclear Rocket Propulsion Concepts

In the field of advanced nuclear rocket propulsion concepts, basic studies and research are continuing on dust bed, liquid core, and gaseous core nuclear-rocket concepts, with primary emphasis being given at this time to the fluid flow and heat transfer aspects. Work conducted under AEC auspices included exploratory deuterium oxide cavity reactor critical experiments at the Los Alamos Scientific Laboratory, and investigations of the behavior of fluidized beds subject to high centrifugal accelerations at Brookhaven National Laboratory.

ISOTOPIC THRUSTER PROPULSION

The isotopic thruster concept envisions the use of a radioisotope to heat hydrogen, which is expelled through a nozzle to produce low thrust. Such a small rocket engine, or thruster, would have total thermal powers ranging from a few watts to about five kilowatts, and would be capable of producing thrusts ranging from a few millipounds to a quarter of a pound at a specific impulse of up to 700 to 800 seconds with hydrogen. Based upon these performance capabilities, isotopic thruster systems appear attractive as an upper stage for missions such as deep-space probes, for propelling payloads from low earth-orbit to high earth-orbits, or for low-thrust orbital operations.

In February 1965, an experimental model isotopic thruster was tested at the AEC's Mound Laboratory, using heat from the radioactive decay of polonium 210. Mound is continuing the development of polonium 210 fuel forms and fuel encapsulating techniques to meet the needs of specific space applications. The engine or thruster technology portion of the program is presently being supported at Thompson-Ramo-Wooldridge, Inc. (TRW, Inc.) in California.



Isotopic Thruster. A radioisotope-fueled rocket thruster experiment was successfully conducted at the AEC's Mound Laboratory during the year in a cooperative effort with the Air Force. Photo shows the inner liner of the thruster after being removed from its cooling transfer cask and in the process of being loaded into the outer thruster assembly, which has been installed in the thick-walled stainless steel test chamber. The inner liner holds the three fuel capsules, each containing nearly 10,000 curies of polonium 210. The decay heat from this highly radioactive isotope is used to directly heat the hydrogen propellant.

SATELLITE AND SMALL POWER SOURCES

Under its SNAP (Systems for Nuclear Auxiliary Power) program, the AEC is developing compact, lightweight nuclear devices for space use. (See Chapter 9—Auxiliary Electrical Power for Land and Sea, for other uses of SNAP units.) The program includes the development of techniques, materials, and equipment required to apply to and advance the technology of nuclear auxiliary and propulsive electric power. Under this program, compact nuclear electric power packages through conversion of fission heat (reactors) or radioactive decay (isotopic) heat to electricity, are being developed for use in satellites and space vehicles.

SPACE REACTOR ACTIVITIES

SNAP–10A Flight Test (Snapshot–1)

History was made on April 3, 1965, with the successful launch and operation of the first reactor power unit in space. The 500-watt SNAP–10A reactor system, mated to the forward end of a specially modified and adapted Agena spacecraft, was boosted by an Atlas missile from Vandenberg Air Force Base, Calif., into a 700-nautical mile-high Polar orbit circling the earth every 112 minutes. The SNAP–10A spacecraft will continue to orbit for several thousand years. In its 43 days of operation, until May 16, the Atomics International-built SNAP–10A system produced more than a total of 500,000 watt-hours of electricity. Then, the spacecraft failed to report as it passed over the Hawaii Tracking Station. When satellite telemetry signals, powered by batteries designed to function in case of reactor malfunction, again resumed about 40 hours later, they indicated the reactor had been shut down and was inoperable.

Snapshot–1 was considered to be successful in that all test systems operated satisfactorily throughout the critical early stages of the flight, and all performance data recorded during the test confirmed design predictions and ground test experiences. The system achieved a stable orbit approximately four hours after lift-off and a ground command then initiated nuclear startup. Nine hours later, the power unit had achieved full power. On the sixth day after launch, the reactor was put on static control—i.e., it operated automatically without manipulation of the controls either from the ground or from its own electronic controller.

After the reactor system suddenly stopped operating, various ground tests were made in an effort to simulate the failure, and telemetry data acquired from the satellite during the reactor's operation were analyzed in an attempt to determine the cause of the premature reactor shutdown. The analysis concluded that the most probable cause of the shutdown was a sequence of failures in electronic components of the spacecraft which generated spurious signals that commanded the reactor to shut down. No other Snapshot flights are currently planned.

SNAP–10A Ground Tests

The SNAP–10A nuclear ground test system—designated the Flight System–3 (FS–3)—a flight qualified copy of the Snapshot–1 orbital test system, was put into operation on the ground in a vacuum environment on January 22. The system accumulated more than 70 days of operating time prior to the Snapshot–1 launch. Throughout the remainder of the year, the system continued to operate satisfactorily but with a gradual degradation in power output. The power output change is due to a combination of thermoelectric performance decrease and a downward drift of the reactor outlet coolant temperature which is following a trend noted in the flight test also. Laboratory tests are in progress to avoid such performance loss. The FS–3 system has operated continuously since January 1965, and as of December 1965 had exceeded by four months the previous record for continuous power operation of any known reactor. At year's end it was still operating.

SNAP–8

Development of SNAP–8 as a complete 35-electrical-kilowatt power system was deferred as a result of budgetary decisions early in 1965. NASA is continuing its development work on the power conversion system to obtain as much test time and experience as possible within the fiscal year 1965 funds available. AEC is continuing reactor development through testing of the SNAP–8 Development Reactor (S8DR) now being fabricated to test advanced fuel elements and automatic controls. Such testing is needed to establish the technology needed to provide such power levels.

The SNAP–8 Experimental Reactor (S8ER)—the first power reactor of the SNAP–8 series—was shut down April 15, completing test operation for this reactor. During 500 days of non-continuous nuclear operation, S8ER produced in excess of 5 million kilowatt-hours of heat. The Atomics International-developed unit was operated in the 400 to 600 thermal kilowatt power range with a 1,300° F. coolant outlet temperature for 365 days, 100 days of which were at 600 thermal kilowatts and 1,300° F. The last 5,000 hours (over 200 days) of operation were uninterrupted. After shutdown, examination of the S8ER showed that 80 percent of the fuel elements had cracked cladding tubes. The cause of these cracks is being determined, and the fuel elements for the next SNAP–8 reactor will be modified accordingly.

Testing of the SNAP–8 Developmental Reactor Mockup (S8DRM) was completed in July 1965. The S8DRM is a nonnuclear version of the second power reactor in the SNAP–8 series and is used to investigate the survivability of the SNAP–8 reactor system under environmental conditions of launch and space operation. Successfully completed tests involved launch shock and vibration, orbital startup simulation, and exposure to high operating temperature and vacuum.

Advanced Space Reactor Technology Development

SNAP–50. In June, 1965, the SNAP–50 nuclear space electric power effort was redirected to a broad technology development program so as to provide the capability to respond to a variety of long-term future space mission requirements when such requirements develop. The Pratt & Whitney work conducted at the Connecticut (Middletown) Advanced Nuclear Engineering Laboratory (CANEL), which was oriented to a specific type of system, was terminated and follow-on work was initiated at the AEC's Lawrence Radiation Laboratory (LRL), Livermore, Calif. This work will include a broadened liquid-metal-cooled reactor development effort placing emphasis on achieving the best reactor system possible. Power conversion component development work which has been in progress at AiResearch (Phoenix, Ariz.) and Westinghouse Corp. (Lima, Ohio) is being continued.

Medium Power Reactor Experiment (MPRE). The MPRE under development at the Oak Ridge National Laboratory is an advanced reactor concept which employs boiling potassium as the coolant. The feasibility of the concept is being tested with electrically-heated "fuel elements" in mockups of the boiling reactor core and other system components. During 1965, both potassium and water (simulating potassium) systems were built and operated. Smooth initiation of nucleate boiling was demonstrated and stability and control characteristics of these loops were shown to be good under load demands.

710 Program. The objective of the Advanced High Temperature Reactor Program (710 Program) was changed in 1965 from a short-time, very high-temperature reactor experiment to a reactor suitable for a nuclear Brayton cycle space power system. The Brayton cycle utilizes an inert gas for cooling the reactor and driving the power conversion equipment. This concept avoids some of the fundamental difficulties that may arise in developing and using high-temperature liquid-metal-cooled reactors in space. The technology previously developed in this program is applicable, and major emphasis during 1965 was placed on developing and testing gas-cooled fuel elements with the necessary long lifetime. This work is being performed by the General Electric Co. at Evendale, Ohio.

SPACE ISOTOPE POWER ACTIVITIES

Operable Units

SNAP–3. On June 29, 1965, the first nuclear power generator to be launched into space marked its fourth anniversary. During its 4½ years in orbit aboard a 175-pound drum-shaped experimental Department of Defense (Navy) navigational satellite, the 5-pound, grapefruit-sized, 2.7-watt SNAP–3 radioisotopic generator, which was developed for the AEC by the Martin Co., Baltimore, Md., has traveled more than 500 million miles—the equivalent of more than 1,000 round trips to the moon—and has been continuously supplementing solar power for the transmitters on the satellite, which is signalling clearly and regularly to tracking stations around the world.

SNAP–9A. The two Martin-developed SNAP–9A generators which were launched into orbit in September and December 1963 provided all of the power required by two of the Navy's navigational satellites for the life of the functional satellite components. The telemetry data received since launch indicates that, although the stability of power output of the generators was adequate, there were design deficiences in SNAP–9A (notably in the hermetic seals of the generator housing and in the thermoelectric materials used) which have caused a power degradation rate greater than predicted before launch. These design deficiencies have been taken into account in the designs of newer power systems.

Earlier aerodynamic analysis had predicted the burnup of the plutonium 238 fuel inventory of the SNAP–9A space nuclear generator which failed to achieve orbit in April 1964.[4] These predictions have been verified through analyses, made in 1964 and 1965 by the AEC's Health and Safety Laboratory in New York City, of samples of radioactive material collected in the upper atmosphere by balloons. The analyses of the balloon samples clearly indicated that upon its re-entry into the earth's atmosphere, the 9A's fuel burned up to submicron-size particles at an altitude of more than 130,000 feet and hence involve no health hazard.

Generator Development

SNAP–11. A SNAP–11 thermoelectric generator capable of producing between 20 and 25 electrical watts is being prepared by the Martin Co. for loading with a curium 242 radioisotope heat source in

[4] See p. 117, "Annual Report to Congress for 1964"; pp. 113–114, "Annual Report to Congress for 1963."

TABLE 1.—SPACE ISOTOPE POWER UNITS

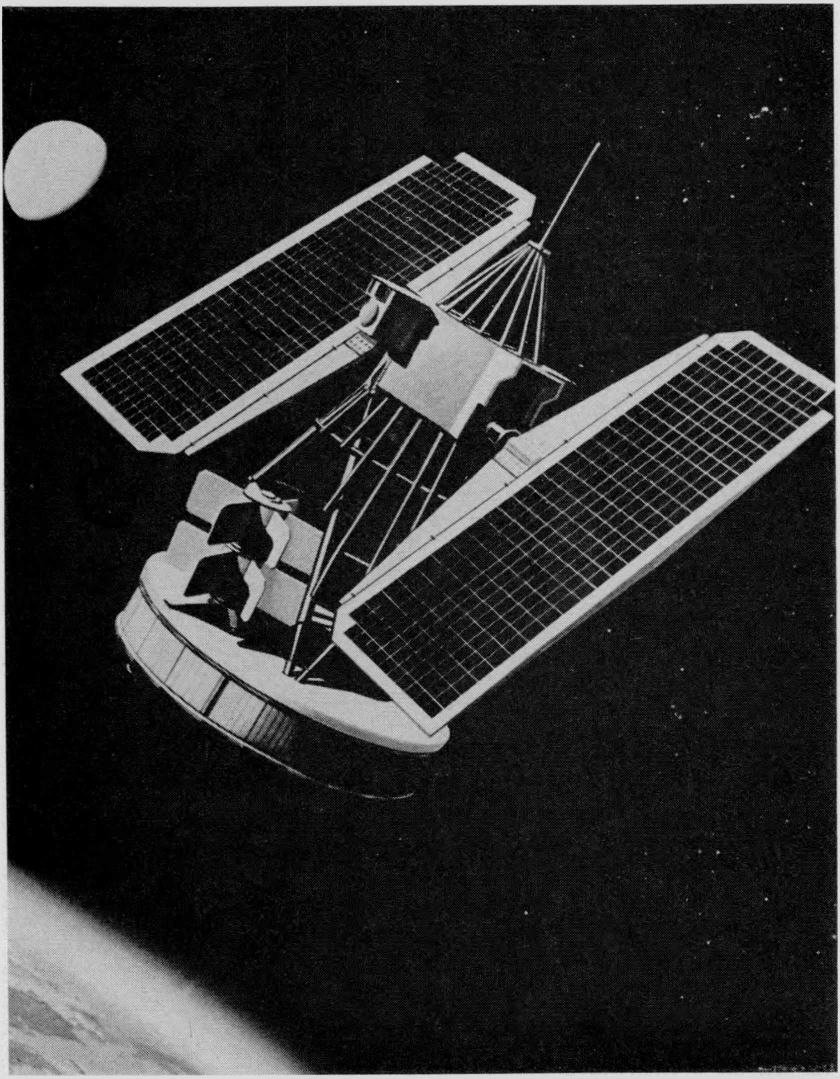
SNAP Number	Prime Contractor	Power Electrical (Watts)	Isotope	Application
3	Martin Co.	2.7	Pu^{238}	Navigational satellites (DOD).
9A	do	25	Pu^{238}	Navigational satellites (DOD).
11	do	20–25	Cm^{242}	Experimental devices.
19	do	30	Pu^{238}	Nimbus-B (NASA).
27	General Electric Co.	50	Pu^{238}	Apollo lunar surface experiment package (NASA).

mid-1966. Electrically-heated prototype models will be delivered to NASA's Jet Propulsion Laboratory (Pasadena, Calif.) and the Houston Manned Spacecraft Center in Texas for environmental and compatibility testing. The SNAP–11 system is unique in that it makes use of power flattening—a regulated, insulated door system controls the release of excess heat generated by the high-power-density short-half-life radioisotope. In the event that early Surveyor missions should show that the present solar-panel power system is not usable on the lunar surface because of dust or other unknown factors, consideration would be given to the use of SNAP–11 generators in this NASA Surveyor soft-lunar-landing program.

SNAP–19. Two SNAP–19 30-watt generators mounted in tandem will be used to deliver auxiliary electrical power to the NASA Nimbus-B weather satellite scheduled for launch in late 1967. In February, two electrically-heated SNAP–19 prototype generators were delivered by the Martin Co. to NASA's Goddard Space Flight Center (Greenbelt, Md.) where they were subjected to electrical performance and electrical integration tests based on Nimbus-B weather satellite specifications. In November, two SNAP–19 generators were shipped to General Electric (Valley Forge, Pa.) for dynamic mechanical testing aboard a simulated Nimbus–B sensory ring.

SNAP–27. The SNAP–27 program, initiated in 1965, is aimed at the design, development, test, and demonstration of a 50-watt plutonium 238-fueled power supply to be used by NASA in the Apollo program. This isotopic power system, planned to provide the total power requirements for the Apollo Lunar Surface Experiments Packages (ALSEP), will be placed on the lunar surface by the astronauts.

ALSEP is a combination of instruments and supporting subsystems (self-contained and automatic) aimed at collecting and transmitting back to earth various scientific data regarding the moon and its associated environments for a period of about a year. General Electric's



SNAP–19. When NASA puts an experimental Nimbus-B weather satellite into orbit late in 1967, two SNAP–19 isotopic generators will be aboard to provide power for the instrumentation. Now under development for the AEC by the Martin Co. at Baltimore, Md., the plutonium 238-fueled SNAP–19's will provide 30 watts of electricity and have a design life of 5 years. Artist's conception shows how the Nimbus-B will look with its isotopic power source (left side of drum).

Missile and Space Division at Valley Forge, Pa., is developing the radioisotope thermoelectric generator, SNAP–27, under AEC contract.

Generator Studies

High-powered, long-life units. In December 1965, the AEC initiated generator engineering studies to determine the feasibility of 250 to 300 watt plutonium- and strontium-fueled thermoelectric power systems which would be particularly suitable for long life space applications. These studies will include consideration of advanced technologies which are needed to achieve a lightweight design and also to investigate safety features which include the use of a controlled re-entry system. Because of the amount of plutonium and strontium fuel which must be used in such a power system, and because the isotopic power system is to be applicable to a variety of space missions, the controlled re-entry package will be included as an integral part of the power supply design.

Polonium power system. In September 1965, the AEC initiated preliminary engineering, design, and integration studies on a polonium-fueled thermoelectric generator for possible application in a DOD mission.

Large heat source studies. Large radioisotope heat sources using curium 244, plutonium 238, and polonium 210 which are compatible with thermoelectric or dynamic conversion devices [5] are of interest as subsystems of manned and unmanned space electric power systems which provide 1 to 10 kilowatts of electricity. As a first step in the AEC's consideration of such power systems, two parallel preliminary design and safety studies are being conducted: one by Atomics International, Canoga Park, Calif., the other by General Electric's Missile and Space Division, Valley Forge, Pa. The design studies will be sufficiently detailed to define and evaluate the general configuration and the attractiveness of using each of the isotopes, to indicate a technical approach to the associated problems of nuclear hazards, and to recommend research and development areas to be investigated before proceeding with a detailed design.

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[5] *Thermoelectric conversion:* Thermoelectric conversion is based upon a principle discovered about 150 years ago by a German scientist, Thomas Johann Seebeck. Seebeck observed that an electrical current is produced when two dissimilar metals are joined in a closed circuit and the two junctions are kept at different temperatures. Such junctions are called thermoelectric couples or thermocouples. *Dynamic conversion:* A dynamic conversion system utilizes moving machinery in converting thermal energy to electrical energy. A reciprocating steam turbine powering an electric generator is an example of a dynamic conversion system.

POWER CONVERSION TECHNOLOGY

Compact Thermoelectric Converter

In June, Westinghouse Electric Corp.'s Astronuclear Laboratory, Pittsburgh, Pa., and the Radio Corp. of America, Harrison, N.J., under AEC contract, initiated parallel development programs on two concepts of a high-performance, compact thermoelectric converter to be used in space applications with either zirconium-uranium hydride reactors or radioisotopes as the heat source. Each converter is to be of modular form and develop 1 to 20 electrical kilowatts. The modules permit close packing of the thermoelectric elements—which convert heat directly into electricity—into small prepackaged units. This arrangement offers the advantages of high reliability and increased flexibility for integrating the converter with the power system and the power system with the spacecraft. The converter will use a secondary coolant system to remove waste heat from the converter and transport it to a separate radiator for rejection to space, thus facilitating the installation of the radiator and minimizing the radiation received in the crew compartment from primary (reactor) coolant.

The complete three- to five-year program will be conducted in four phases. The current competitive phase, an engineering study, is scheduled to be completed early in 1966. Later phases will cover module development, module qualification, and prototype converter fabrication and qualification.

Thermoelectric Technology

Lightweight generator. A lightweight thermoelectric generator concept under development at the General Atomic Division of General Dynamics Corp., San Diego, Calif., uses radiant thermal coupling between the heat source and the hot junctions of small thermocouples. In 1965, this program progressed from the testing of two-couple modules to the fabrication and test of a complete six-panel device which is a thermal simulation of an isotopic power generator.

Cascaded and segmented thermoelectrics. Improved energy conversion efficiency is achieved when the heat passes first through a high-temperature stage (using germanium-silicon alloy thermoelectrics) and then through a low-temperature stage (using lead telluride thermoelectrics). The difference in physical properties of these materials requires engineering development to permit cascading them. Alternatively, certain promising semiconductors, whose material properties are similar to germanium-silicon, can be combined directly with it (segmented couples) to improve power output. The Radio Corp. of America, Harrison, N.J., is testing prototype modules of these types in order to establish their suitability for space applications.

Airvac (Si/Ge) thermoelectric module development. This new program is intended to provide basic technology useful to a wide range of future radioisotope thermoelectric generator designs. It will be directed at developing fabrication techniques and establishing operational feasibility for beryllium based modules utilizing RCA's silicon-germanium Airvac thermocouples. Module operation in both

Unique New Pump. Development of a new liquid metal thermoelectromagnetic pump, which has no moving parts and requires no power hookup to operate, is an outgrowth of work conducted by Atomics International under the AEC's SNAP nuclear reactor power program. About a foot long, it consists of a direct current liquid metal conduction pump powered by a thermoelectric generator. Heat from the liquid metal being pumped is converted directly into electricity by the integral thermoelectric elements. This electricity then drives the conduction pump.

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air and vacuum at hot junction temperatures from 800 to 1,000° C. and cold junction temperatures from 300 to 500° C. are the initial objectives.

Insulation. A new program for the experimental development of high temperature thermal insulation for isotope heated thermoelectric and thermionic power systems was initiated by the AEC in 1965. This program will pursue two concepts: one a fibrous or particulate insulation operable in the temperature range of 400° to 1,800° F., and the other a multiple layer, vacuum, metallic foil insulation spanning the temperature range of 400° to 3,100° F. A multi-purpose composite insulation structure, adaptable to intricate shaping within the isotope power generator, is the object of this program.

Thermionics technology. The SNAP-13 low power (12.5 watts) thermionic [6] demonstration has achieved its objectives of module performance, life, and environmental integrity. Radioisotope fueling of the SNAP-13 generator with curium 242 was accomplished by Oak Ridge National Laboratory in November 1965. A new multiphase program has been initiated in which the goal is the development of radioisotope-fueled thermionic modules, adaptable to power demands in the 100 to 10,000 watt range. Fuel will be either curium 244 or polonium 210, suitable for use in various space power applications.

SPACE NUCLEAR POWER SAFETY INVESTIGATIONS

A number of safety investigations were conducted during the year in the space nuclear power program. In the SNAP reactor area, countermeasures and safety design concepts were investigated, including means of maintaining the reactors subcritical in the event of launch accidents, postmission disposal techniques, and range safety techniques. Safety investigations and analyses continued in the areas of impact, reactor disassembly during re-entry, and aerothermodynamic effects on reactor fuels. In the SNAP isotopic power area, investigations were conducted on countermeasures, including controlled re-entry, recovery, burnup, and impact-resistant fuel capsules. Radiobiological experiments were conducted on SNAP fuels at the Los Alamos and Pacific Northwest Laboratories. This effort is in support of new and emergent SNAP systems.

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[6] *Thermionic conversion:* In thermionic conversion, two metals of different energy levels are placed in close proximity with a vacuum or an ionized medium between. The high-energy material is heated and the electrons which "boil off" its surface are collected by the cooler low-energy material, creating a flow of electricity.

Chapter 9

AUXILIARY ELECTRICAL POWER FOR LAND AND SEA

The AEC is actively engaged in the development of a family of compact, lightweight, reliable, long-lived nuclear power systems for use in a variety of applications on the earth's surface, in outer space, on the sea's surface, and under the sea. These systems—some of which use the heat of radioisotopic decay as their energy source, and others of which use the heat produced by atomic fissioning in a small nuclear reactor—have heretofore been included under the general term "Systems for Nuclear Auxiliary Power"—better known by its acronymous title, SNAP.[1]

The development of SNAP systems for space applications is reviewed in Chapter 8—"Nuclear Space Applications." This chapter concentrates only on the programs for land and sea applications.

SNAP radioisotopic systems capable of producing from a thousandth of a watt (one milliwatt) to 200 watts of electrical power are currently under development; it is anticipated that within the near future higher-power isotopic generators and nuclear reactor systems capable of providing electrical power in the kilowatt to megawatt range will also be under development.

POTENTIAL APPLICATIONS

Deep-Sea Applications

There is little doubt that nuclear power can materially enhance man's ability to pursue many deep-sea and ocean-bottom applications. Both isotopic and reactor heat sources hold great promise for providing the auxiliary and propulsive power needed for many such future oceanographic applications as: (*a*) exploration and survey,

[1] Actually, however, some of the SNAP systems are being developed to provide a source of primary power as well as for auxiliary power functions; hence, the program title has become a misnomer and has been superseded by the title, "Satellite and Small Power Sources." The systems developed and to be developed under this program, however, continue to bear SNAP designations.

(*b*) research into physical properties of the oceans, biological life cycles, etc., (*c*) search, identification, and recovery of underwater objects, (*d*) exploitation of underwater oil and mineral resources, (*e*) navigation, detection and identification systems, and (*f*) underwater stations and facilities.

Terrestrial Applications

Future requirements for nuclear power are almost unlimited when the power requirements for the remote and semi-remote areas of the world are considered. Isotopic units, for example the advanced SNAP–23 series of strontium 90 generators, are expected to have application in airfield instrument landing aids, seismological stations, and small instrumentation packages. Additional intended applications for these and future generators will be in microwave relay stations, unmanned tracking sites, automatic weather stations, instrumentation packages, lighthouses, and floating buoys.

ISOTOPIC DEVICES

Radioisotope generators operate on the principle of directly converting the heat generated during radioactive decay to electrical energy. A typical radioisotope such as strontium 90 (Sr^{90}) decays or disintegrates spontaneously, at a completely predictable and reliable rate, emitting particles that generate heat when they are absorbed either in the encapsulating material or in the radioisotope itself.

Conversion Methods

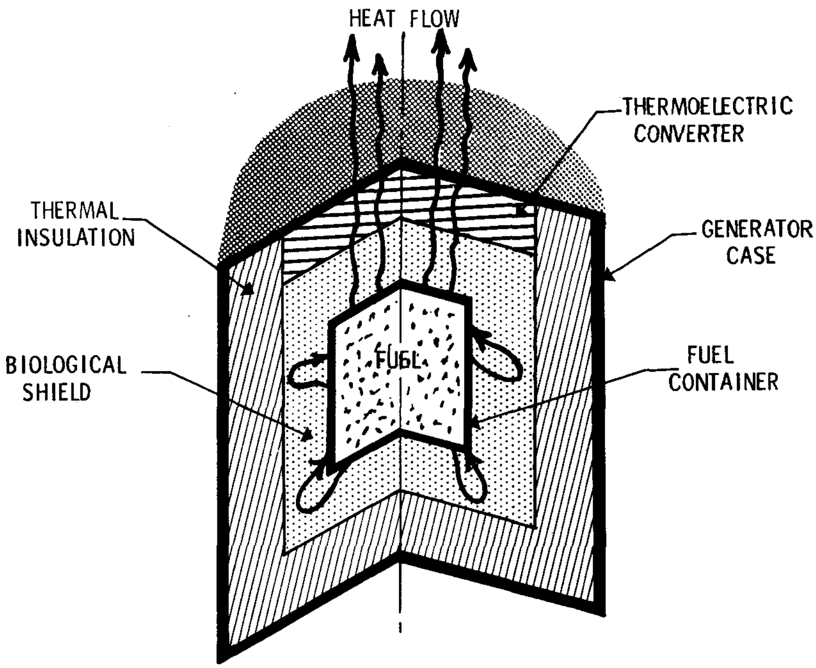
The heat from decaying isotopes may be converted to useful electrical energy by means of a thermoelectric, thermionic, or dynamic-conversion system (see footnotes, numbers 5 and 6 of Chapter 8). Radioisotopic generators developed, and under development, use the thermoelectric principle. Thermionic conversion is primarily limited at this time to space applications. Dynamic-conversion devices will come into use in the high power range of from one to five kilowatts.

A typical radioisotope thermoelectric generator consists of a fuel capsule (the radioisotope fuel is enclosed in a strong, corrosion-resistant container) surrounded by a very efficient thermal insulating material. This insulator directs the heat of the fuel out one particular section of the generator where the thermocouples are positioned to convert this heat to electrical energy. The entire assembly is enclosed in a protective outer metal shell to contain all of the components of the generator and provide protection from corrosive environments. There are many variations to the assembly of these vital components; the above illustrates but one.

Necessary Characteristics

For a radioisotope to be suitable to serve as the energy source in a generator, it must have several important characteristics: (*a*) it must have a half-life (the time it takes a radioisotope to decay to half its

TYPICAL RADIOISOTOPE THERMAL ELECTRIC GENERATOR



Typical Radioisotope Thermoelectric Generator. The above schematic of the radioisotope thermoelectric generator depicts the major components used in a typical terrestrial unit. Nuclear-decay particles from the spontaneous decay of the radioisotope fuel are absorbed in the fuel and fuel container, producing heat. The flow of this heat is directed to the thermoelectric converter by proper positioning of the thermal insulation. Shielding from the nuclear radiation produced by the fuel is provided by a dense-material shield surrounding the fuel container. Heat, upon entering the thermoelectric converter, causes one thermoelectric-couple junction (hot junction) to be heated to a higher temperature than the other (cold junction), and electrical power is generated. A number of these thermoelectric couples are connected in series to produce the amount of power and voltage desired.

original strength) of at least 100 days—long enough to make it worthwhile to put into a generator; (*b*) it must not produce excessive radiation—the protective shielding required to reduce radiation external to the containment device would be too heavy for some applications; (*c*) it must produce at least 0.1 watt of electrical energy per gram; and (*d*) it must be capable of being produced in adequate quantities at a reasonable cost. Of the well over a thousand radioisotopes which are known to exist, there are eight that meet these requirements. For land and deep-sea applications, strontium 90 has been predominant in its use because of its desirable combination of the above characteristics. However, other isotopes do fit special needs and are either being used, or are being considered for use.

REACTOR DEVICES

Mounting awareness that the oceans of the world are a highly important and relatively untapped field for technical study, and a resource of great potential utility to mankind, is giving rapid recognition to the unique capabilities of nuclear energy for oceanographic applications. Some of the characteristics of nuclear power sources that contribute to this unique capability are: (*a*) compatibility with an undersea environment, having no need for oxygen, sunlight, or short-term attention; (*b*) availability in an electrical power range from milliwatts to megawatts, (*c*) ability to operate unattended for extended periods of time; (*d*) general availability as a compact, entirely self-contained unit; and (*e*) a demonstrated history of safe, reliable operation over the years.

Isotopic power sources have already demonstrated the ability to supply sustained unattended power for extended periods in undersea environments. Although nuclear submarines have been in operation for more than a decade, nuclear reactors have not yet been employed in non-propulsive oceanographic applications. Reactors for oceanographic applications will use the same reactor operating principles and concepts so well proven in the past. However, they will differ in specific design features since an undersea or marine environment imposes certain characteristic criteria and requirements. The program to develop reactors for oceanographic applications will be built upon the wide base of nuclear technology that has been developed to date. It will also develop the additional technology required for oceanographic reactor systems. Among the areas where specialized development is anticipated to be required are: heat rejection systems, methods of reactor and plant control, physics of undersea shielding, containment, and safety, maintenance and repair concepts.

OPERABLE SNAP GENERATORS

A number of prototype strontium 90-fueled generators have demonstrated the feasibility, reliability, and long life of isotopic sources of electrical energy. These generators, in the 7.5 to 60-watt power level, were developed under the SNAP–7 program.

The rather costly and relatively inefficient SNAP–7 generators were the first efforts at developing radioisotope thermoelectric generators for terrestrial uses. They were designed, fabricated, and operationally tested under varying terrestrial and marine environments. Tests were made to determine the reliability and performance characteristics and to demonstrate to potential users the advantages that these units offer where long unattended operation is required. Use of these first-generation units has led to development effort on an advanced series of radioisotope thermoelectric generators. The general characteristics of these units are shown in Table 1.

TABLE 1.—LAND AND SEA SNAP UNITS

Designation	Use	Power (watts)	Weight (lbs.)	Isotope	Minimum design life (years)	Remarks
Undesignated (Sentry)	Axel Heiberg Weather Station.	5	1,680	Sr^{90}	2	Installed Arctic, August 1961; removed October 1965.
SNAP–7A	Navigational buoy	10	1,870	Sr^{90}	2	Test at Coast Guard's Curtis Bay, Md., facility, January 1964.
SNAP–7B	Fixed navigational light.	60	4,600	Sr^{90}	2	Installed Chesapeake Bay, May 1964.
SNAP–7C	Land weather station.	10	1,870	Sr^{90}	2	Installed Antarctica, February 1962.
SNAP–7D	Floating weather station.	60	4,600	Sr^{90}	2	Installed Gulf of Mexico, January 1964.
SNAP–7E	Ocean-bottom beacon.	7.5	6,000	Sr^{90}	2	Installed Atlantic Ocean, July 1964.
SNAP–7F	Navigational equipment on oil rig.	60	4,600	Sr^{90}	5	Installed Gulf of Mexico, June 1965; removed, October 1965.
SNAP–15	Small electronic apparatus.	0.001	<1	Pu^{238}	5	Operational test of fueled prototypes.
SNAP–21	Advanced undersea.	10–60	[1] 500	Sr^{90}	5	Prototype generator fabrication and testing started, December 1965.
SNAP–23	Advanced terrestrial.	25–200	[2] 900	Sr^{90}	5	Design and component development completed, December 1965.

[1] For 10-watt version.
[2] For 60-watt version.

Land Units

Axel-Heiberg (Sentry). A strontium 90 thermoelectric generator became operational in August 1961 on the uninhabited Axel-Heiberg Island 700 miles from the North Pole, and provided continuous electrical power to a U.S. Weather Bureau automatic weather station for four years. Because of technical difficulties with the electronics section of the weather station, the still-operable generator was returned to the United States in October 1965. It is anticipated that the repaired electronics section and the radioisotope generator will be placed under test at another, as yet undetermined, remote site in the near future.

SNAP–7C. In February 1962, the U.S. Navy placed an automatic weather station in operation near McMurdo Sound some 700 miles from the South Pole. The 10-watt SNAP–7C radioisotope generator has provided continuous and satisfactory performance, and has proven the reliability and adaptability of these units for locations where the severity of the environment would cause other electrical power supplies to falter.

Marine Units

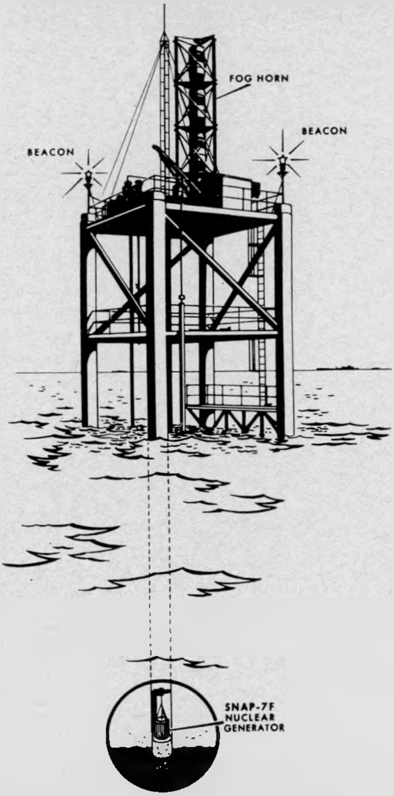
SNAP–7A. The U.S. Coast Guard is presently evaluating the 10-watt thermoelectric SNAP–7A generator in a navigational buoy located on the sea's surface at Curtis Bay, Md. A reworked generator began operating in January 1964, and is producing 5½ watts of electrical power needed to periodically flash the buoy's light. Although the generator's power is steadily declining, its testing and evaluation will be continued so long as it is able to power the buoy.

SNAP–7B. This heavy 60-watt generator, after months of laboratory testing, was installed during May 1964 in Baltimore Light (lighthouse) in Chesapeake Bay. As the only source of power to the light, it has functioned perfectly during its installed lifetime. Testing of this early-model generator has provided data important to the Coast Guard in determining the future use of improved radioisotope generators in their lighthouse network. Consideration is presently being given by the Coast Guard to relocating the unit in a remotely located and unattended lighthouse.

SNAP–7D. A floating Navy automatic weather station anchored in the center of the Gulf of Mexico is powered by the 60-watt SNAP–7D radioisotope generator. Called NOMAD (Navy Oceanographic and Meteorological Automatic Device), this barge-type weather station is a forerunner of a network of such stations planned by the Navy. Having operated successfully since installation in January 1964, and having successfully weathered Hurricane Hilda in 1964 and Hurricane Betsy in 1965, the NOMAD with nuclear power has established itself as a reliable source of weather information, especially during the hurricane season. SNAP–7D will continue to be operated to further illustrate the continued reliability and economic attractiveness of radioisotope generators for applications such as this.

SNAP–7E. Continuous operation since July 1964 of an underwater sound transducer powered by a thermoelectric generator, the 7.5-watt SNAP–7E, has helped to demonstrate the reliability and capability of these units. Implanted under 15,800 feet of water on the bottom of the Atlantic Ocean about 750 miles east of Jacksonville, Fla., the SNAP–7E has remained unattended and still faultlessly powers its associated electronic equipment. The transducer and generator will remain undisturbed so long as they continue to perform satisfactorily. This unit is similar in construction to others in the SNAP–7 series, although it uses a forged-steel pressure vessel to withstand the 8,000 pounds per square inch pressure at its operational site on the ocean bottom.

SNAP–7F. The first radioisotopic generator to be put into commercial use, the SNAP–7F, was installed in June on an offshore oil and gas platform in the Gulf of Mexico about 80 miles southwest of Morgan City, La. Under a two-year AEC-cooperative demonstration program, the AEC provided, at no cost, the 60-watt generator which the Phillips Petroleum Co. installed on one of its offshore drilling rigs to power navigational warning aids. Phillips was to continuously monitor the operation of the 7F and make the operational data available to all members of the offshore oil and gas industry. The strontium 90-fueled SNAP–7F performed satisfactorily from June until late October when its power was observed to have dropped sharply from 56 to 30 watts. The generator was removed from the offshore platform and returned to the Martin Co., Baltimore, Md., where it is undergoing extensive analysis and testing to pinpoint the precise cause of its loss of power. Upon restoration of power, the unit will be returned to the Phillips platform for continued environmental testing.



SNAP–7F. Navigational aids on the oil and gas platform in the Gulf of Mexico were being powered for the first time by a nuclear generator, the SNAP–7F, at time photo *above* was taken. Operation of the generator represented the first commercial use of such a device. Drawing at *left* shows how the 60-watt SNAP–7F generator was installed at the bottom of one of the platform's four steel tubular legs. The generator rested on a concrete pad about 40 feet below the waterline and was used to power two flashing light beacons and an electronic foghorn. The generator was installed during June and operated effectively until late October when its power suddenly dropped from 56 to 30 watts. It was removed and was taken to the Martin Co. plant near Baltimore, Md., to determine the cause of the power decrease. The unit will be returned to the platform when its power has been restored.

DEVELOPMENTAL WORK IN PROGRESS

Isotopic Devices

When the feasibility of terrestrial radioisotope generators was conclusively demonstrated with the application and testing of the SNAP–7 series, the AEC began development work on an advanced generation of isotopic devices. This developmental program is aimed at significantly advancing radioisotopic thermoelectric generators to the point where these systems will not only have greater reliability and longer operating lifetimes, but will also, in many cases, be economically competitive with existing power sources.

SNAP–21. The first isotopic generator development effort specifically directed toward deep-sea applications began in March 1964 and was designated SNAP–21. SNAP–21, designed to provide electrical power for various undersea applications, is to be a very compact strontium 90-fueled generator enclosed in a lightweight, corrosion-resistant pressure vessel capable of withstanding undersea pressures of up to 10,000 pounds per square inch. It is to be developed in 10, 20, and 60 watt power levels, with the lowest power level to be developed first to demonstrate the adequacy of the design and to provide sufficient operational test data for development and test of the higher power levels. In 1965, an electrically-heated prototype 10-watt generator was fabricated and successfully tested by the Minnesota Mining & Manufacturing Co., St. Paul, Minn. A fueled prototype 10-watt unit is expected to be ready for testing under actual operating environments in 1966. Increased efficiency, reliability, and a substantial reduction in size and weight of the SNAP–21 thermoelectric generator is expected to be achieved through the use of newly developed and proven thermoelectric materials, higher hot-junction temperatures, improved thermal insulation, and an improved design. As an example, the 7.5 watt SNAP–7E undersea generator weighed 6,000 pounds; a 10-watt SNAP–21 unit is expected to weigh about 500 pounds.

SNAP–23. The second major development effort has been in progress since June 1964 on an advanced radioisotope generator for operation on land or on the sea (buoys, lighthouses, etc.). Designated SNAP–23, these devices will also be developed in three power levels—25, 60, and 100 watts—with the 60-watt size being developed first. The Minnesota Mining & Manufacturing Co. is conducting the first phase of this effort—design and component development. Results have indicated that the second phase—prototype generator fabrication and testing—will be started during 1966, with a fueled 60-watt prototype being made available in 1967 for environmental testing in operational situations to validate the design characteristics and assure their reliability and stability.

With the use of many of the same advancements as are being incorporated in SNAP–21, the SNAP–23 generators are also expected to produce reliable, long-lived, and economical electrical power, but at higher power levels. Terrestrial generators must be economically competitive with other more conventional power sources if they are to be widely used. The SNAP–23's, therefore, are being especially designed for ease of fabrication, ease of maintenance, and extended operating lifetimes. It is anticipated that these features, together with greatly increased conversion efficiency, will eventually lower production costs to the point where these generators can compete economically with conventional portable power supplies, especially in the remote and semi-remote areas of the world.

SNAP–15. In addition to the above two major development efforts, work is also in progress to improve and upgrade the SNAP–15 one-milliwatt generator being developed for possible use with control instrumentation. Current efforts are directed toward perfecting an outer canister seal and an improved electrical insulation for the generators. It is anticipated that greatly enhanced generator life will result from these improvements.

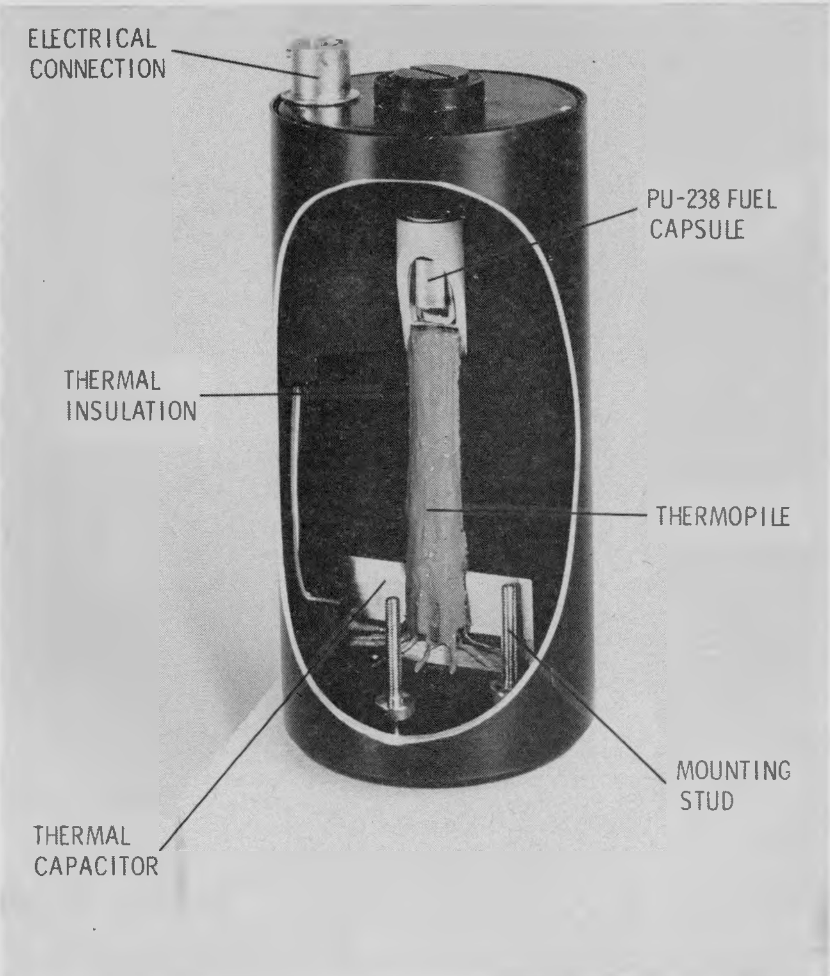
Reactor Units

Prior to initiating the development of auxiliary nuclear power reactors for terrestrial or oceanographic use, application and powerplant definition studies must be conducted. These studies, the development of the required reactor technology, and the definition of the future auxiliary power reactor program will begin in 1966.

SNAP SAFETY PROGRAM

Extensive safety analysis work has been conducted for SNAP isotopic generators. Containment and shielding of the nuclear fuel in these isotopic units to meet the requirements of normal operation and all credible accidents has constituted the heart of the SNAP safety program.

Containment of the fuel is possible by using a suitable metallic fuel container. Only after a fuel capsule has been actually fabricated of highly corrosion-resistant and chemically compatible metals and satisfactorily passed a specified series of severe qualification tests, including fire, thermal shock, vibration, hydrostatic pressure, weld



SNAP–15A. The SNAP–15A radioisotope thermoelectric generator is a rugged, compact, power supply producing 1 milliwatt (0.001 watt) of power at a voltage level of 6 volts. Weighing less than a pound, and of beer-can size, this unit uses plutonium as its nuclear fuel. Developed for the AEC by the General Atomic Division of General Dynamics, San Diego, Calif., this device is capable of supplying its rated power under extreme conditions of temperature, shock, and vibration for periods of up to 5 years or longer. Fueled prototype units have been fabricated and successfully tested to demonstrate the adequacy of design. Devices similar to this design have potential for use in providing small individual power supplies for critical components in electronic assemblies, or in providing power to a series switch for a long-lived system with intermittent activation.

penetration, metallographic, and, in some cases, impact tests, is its design considered acceptable.

Radiation shielding for personnel protection is incorporated within the generator. This protection is normally provided by surrounding the fuel capsule with a very high-density metal, typically exemplified by lead, in such a fashion that the capsule and the protective shielding are maintained as an integral unit even under extreme conditions.

Additional studies and tests are conducted to select generator materials that will not undergo galvanic corrosion in sea water and release radioactive material to the sea. Thorough testing and analysis is also conducted on other components of a generator—pressure vessels, feed-through connectors, and thermal insulation—to assure that the materials and generator design meet the stringent nuclear-safety needs of these unique power supplies.

Before a radioisotope generator is transported to an operational site, a very extensive and thorough safety analysis is conducted. In this analysis, all the test and analyses data produced during the generator development are reviewed. A site-safety analysis is also made that evaluates the credibility of various postulated accidents at the site during implantment and operation. In addition, several independent groups are asked to make a nuclear safety evaluation of the generator operating at its intended location. Only after these various analyses have shown the generator to be safe can it be installed.

It is because of this continuing analysis of the safety of generators and missions, and by backing up analysis with comprehensive testing programs, that the many radioisotope generators now in service have a spotless safety record.

Chapter 10

MILITARY REACTORS

In the Army reactors program, four powerplants continued operation throughout the year; one project, the barge-mounted nuclear powerplant, is nearing completion; and two projects were terminated. The naval nuclear propulsion program continued to meet its objectives.

NAVAL PROPULSION REACTORS

The objective of the naval nuclear propulsion program continues to be the design and development of improved naval nuclear propulsion plants for installation in ships ranging from small submarines to large combatant surface ships.

Nuclear Fleet

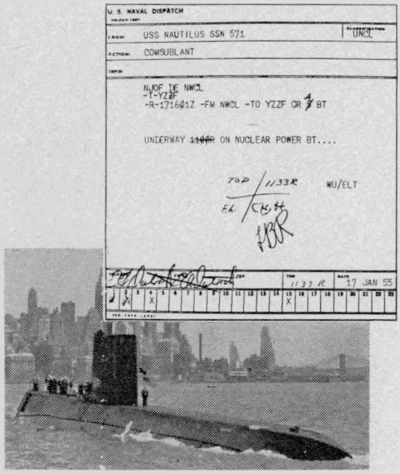
To date, Congress has authorized 99 nuclear-powered submarines, of which 56, including 34 of the Polaris missile-launching type, are in operation. The aircraft carrier *Enterprise*, the guided missile cruiser *Long Beach*, and the guided missile destroyer leader *Bainbridge* are also operational, and a second guided missile destroyer leader, *Truxtun*, has been launched.

The *Enterprise* completed her first general overhaul and refueling of all eight reactors in July 1965. *Enterprise* and *Bainbridge* joined the 7th Fleet in the Pacific for assignment off South Vietnam in late 1965.

New Project

As announced by the President in April 1965, the AEC and the Department of the Navy are jointly developing a nuclear-powered deep submergence research and ocean engineering vehicle. Nuclear propulsion in a vehicle of this nature will provide greater independence from surface support ships and essentially unlimited endurance of propulsion and auxiliary power for detailed exploration of the ocean.

UNDERWAY ON NUCLEAR POWER: 1955–1965



January 17, 1955

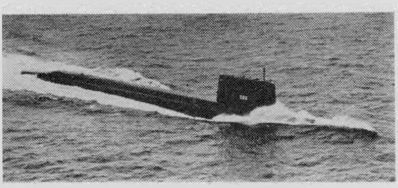
U.S.S. *NAUTILUS*

went to sea for the first time—"Underway on Nuclear Power"—at 11 a.m. *Nautilus,* shown here entering New York Harbor in 1956, made the first submerged polar transit, submerging off Point Barrow, Alaska, on August 1, 1958, and surfacing 96 hours later in the Greenland Sea, 1,830 miles from Point Barrow.

March 17, 1959

U.S.S. *SKATE*

became the first ship to surface at the North Pole. During the voyage *Skate* traveled 11,495 miles, 11,220 of which were fully submerged and 3,090 of which were under the polar ice cap.



May 10, 1960

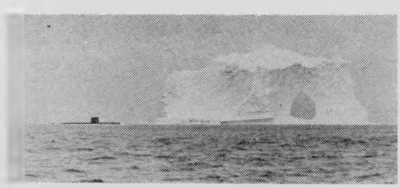
U.S.S. *TRITON*

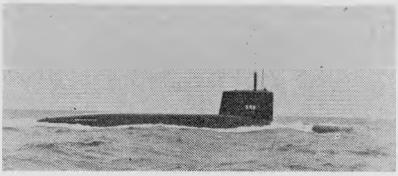
completed the first submerged circumnavigation of the world, following the route of Ferdinand Magellan—36,000 miles in 84 days.

August 25, 1960

U.S.S. *SEADRAGON*

charted the Northwest Passage. Surfaced at the North Pole where the crew played softball.





November 15, 1960

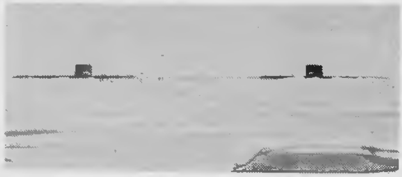
U.S.S. *GEORGE WASHINGTON*

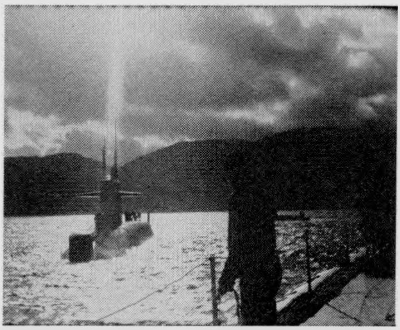
deployed in the Atlantic on the initial armed Polaris missile patrol.

August 2, 1962

U.S.S. *SEADRAGON* and U.S.S. *SKATE*

conducted the first rendezvous beneath the ice at the North Pole to conduct antisubmarine warfare exercises; surfaced together through an opening at the geographical North Pole.





April 14, 1963

U.S.S. *SAM HOUSTON*

entered the Mediterranean to begin the first Polaris patrol in that sea. The ship is shown here as she returned to the Holy Loch, Scotland, upon completion of this patrol.

October 3, 1964

U.S.S. *ENTERPRISE*
U.S.S. *BAINBRIDGE*
and U.S.S. *LONG BEACH*

comprising the world's first nuclear-powered task force, completed "Operation Sea Orbit", a 2-month 30,500-mile around-the-world cruise which demonstrated the Navy's ability to send these high-speed ships anywhere in the world without logistic support.

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Research and Development

Throughout 1965, research and development continued on development of advanced longer-life naval reactor cores and on improvement of naval reactor systems, components, materials, and operating techniques. Emphasis was placed on design and development of a reactor for application to a two-reactor nuclear-powered attack aircraft carrier on a schedule which will permit its installation in the next aircraft carrier planned for construction.

Testing of advanced longer-life reactor cores commenced at two land prototypes—the Submarine Advanced Reactor (S3G) at West Milton, N.Y., and the Natural Circulation Reactor (S5G) at the National Reactor Testing Station (NRTS), Idaho. Fabrication of an additional advanced longer-life core for surface ship application was completed, and its testing will commence at the Large Ship Reactor (A1W) prototype plant at NRTS in 1966.

ARMY REACTORS

Status of Reactor Plants

McMurdo Station, Antarctica. After the summer work season, during which a new core was installed in the Portable Medium Power Plant No. 3A (PM-3A), the reactor resumed carrying the full McMurdo Station, Antarctica, electrical load on March 31. From that time through December 18, the PM-3A was available for power operation 78.5 percent of the time. During this period, it supplied approximately five million kilowatt-hours of electrical power and recorded continuous power runs of 1,096,993, and 682 hours.

Fort Greely, Alaska. On October 13, the Stationary Medium Power Plant No. 1A (SM-1A) at Fort Greely, Alaska, was shut down to load its third core and conduct annual maintenance. It is scheduled to return to power operation early in January. As of December 11, the reactor had, during 1965, produced 5.4 million net kilowatt-hours of electrical power and 82.7 million pounds-per-hour of steam for space heating, with a total accumulated burnup of 14.11 megawatt-years on the first core and a total accumulated burnup of 12.64 megawatt-years on the second core. The SM-1A had achieved an availability factor of 69.8 percent as of December 11.

Fort Belvoir, Va. The Stationary Medium Power Plant No. 1 (SM-1) at Fort Belvoir, Va., remained shut down throughout the major portion of 1965 while major building modifications, which were started in September 1964, continued. Plant operation resumed in mid-September 1965. The reactor operated in its customary intermittent manner in fulfillment of its normal training mission until December 17 when it was shut down for scheduled maintenance. It was returned to power operation on December 29.

National Reactor Testing Station, Idaho. Preparations for conducting a series of tests on the pressure vessel of the Portable Medium Power Plant No. 2A (PM–2A) to examine the nil ductility (embrittlement) phenomenon as a result of long-term irradiation started in January, and the pressure vessel is now being readied for a static pressure test. The test program will include destructive testing of the vessel. The PM–2A had been dismantled and returned to the United States in August 1964 after almost three years of operation at Camp Century, Greenland. The remainder of the PM–2A primary reactor system is in storage at NRTS, and the power conversion secondary system at New Cumberland Army Depot, New Cumberland, Pa., pending commitment by the Army in support of another mission.

Sundance, Wyo. The Air Force continued throughout the year to operate the Portable Medium Power Plant No. 1 (PM–1) at the Sundance Air Force Radar Station, Wyo. As of October 31, the plant had, during 1965, supplied 4.6 million kilowatt-hours of gross electrical power and 2.6 million equivalent kilowatt-hours of station heat load. The first core had an accumulated burnup of 12.42 megawatt-years through October 31. Control rod actuator thimble corrosion and malfunctioning of the pressure relief valves are the major operational problems of this reactor. The corrosion problem has been the primary cause of reactor down-time since the plant was accepted by the Air Force in November 1962. Interim measures have been applied to correct these problem areas until a permanent solution is attained. As a result of these interim measures, the PM–1 had a plant availability factor, through October 31, of 86.8 percent for the year.

MH–1A (Sturgis)

Construction of the Army's barge-mounted nuclear powerplant continued throughout the year. Completion is scheduled in early 1966.

Projects Cancelled

MCR. The Military Compact Reactor (MCR) base technology program was terminated effective June 30, following a joint determination by the AEC and Army that its continuation was not warranted in view of higher priority programs in the AEC. Topical reports on fuels and materials investigations conducted under the program have been published.

ML–1. The joint AEC-Army program for the development of low-power, mobile gas-cooled reactor systems for the military will be phased out during fiscal year 1966. Principal activities of the program were conducted at the National Reactor Testing Station (NRTS), Idaho, and at the Aerojet-General Nucleonics plant at San Ramon, Calif. Phaseout began in late October following a Commission review of the program in which major considerations were the current status of the ML–1 development and the Army's position that ML–1 type power systems were too costly for early procurement.

During the approximately nine years that the program has been in effect, it has achieved many significant developments in the field of closed-cycle gas-cooled reactor systems. Among these were the operation of the ML–1 plant at NRTS at rated turbine speed for more than 3,000 hours, and operation of the reactor for more than 7,500 megawatt-hours. The technology associated with the design, fabrication, and testing of high-temperature gas-cooled reactors and the compact Brayton closed-cycle power conversion components was greatly enhanced by the work done in the program. Fuel elements that can operate at temperatures above 1,750° F. in excess of 10,000 hours were developed. Many of the power conversion components developed could have use in small electric power source applications, both nuclear and nonnuclear.

Chapter 11

ADVANCED REACTOR TECHNOLOGY AND NUCLEAR SAFETY RESEARCH

During the year, the advanced reactor technology program continued to make progress in providing basic information applicable to the development and improvement of reactor systems of all types. In mid-August the Commission appointed a steering committee, composed of top AEC officials, to coordinate the reactor safety research program.

ADVANCED REACTOR TECHNOLOGY

Development of Research and Test Reactors

The advanced reactor technology program includes research and development work necessary for the design and construction of advanced reactor facilities for research and irradiation testing. Important current projects include the 100-thermal-megawatt High Flux Isotope Reactor (HFIR) at Oak Ridge, the Argonne Advanced Research Reactor (AARR), the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory, the 250-thermal-megawatt Advanced Test Reactor (ATR) in Idaho, and the High Temperature Lattice Test Reactor (HTLTR) near Richland, Wash.

HFIR. During the year, HFIR construction was completed, and operation of the reactor at powers up to 50 thermal megawatts (Mwt) was achieved. Post-operational development work is being continued to reduce fuel element fabrication costs and increase the fuel element cycle time. (See also Chapter 14—Facilities and Projects for Basic Research.)

AARR. Engineering design of the AARR (also referred to as the A^2R^2) was started with the award of a contract in March to Burns & Roe, Inc., of New York City, to perform architect-engineer services. Operation of this advanced research reactor facility at Argonne National Laboratory is expected to start in 1970. Development tasks are in progress to provide the design bases for fuel elements, control blades, and other reactor internals. In 1965, critical experiments were conducted in which nuclear mockups of the core at several stages of burnup were studied. (See also Chapter 14—Facilities and Projects for Basic Research.)

HFBR. Construction of the 40-thermal-megawatt High Flux Beam Reactor was completed and criticality achieved in October 1965. This heavy water moderated and cooled research reactor incorporates design features to reduce the fast neutron background while enhancing the low energy neutron flux to the beam tubes from which streams of neutrons are extracted for basic research external to the reactor. In addition to the beam tubes, irradiation facilities are provided in the reflector and central core areas of the HFBR where a maximum flux of more than a quadrillion (1.6×10^{15}) neutrons per square centimeter per second will be provided at full power.

ATR. The 250-thermal-megawatt Advanced Test Reactor (ATR) under construction at the National Reactor Testing Station in Idaho is scheduled for initial startup early in 1966.

System tests conducted in January 1965 disclosed leaks in two of the four primary heat exchangers. Subsequent examination indicated that excessive vibration at certain flow conditions resulted in abrasive wear which damaged about 6 percent of all the tubes in the four exchangers; the remaining 94 percent of the tubes were considered reusable. The Westinghouse Electric Corp., Sunnyvale, Calif., was selected in June to dismantle, redesign, and repair the four exchangers, and to design and fabricate a fifth exchanger for excess coolant capacity and redistribution of the pressure at a lower flow rate. It was estimated that about a year would be required to complete this work.

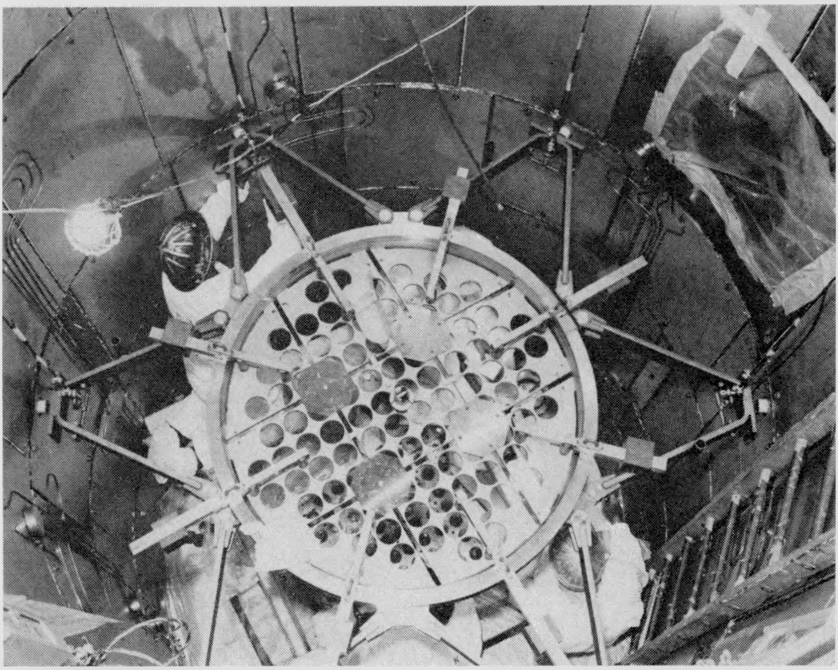
The heat exchanger modification did not significantly affect the schedule for ATR operation, since various system tests and low-power physics studies were performed concurrently with the modification. Criticality of the ATR is expected early in 1966, and attainment of full power in the summer of 1966.

Design and procurement continued throughout the year on a 2,000° F. helium-cooled irradiation loop to be installed in the ATR, with completion expected in 1967.

HTLTR. Construction of the High Temperature Lattice Test Reactor (HTLTR) for the Pacific Northwest Laboratory at Richland, Wash., is expected to be completed in 1966. The HTLTR will be used to obtain fundamental reactor physics data for high-temperature, solid moderator reactor lattices, and nuclear engineering data for the support of design and safety analyses of high-temperature power reactors. Extensive testing on the materials to be used in the reactor was performed throughout 1965.

Reactor Experiments

During the year, research and development continued on a number of advanced reactor experiments which show promise of contributing important technical information pertinent to the ultimate exploitation of the following specific reactor concepts for varied applications: the Experimental Beryllium Oxide Reactor (EBOR), for investigating beryllium oxide as a moderator in high-temperature gas-cooled reactor systems; the Ultra High Temperature Reactor Experiment (UHTREX), for studying the fission product retention characteristics of high integrity ceramic fuels and the problems of dealing with



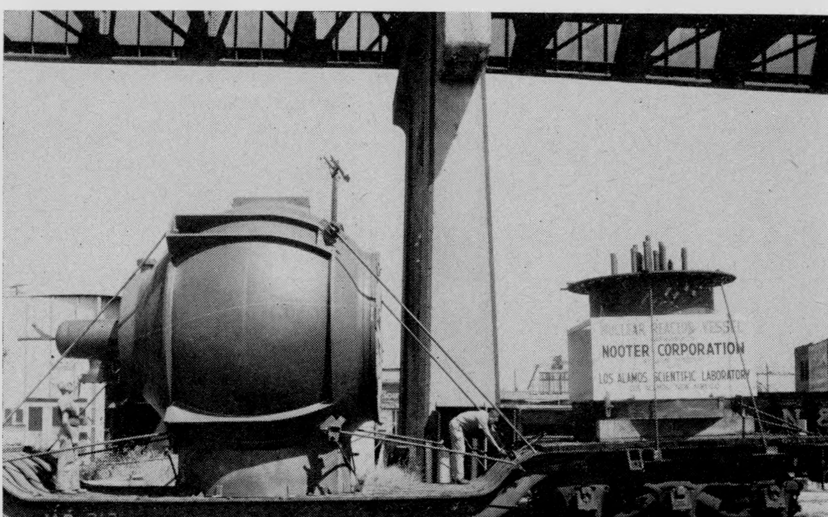
EBOR Completed. Workmen are shown installing the lower core support for the Experimental Beryllium Oxide Reactor (EBOR) which was 99 percent complete in the fall of 1965 at the National Reactor Testing Station in Idaho. EBOR is an experiment on high-temperature, helium-cooled, beryllium-oxide-moderated reactors which could be used with a closed-cycle gas turbine or steam cycle. The reactor experiment was designed and will be operated for the AEC by General Atomic Division, General Dynamics Corp., San Diego.

contaminated gas reactor systems; and the Fast Reactor Core Test Facility (FRCTF) for studying the problems of molten plutonium fuel systems for fast breeders.

EBOR. Construction of the EBOR at the National Reactor Testing Station was 99 percent completed during 1965, and initial criticality should be attained by mid-1966. A program of low-power testing will precede achievement of full power (10 thermal megawatts) and the initiation of extended reactor operation by General Atomic.

UHTREX. The three-thermal-megawatt UHTREX at Los Alamos Scientific Laboratory is scheduled for completion of construction in mid-to-late 1966, with criticality planned by the early part of 1967.

FRCTF. Construction of the FRCTF building at Los Alamos is expected to be finished in 1966, and installation of the initial reactor experiment will begin immediately thereafter. Criticality is expected to occur in 1970. The reactor will also contribute information useful to the Los Alamos Molten Plutonium Program (LAMPP).



UHTREX. The reactor vessel for the UHTREX (Ultra High Temperature Reactor Experiment), shown here at the beginning of its journey, arrived at the Los Alamos Scientific Laboratory, N. Mex., on August 23, 1965. The vessel, which weighs 55 tons, will house a reactor designed to evaluate the problems of operating a helium-cooled reactor at temperatures up to 2,400° F. including the performance of unclad fuel elements fabricated of graphite and uranium carbide.

Other concepts. Analytical and experimental evaluation of the Paste Blanket Reactor concept (Atomic Power Development Associates, Detroit, Mich.) continued during 1965, as did work on the Settled Bed Reactor (Brookhaven National Laboratory).

Direct Conversion

Research and development effort on the direct conversion of nuclear energy to electrical energy has been directed primarily to fission-heated thermionic converters. During 1965, tests were successfully conducted over longer time periods than those previously attained; several simulated fuel elements, consisting of three-cell assemblies within a common envelope, were operated in-pile with fission heat. Increased emphasis was placed on thermionic reactor analysis to determine optimum cell dimensions and component design. This work is being carried out at General Electric's Vallecitos Atomic Laboratory, near Pleasanton, Calif., and at the General Atomic Division of General Dynamics Corp. in San Diego, Calif.

NUCLEAR SAFETY RESEARCH AND DEVELOPMENT

In addition to project-oriented safety efforts, the AEC is engaged in a general nuclear safety research and development program to generate and apply information which will insure the safe development, design, construction, and operation of nuclear reactors and nuclear devices in environments ranging from the ocean depths to outer space. The major areas covered by this program are: (*a*) reactor safety research and development, (*b*) engineering field tests, (*c*) effluent control research and development, and (*d*) analysis and evaluation. During 1965, a broad new effort, involving all four of these areas, was initiated. This effort entails planning and special testing to provide additional assurance that large nuclear powerplants of the future may be safely located in or near high population zones.

Steering Committee on Reactor Safety Research

In mid-August, the Commission appointed a steering committee, composed of top AEC officials and chaired by the Assistant General Manager for Reactors, to assure that the experimental information developed in the reactor safety research and development program is keyed to the needs of the continuing development of the nuclear industry and to the requirements of the AEC's regulatory program. The principal functions of this committee will be to (*a*) review, evaluate, and recommend priorities in reactor safety research; (*b*) review and evaluate the specific research programs now in progress or which may be proposed; (*c*) review and encourage the development of procedures and programs through which the information generated in the reactor safety research program can be promptly disseminated and used by the nuclear community; (*d*) review and evaluate plans and programs for the development of criteria, standards, and codes for nuclear reactor safety, and act as a focal point for coordination of the work of the regulatory and operational staffs of the AEC on criteria, standards, and codes; and (*e*) carry out such other specific assignments and functions as they may be assigned.

Reactor Safety Research and Development

SPERT program. The SPERT (Special Power Excursion Reactor Test) program, conducted for the AEC by the Phillips Petroleum Co. at the NRTS, is devoted to the experimental and theoretical investigation of reactor excursion phenomena.

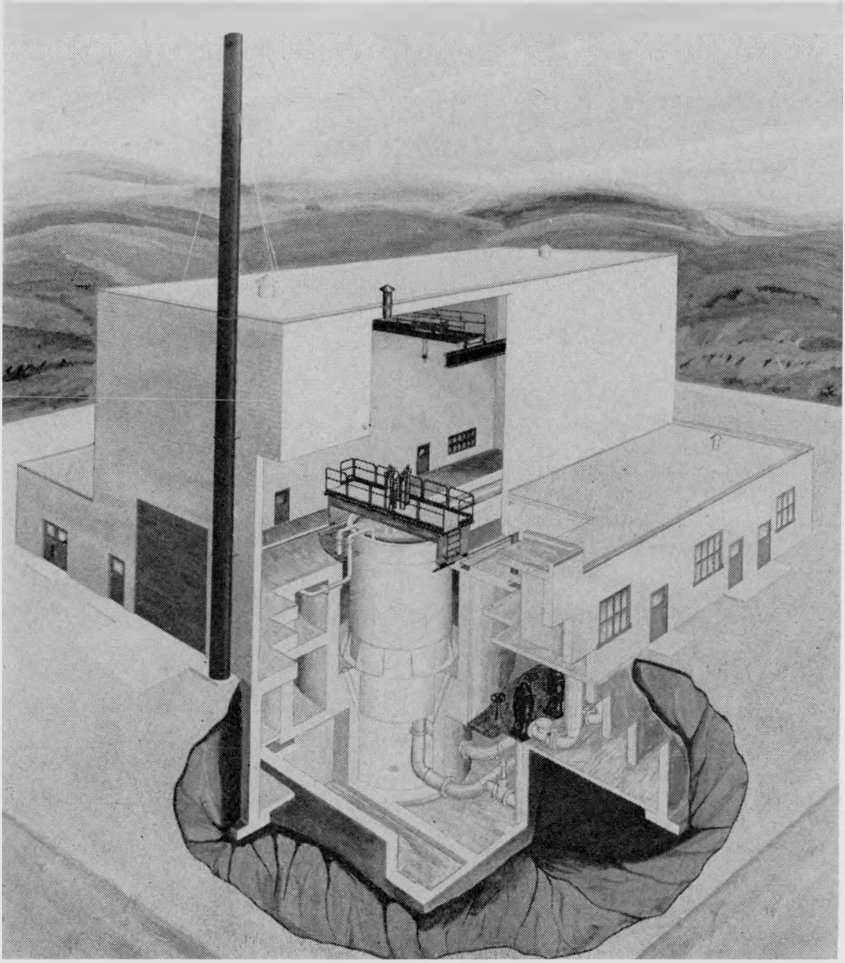
During the year, the SPERT–III, a high temperature and pressure facility, was loaded, after appropriate modifications, with a low-enrichment uranium oxide, stainless steel-clad core of the type used in current power reactors. A program to study the self-shutdown effects of this core at various conditions representative of pressurized water reactor operation was initiated.

A program of capsule experiments on the phenomena associated with the rapid meltdown of reactor fuel samples was initiated in the Capsule Driver Core (CDC) utilizing the SPERT–IV facility. This program will be a precursor to the more extensive subassembly meltdown program planned for the Power Burst Facility.

Power Burst Facility. The design of the Power Burst Facility (PBF) was modified to include steady power operation up to 20 thermal megawatts in addition to its capacity of testing reactor materials under transient conditions. This addition will permit the study of long-term loss-of-flow, loss-of-coolant effects, as well as transient phenomena. Construction at NRTS of the PBF began late in 1965 by Howard S. Wright & Assoc., Seattle, Wash., and is expected to be complete in about two years.

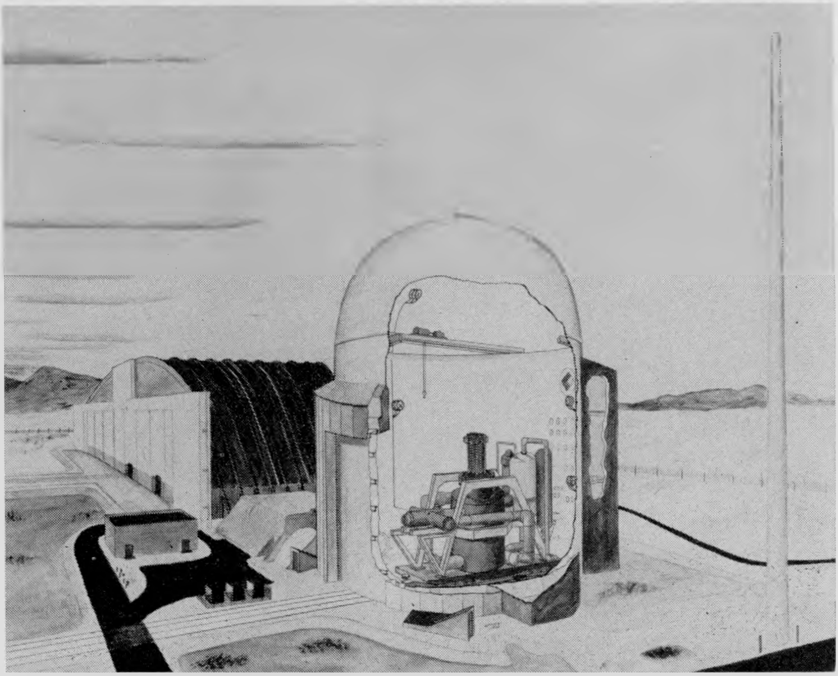
Engineering Field Tests

Engineering field tests are conducted for both terrestrial and aerospace application to assess the predicted behavior of complete nuclear systems when subjected to both normal and abnormal operating conditions.



Power Burst Facility. Construction was begun in late 1965 on the Power Burst Facility (PBF), shown in this artist's conception, at the AEC's National Reactor Testing Station in Idaho. The $9.2-million safety test facility will include a pool-type pulsed reactor (a type of research reactor which produces short, intense surges of power and radiation and a much higher neutron flux than could be tolerated in steady-state operation). It will also be able to operate at steady-state power levels up to 20,000 kilowatts for short periods before initiation of a power burst. The reactor is being designed to produce transient power bursts capable of melting test fuel samples without damaging the facility itself, and thus lead to a better understanding of phenomena which affect the reactivity and stability of a reactor's system. The PBF is to be part of the Commission's reactor safety testing program and will be operated for the AEC by Phillips Petroleum Co.

Terrestrial systems. Detailed design of the Loss of Fluid Test (LOFT) facility was essentially completed in December by Kaiser Engineers, Oakland, Calif. A contract to fabricate the containment vessel for the LOFT facility, which will be located at NRTS, was awarded in January to Pittsburgh-Des Moines Co., Pittsburgh, Pa., by M. W. Kellogg, prime contractor for the construction of the LOFT facility. The reactor vessel fabrication contract was awarded in October to the P. F. Avery Corp., Billerica, Mass. Construction of the facility, expected to be complete in late 1967, had passed the 10 percent completion mark by December. Within this reusable test facility, the flatcar-mounted LOFT reactor system will be used to conduct a loss-of-coolant test on a 50-thermal megawatt pressurized water reactor. Following an extensive nonnuclear test program, the



LOFT Facility. Construction reached ground level during 1965 on the Loss of Fluid Test (LOFT) Facility, depicted here by an artist's conceptual drawing. Below-ground-level construction started in October 1964, and LOFT is expected to be operational in late 1967. A cutaway section of the containment shell shows the reactor safety experiment mounted on a double-width flatcar or dolly which can be pulled by shielded locomotive over quadruple rails to a nearby "hot shop" for post-test analysis. One of the principal reasons for building LOFT is to demonstrate the safety of water-cooled power reactors by deliberately triggering a runaway power burst caused by major coolant pipe rupture, a highly improbable but the worst conceivable accident for such reactors. LOFT is part of the safety test engineering program conducted for the AEC by Phillips Petroleum Co.

first nuclear test will be conducted in the spring of 1969. Supporting research and development programs were established at national laboratories and AEC field installations to test equipment and special instrumentation, and to perform analytical studies for predicting the sequence and magnitude of events expected to occur in the LOFT tests.

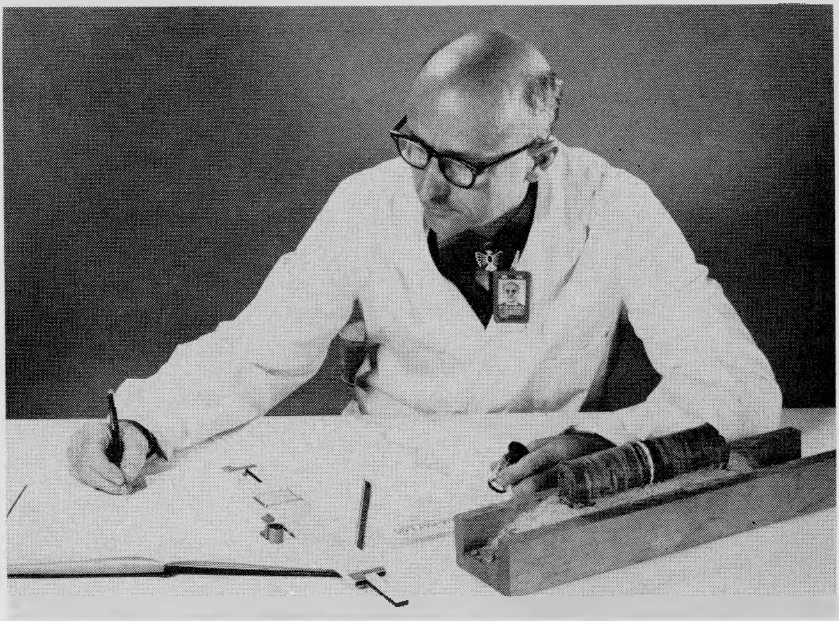
Aerospace systems. Transient experiments on uranium-zirconium hydride reactors for space nuclear power applications continued during the year at the National Reactor Testing Station. These experiments, conducted by the Phillips Petroleum Co. with the support of Atomics International and Edgerton, Germeshausen, and Grier, Inc., are investigating the kinetic behavior of SNAP reactors when subjected to large and rapid reactivity insertions. The SNAPTRAN–1 series of experiments to investigate the behavior of a reactor in the nondestructive region was completed in September 1965. SNAPTRAN–2, to follow, will project the investigations into the destructive range.

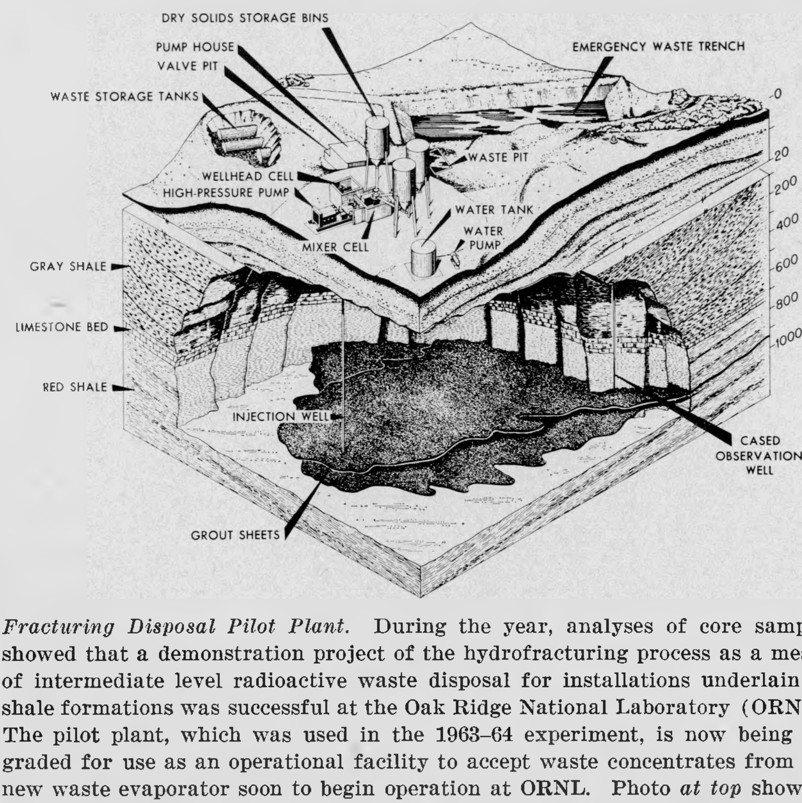
A series of full-scale re-entry flight tests, supported by applied research, have been pursued to determine the effectiveness of using the heat generated by the atmosphere during re-entry to burn up nuclear systems. This burnup, with the subsequent wide dispersal of the debris in the atmosphere, would thus serve as a safe means for radioactive fuel disposal.

During 1965, further analysis was made of the data acquired from re-entry flight tests conducted on a simulated SNAP–10A reactor in May 1963 and October 1964. This flight analysis has provided proof that the specific systems tested would disassemble as designed, and has substantially increased confidence in the ability to predict re-entry heating effects from theoretical analysis.

Effluent Control Research and Development

The programs in effluent control research and development are directed toward the safe management and disposal of various types of radioactive wastes resulting from nuclear reactor operations, the quantitative determination of the behavior of these residual radioactive effluents in the environment, and the development of engineering criteria associated with the environmental aspects of nuclear technology operations. This work provides a basis for defining and controlling the ultimate fate and possible effects of radioactivity in the environment.





Fracturing Disposal Pilot Plant. During the year, analyses of core samples showed that a demonstration project of the hydrofracturing process as a means of intermediate level radioactive waste disposal for installations underlain by shale formations was successful at the Oak Ridge National Laboratory (ORNL). The pilot plant, which was used in the 1963–64 experiment, is now being upgraded for use as an operational facility to accept waste concentrates from the new waste evaporator soon to begin operation at ORNL. Photo *at top* shows a →

High-level waste treatment. Construction and "cold" testing was completed of the Waste Solidification Engineering Prototype (WSEP) plant at the Pacific Northwest Laboratory. A demonstration of several processes for solidifying high radioactivity level power reactor fuel reprocessing wastes is scheduled to begin early in 1966.

High-level waste storage. Construction phases were completed, and "Project Salt Vault" operation began in November at an abandoned mine of the Carey Salt Co. near Lyons, Kans. This two-year experimental project is designed to demonstrate the suitability of rock salt deposits for the long-term storage of solidified high-level radioactive wastes such as those from power reactor fuel reprocessing. Since such solid wastes are not currently available, canned irradiated fuel elements from the Engineering Test Reactor are being shipped from the National Reactor Testing Station and installed in the Kansas facility in order to simulate the radiation and heat characteristics of future solidified wastes. The canned fuel assemblies will be exchanged for freshly-irradiated assemblies every 6 months for a period of two years to insure a high radiation dose to the salt for determining the long-term effects of radiation on salt formations. At the end of the two-year program, sufficient data should be available on which to base a determination of the feasibility of using underground salt mines for the full-scale disposal of high-level radioactive waste.

Filter testing device. A chemical method of analysis has been developed by the Harvard Air Cleaning Laboratory which allows in-place checking of the efficiency of the air cleaning (halogen removal) system aboard the NS *Savannah* with immediate interpretation of test results. The method will allow testing of the *Savannah*'s iodine-adsorption system before entry into any port to further demonstrate the safety of its nuclear operations. Previously, the filter tests required radiometric analyses which were performed by land-based laboratories; hence, the results were not immediately available.

Analysis and Evaluation

In the analysis and evaluation program, increased emphasis has been given to assuring that objectives of separate programs are di-

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Core sample from hydraulic fracture waste disposal experiment being examined. The thin, white vein in the sample, *lower right*, is the layer of radioactive grout. Core samples were useful in determining the spread of wastes through the bedded shale and the size of the individual grout veins. The *lower* drawing is a cutaway illustration of the hydraulic fracture radioactive waste disposal experiment showing the path of wastes as they are injected into impermeable sheets of bedded shale about 700 to 1,000 feet below the ground's surface.

rected toward safety-related needs of particular reactor systems in the most adequate and efficient way. Preliminary steps have been taken to assign to single management contractors the task of coordinating all related efforts in particular areas of endeavor in the program. A study of power reactor safety experience and system reliability has been completed. In its final phase is a study attempting to correlate measurable personal characteristics and attributes with those of the ideal operator. A study to formulate a probabilistic methodology for the safety evaluation of commercial power reactor systems is also in its final stages. Direct participation in national standards committees has increased. New programs in the collection and dissemination of safety-related information through the Nuclear Safety Information Center (see Table 2, Appendix 6) have been initiated.

Chapter 12

THE PLOWSHARE PROGRAM

Progress in the AEC's Plowshare program to develop peaceful applications for nuclear explosives can be viewed as resulting from three separate but interrelated efforts: Research and development in the laboratory, field experiments, and studies and demonstrations of applications in conjunction with groups which would make use of nuclear explosives. During 1965, advances occurred mainly through studies and development of plans for Plowshare applications and through research and development based on data gathered during the year from seven 1964 field experiments and from experiments conducted in other programs such as the AEC–DOD Vela Uniform Salmon event. Only one Plowshare field experiment, a cratering experiment called Palanquin, was conducted in 1965.

Companies in the natural resources fields are becoming increasingly interested in contained nuclear explosions for underground engineering applications. Several companies are evaluating the possibilities for the use of nuclear explosives in their operations. As a result of such evaluations, the El Paso Natural Gas Co., Kennecott Copper Corp., and the Columbia Gas System Service Corp. have joined with the AEC in feasibility studies of applications.

POSSIBLE APPLICATIONS

UNDERGROUND ENGINEERING

The underground engineering category of applications mainly involves contained nuclear explosions to fracture rock for a variety of industrial purposes, such as stimulating production of natural gas and oil; storing natural gas, other products, or wastes; and mining minerals by leaching or block caving. During 1965, a preliminary feasibility study of natural gas production stimulation was completed. Two other studies were begun on copper leaching and natural gas storage. The preliminary feasibility study of natural gas production stimulation resulted in a proposal from the El Paso Natural Gas Co.

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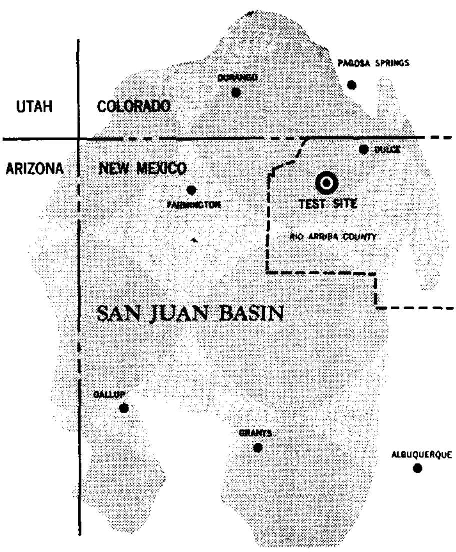
of El Paso, Texas, for undertaking jointly with the AEC, the experiment, called the Gasbuggy, proposed by the study group. These activities grew out of work that has been underway for several years with industry and other Government agencies, particularly the U.S. Bureau of Mines.

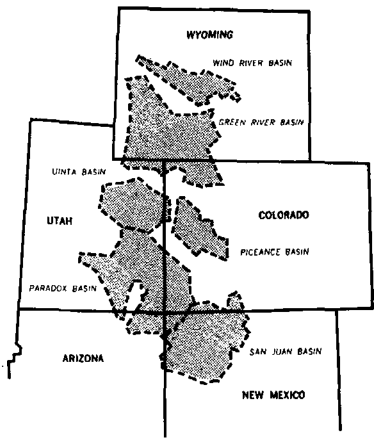
The Commission's policy of cooperating with industry in developing peaceful uses for nuclear explosives was most recently expressed by Chairman Seaborg on January 5, 1965, during hearings on the Plowshare Program before the Joint Committee on Atomic Energy when he said:

> "We believe that we now have enough data on underground engineering to warrant undertaking a demonstration project in cooperation with industry. We have had numerous discussions with several companies about possible joint projects. Our next step in this area will probably be guided by these interests." [1]

PROPOSED GASBUGGY TEST SITE



MAJOR BASINS OF THE ROCKY MOUNTAIN STATES



Gasbuggy Location. If nuclear fracturing proves commercially feasible for increasing production from a natural gasfield in the San Juan Basin (*left* above), it might be employed to great advantage in the other Rocky Mountains natural gas-producing fields (*right* above) which contain certain similar gas-bearing formations. Fracturing refers to cracking the formation rock to induce greater production. For best results from nuclear stimulation, a reservoir should be too "tight" for conventional methods of fracturing to be of much value, and thick enough to absorb the full effect of the nuclear explosion. An experiment, Project Gasbuggy, in the San Juan Basin was recommended in a report made by a study group comprised of representatives of El Paso Natural Gas Co., the San Francisco Operations Office of the AEC, and the U.S. Bureau of Mines.

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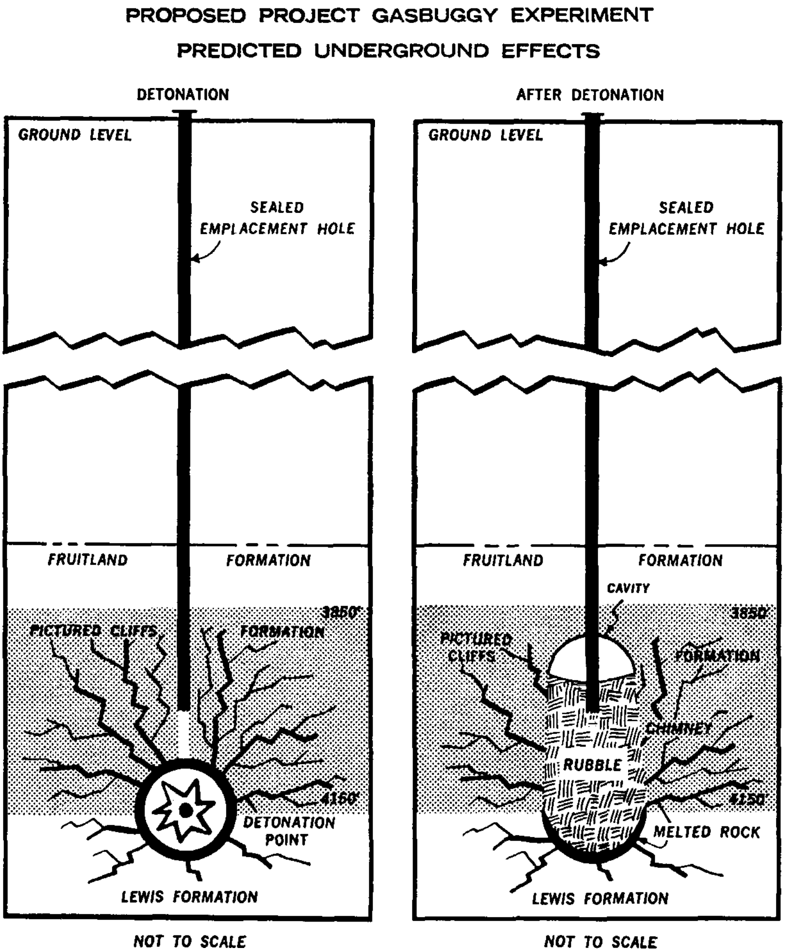
[1] "Peaceful Applications of Nuclear Explosives—Plowshare," hearing before the Joint Committee on Atomic Energy, January 5, 1965; available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, $2.

Project Gasbuggy

After 18 months of study, a technical group composed of representatives of the El Paso Natural Gas Co. (EPNG), the AEC San Francisco Operations Office (SAN), and the U.S. Bureau of Mines (USBM), assisted by the Lawrence Radiation Laboratory (LRL), Livermore, Calif., reported on May 14, 1965, their conclusion that



Gasbuggy Concept. The simplified drawings illustrate the anticipated effects of a nuclear explosion deep in the earth. Such an explosion has been proposed for Project Gasbuggy as a means of increasing production from a natural gasfield. At the moment of detonation (*left*), the explosion creates a giant cavity and fractures the rock in all directions. Shortly afterward (*right*), the ceiling of the cavity collapses, resulting in a rubble-filled "chimney." On June 17, the El Paso Natural Gas Co. (EPNG) proposed that Project Gasbuggy be carried out as a joint AEC-EPNG project.

the effects of a contained underground nuclear explosion could substantially increase the production of natural gas from low-permeability geologic formations. A specific gas reservoir formation of low productivity was chosen by the group for analysis to determine whether a field test was feasible and desirable. The analysis indicated that the effect of the explosion might well have a beneficial effect upon the producing characteristics of the formation. Estimates based largely upon anticipated fracturing effects indicate that production rate and producible reserves will be greatly increased by this treatment, thereby providing the means by which the natural gas resources of the United States could be more effectively exploited.

Subsequently, on June 17, EPNG proposed to the Commission that Project Gasbuggy be carried out as a joint experiment to obtain further data and to test specifically the effect of the explosion on the production of gas. After an extensive review of this proposal, the AEC has developed a concept for the experiment which would involve the detonation of a 20-kiloton nuclear explosive some 4,200 feet underground in an area about 55 miles east of Farmington, N. Mex. The company and USBM would participate in the evaluation of the effect of the experiment on the production of natural gas. In addition, the company would provide such things as an existing gas well on the site, geologic and production data, technical personnel, certain supporting services, and would assume the risk for damage to their neighboring property. If the experiment were carried out it would be the first use of a nuclear explosive for industrial purposes anywhere in the world.

Although the Commission has concluded Gasbuggy would be a valuable technical experiment in the development of the technology for the peaceful application of nuclear explosives, funds are not presently expected to be made available to the AEC in fiscal year 1967 to proceed with the experiment.

Other Underground Engineering Applications

Project Ketch. Based upon a general economic appraisal of gas storage in underground fractured zones made by nuclear explosions, the preliminary review of data on the volume of space made available by a nuclear explosion, and studies of the ability of the zone to hold pressure, the Columbia Gas System Service Corp. (CGSSC) has suggested a more detailed examination of this application. For this purpose, another feasibility study group has been formed with personnel from the CGSSC, SAN, and LRL. Since the technical feasibility of this application, called Project Ketch, depends greatly on the specific geologic formation involved, the group will carefully examine alternative, specific locations. The locations being examined are within the central portions of Columbia's service territory which includes parts of New York, Pennsylvania, Ohio, Maryland, West Virginia, Virginia, and Kentucky. The AEC's Nevada Operations Office will also participate in the preliminary study. This application is dependent upon the availability of appropriate geologic formations: a tight competent rock which would hold the gas in the nuclear chimney under pressure, or a permeable formation with a tight caprock in a suitable geologic structure.

Project Sloop. Technical studies, which have been underway for several years of *in situ* leaching of copper from low-grade ore fractured by nuclear explosions, reached the point during the year that the Kennecott Copper Corp. joined with the AEC and USBM in a specific preliminary feasibility study of this application, called Project Sloop. A study group was formed of personnel from Kennecott, SAN, USBM, and LRL to consider the feasibility of this application in the context of specific ore bodies, *e.g.*, a Kennecott-owned deposit near Safford, Ariz. The group is considering available data and will determine whether an experiment is necessary to acquire additional data. If so, the group is expected to propose a preliminary concept for such an experiment. The Oak Ridge National Laboratory is making a preliminary assessment of the feasibility and costs of processes which might be necessary to remove radioactivity from the processing plant. It is expected that the study will be completed during 1966.

Other applications. Discussions are continuing with other companies and groups to determine their interest in participating with the AEC in studies of other applications in the specific technical and economic framework of the user. (Progress in research and development related to these applications is described later in this section under the heading "Contained Explosions.") Applications of particular interest to AEC for detailed examination are waste disposal, recovery of oil from oil shale, and block caving mining applications.

EXCAVATION

When nuclear explosives are detonated underground at an appropriate depth, they excavate earth, leaving a crater useful for engineering purposes, *e.g.*, canals, harbors, or cuts for roads. Although the basic principle of explosive excavation has been demonstrated, a development program, consisting of several experiments, is considered necessary before the precision required for large engineering projects using explosives in high nuclear yield ranges can be undertaken. (The progress and status of this development program is discussed in a later section of this chapter entitled "Excavation Program.") Sufficient data now exist so that several projects have received preliminary study or are being studied. There were no further activities in 1965 in connection with Project Carryall [2] in view of the present incompatibility of the pace of the nuclear excavation development program and the interstate highway construction program.

Interoceanic Canal

Pursuant to Public Law 88–609, the President appointed, on April 18, 1965, a Commission to "make a full and complete investigation and study, including necessary onsite surveys, and considering national defense, foreign relations, intercoastal shipping, interoceanic shipping, and such other matters as they may determine to be important, for the purpose of determining the feasibility of, and the most suitable site for, the construction of a sea-level canal connecting the Atlantic and Pacific Oceans; the best means of constructing such a canal, whether by conventional or nuclear excavation, and the estimated cost thereof."

The Atlantic-Pacific Interoceanic Canal Study Commission has selected the Chief of Engineers, U.S. Army, as its Engineering Agent to conduct an Engineering Feasibility Study of three sea-level routes: The present Canal Zone, the Darien Region of Panama, and northwestern Colombia. The Engineering Agent will coordinate the activities of the Corps of Engineers, the AEC, and the Panama Canal Co. in this study. The AEC is responsible for collection and evaluation of data on meteorology, high altitude winds and temperatures, seismic wave propagation and structural response, and the land and sea environments. The Environmental Science Services Administration (which includes the U.S. Weather Bureau and the U.S. Coast and Geodetic Survey), the Sandia Laboratory, the Columbus, Ohio, laboratories of the Battelle Memorial Institute, and other specialized groups under contract to AEC will be responsible for implementing these programs. The AEC's requirements for data will be established by technical working groups, under the AEC's Nevada Operations Office. These groups will include scientific personnel from the Lawrence Radiation Laboratory, Livermore, the primary data collection agencies, and other expert groups.

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[2] See pp. 164–165, "Annual Report to Congress for 1964."

In addition, similar technical working groups have been established by the Corps of Engineers to develop technical criteria for nuclear excavation and engineering aspects of a sea-level canal. These groups will make use of data acquired from the AEC's nuclear excavation program. The Canal Study Commission, in its first annual report, pointed to the vital relation between data from further nuclear excavation experiments and its studies.

SCIENTIFIC

The principal scientific applications for nuclear explosives are: production of heavy elements, neutron physics measurements, and geophysical research.[3] Although research in heavy element production continued during the year, it has not reached the point where a specific project can be considered.

Important applications of nuclear explosives to scientific research occurred during the year under the weapons testing program (see Chapter 6—The Nuclear Defense Effort) and have proved the usefulness of the nuclear explosive as a tool for basic scientific research. For example, the Los Alamos Scientific Laboratory carried out several neutron physics experiments which added significant data to basic scientific knowledge. In addition, use of gamma rays from underground nuclear explosions for scientific research was suggested by the AEC's Savannah River Laboratory and research has begun on this possible new application.

EXCAVATION PROGRAM

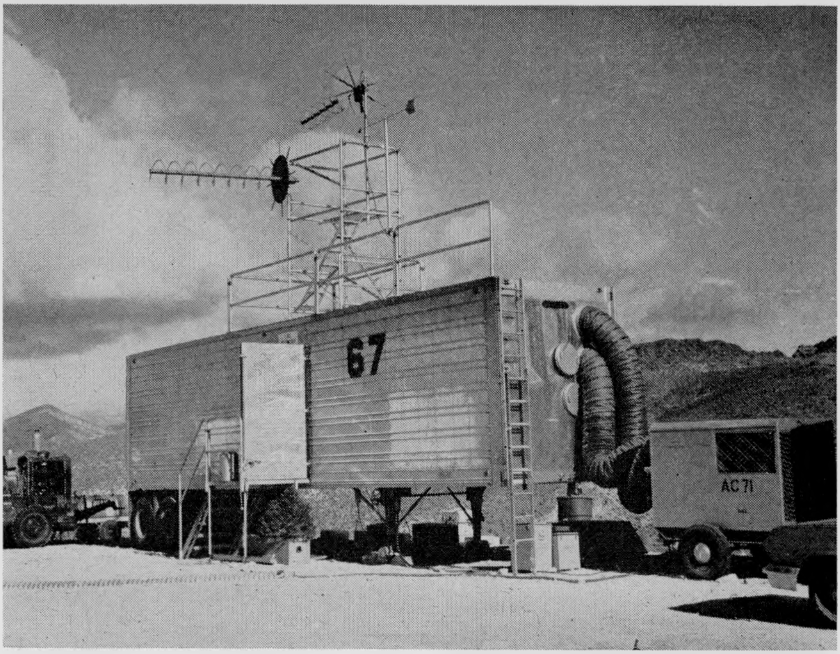
The program to develop a nuclear excavation technology, which was begun in 1962, continued to make steady progress during 1965. Significant activities included: the execution of a small-scale cratering experiment, called Palanquin; the acquisition of empirical data from cratering experiments in hard rock; the development of plans and diagnostic techniques for future cratering, device, and emplacement experiments; and progress in developing a theoretical understanding of cratering.

PROJECT PALANQUIN

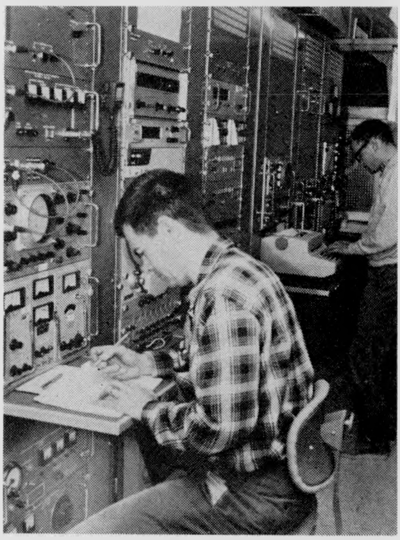
Palanquin was a four-kiloton excavation experiment in a hard, dry rock. It was detonated at a depth of 280 feet on April 14, at the Nevada Test Site (NTS), and was the third small-scale experiment

[3] See pp. 171–172, "Annual Report to Congress for 1964."

Gamma-Monitoring System. A versatile radio-linked system for spot monitoring ground and low-altitude gross gamma radiation over areas as large as 10,000 square miles has been developed by Lawrence Radiation Laboratory, Livermore. The system provides for transmission of radiation data, from unmanned sensor stations equipped with ionization chambers, by radiofrequency signal to a central data-recording station. Photo *above* shows an integrated unit containing both sensor and antenna. The conical cover is an integral part of the antenna and also acts as a roof for the ionization chamber. The chamber is also covered by a lead collimator. The sensor units are designed to operate unmanned and unattended as long as six weeks. Photo *below* shows a repeater station with its helical antenna directed at the data-collection trailer 15 miles away (see photos, *opposite page*). The 10-foot aluminum tower can be carried by one man and the antenna assembly by another. The system represents a decided advance in the technique of routine monitoring for airborne radioactivity and fallout patterns, such as might occur during Plowshare excavation detonations, and for meteorological phenomena. The system was first used in connection with the Plowshare Program's Sulky event of December 18, 1964.



Gamma-Monitoring System—continued. Signals received from the gamma radiation sensors (see photos, *opposite page*) are received at the control and data-collection trailer (shown *above*) which is topped by the helical antennas of the receiver-transmitter assembly. At the extreme left is the power generator, at the right the air conditioning and heating equipment. Photo *at right* shows inside the data trailer. Vertical panels (*left to right*) contain the radiofrequency-telemetry apparatus, the data-storage and the data-readout, the logic circuitry for programing and for interrogating the sensors, and an IBM typewriter.



since 1963 in the excavation program.[4] The main purposes of this experiment were: (*a*) to determine the ability of emplacement techniques developed in 1964 to reduce the amount of radioactivity released to the atmosphere from a deeply buried cratering-type detonation, (*b*) to obtain basic cratering data, and (*c*) to document and study the dispersion and fate of the small amount of radioactivity released.

Atypical Crater Formation

A crater was formed with an apparent radius of 120 feet and a depth of 70 feet. The average lip height was 21 feet. However, the Palanquin cratering behavior was not typical in comparison to other nuclear cratering experiments in hard rock, such as Danny Boy (1962) and Sulky (1964). It appears that the crater was formed by erosion of the broken material rather than by its throw-out. This behavior resulted in the escape of a small amount of radioactivity which would normally have been filtered by the broken material in the dome. The explosive performed as expected, and peak pressures and initial ground motion were very close to predicted values. The extensive data collection program in operation during the experiment provided unprecedented detail on the behavior of the experiment, especially the early cavity history and the dispersion and fate of the radioactivity.

Exploration of Explosion Region

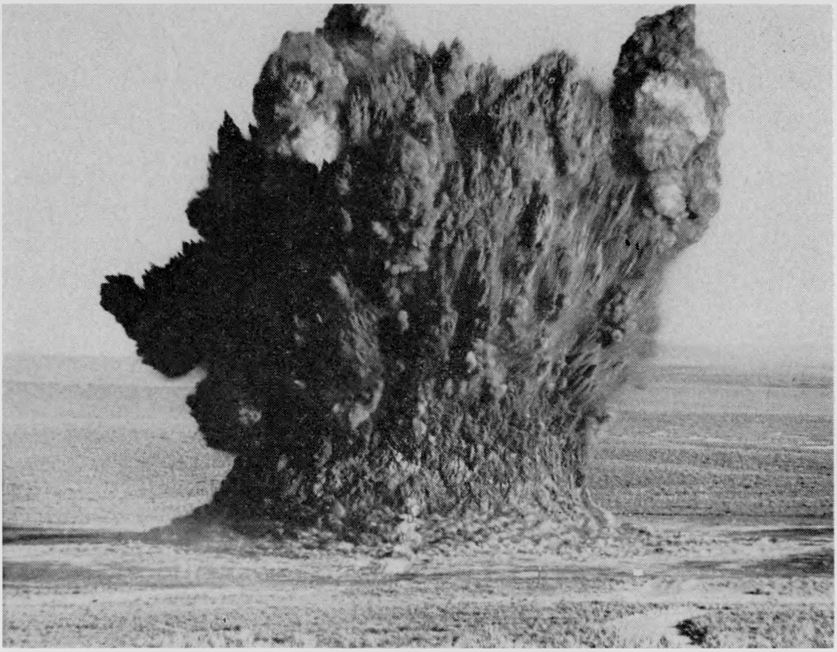
A post-shot exploration program, designed to obtain much needed data on the physical behavior of the emplacement technique used in the Palanquin cratering experiment, is underway. It involves mining a vertical shaft near the edge of the lip and extending a horizontal drift toward the underground region where the explosion occurred so that samples can be obtained and the shot-time cavity and true crater can be defined. The exploration will be completed in 1966.

OTHER CRATERING WORK

Pre-Schooner II Experiment

The Corps of Engineers' Nuclear Cratering Group (NCG) conducted a non-nuclear cratering experiment called pre-Schooner II, on September 30, in southwestern Idaho, to provide cratering efficiency data for the type of hard, dry rock present at the site. This

[4] See p. 157, "Annual Report to Congress for 1964," and pp. 211–213, "Annual Report to Congress for 1963."



Cratering Experiment. On September 30, as a part of the studies leading toward use of nuclear explosives for excavation work, the AEC and U.S. Army Corps of Engineers detonated a high explosive (nitromethane) charge in southwestern Idaho. The photo *above* was taken, by an Idaho Falls Times-News photographer, shortly after the 85 tons of liquid nitromethane high explosive were detonated some 71 feet underground, 50 miles south of Mountain Home. The resulting visible crater, shown *below*, was an average 78 feet deep and 228 feet across. The experiment, pre-Schooner II, was one of a series to provide basic hardrock cratering data and design information for a proposed (Project Schooner) nuclear excavation experiment.

experiment which used 85 tons of the chemical explosive nitromethane, will be of use in further planning for the proposed Schooner nuclear cratering experiment, an event in the joint AEC-Corps of Engineers excavation program (see "Future Excavation Experiments" item, later in this chapter). The pre-Schooner II experiment also provided an opportunity for Lawrence Radiation Laboratory, Livermore (LRL), and others, to obtain basic data on cavity growth and seismic effects for use in the research and development effort. In addition, several new experimental measurement techniques were attempted. Among these were determination of the volume of the debris cloud using a laser gun and measurement of air blast asymmetry with instruments suspended from balloons. Though neither of these was successful, both appear promising and will be attempted on future experiments.

Post-Dugout and -Sulky

Post-shot investigations of the 1964 Dugout and Sulky [5] detonations were carried out in 1965 by the Corps of Engineers to obtain basic engineering data related to slope stability and other properties of nuclear craters. This information is essential to the practical use of nuclear excavation for engineering projects. The data obtained on true crater-cavity boundaries and other parameters is being used by LRL in its research and development effort.

EXPLOSIVES DEVELOPMENT

One goal of research in the area of excavation development is to reduce to a minimum the amount of radioactivity released. From the standpoint of reducing the size of the area near a nuclear crater in which radioactivity falls out in potentially hazardous amounts and consequently which needs to be controlled to assure public safety, remarkable success has been achieved through developments over the past two years. In addition to reducing the amount of this radioactivity to assure public safety, it is necessary to limit the release of radioactivity in order to meet the requirement of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water [6] that any underground nuclear explosion not cause radioactive debris to be present outside territorial limits of the country conducting the test.

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[5] See pp. 157 and 159, "Annual Report to Congress for 1964."
[6] See p. 211, "Annual Report to Congress for 1963."

Developmental Goals

Two approaches to the goal of reducing the amount of radioactivity released are under development: (*a*) reducing the amount of fission yield in relation to the total yield of the explosive, and (*b*) special emplacement techniques to increase the amount of radioactive debris kept underground during the cratering process. Developments so far make it possible to produce explosives in a wide range of yields up to and including a megaton with no more than a few kilotons of fission, and plans were made during the year for further experiments to reduce the amount of fission products released during a cratering detonation.

Progress Made

However, during 1965, chief emphasis was put on emplacement techniques with the extension of the results from the contained Dub (1964) experiment[7] to the cratering-type situation in Palanquin. A great deal was learned from the Palanquin experiment about emplacement techniques, pointing the way to modifications and refinements which can be tried on future experiments.

Progress was also made in the research and development effort at LRL in the chemistry and biomedical areas. Particular effort was placed on identifying substitute structural materials which are not activated, which have less hazardous radioactive products, or which have chemical transitions which make them less available biologically.

FUTURE EXCAVATION EXPERIMENTS

The program of experiments necessary to advance nuclear excavation technology to the point where it can be used in large construction projects has been described in past Annual Reports to Congress[8] and most recently by AEC Chairman Seaborg on January 5, at a hearing before the Joint Committee on Atomic Energy.[9] In January, funds were requested in the President's budget for fiscal year 1966 for the first experiment in this program, Project Schooner. Subsequently, the amount of these funds was reduced by Congress in view of an anticipated delay in execution of the experiment because of the planning and extensive approvals required. In addition, the results of Palanquin showed that further device tests and at least one other small-scale nuclear cratering experiment were needed in order to

[7] See p. 161, "Annual Report to Congress for 1964."

[8] See p. 161, "Annual Report to Congress for 1964."

[9] See footnote 1 of this chapter.

develop more advanced devices and emplacement techniques. Plans are now being made to conduct these experiments in 1966.

RESEARCH AND DEVELOPMENT

The understanding of those effects of nuclear explosions which can be used for peaceful purposes is becoming increasingly refined and sophisticated. Knowledge and theory of these effects begins with an understanding of the immediate results of the detonation, especially the different forms of energy released and their dynamics, and the immediate effects of this energy on the surrounding and often different geological media. An understanding is then sought of the complex transmissions of source energy into its ultimate effects.

Although a distinction can be made between those underground explosions which have the ultimate, apparent effect of leaving a crater and those whose effects are mainly contained underground, the sequence of events shortly after the explosion occurs is the same and the theory, understanding, and predictive capability for them has a common beginning.

In 1961 and 1962, this understanding was largely empirical, being based simply on the relations to each other of observed phenomena; such as crater size, cavity size, depth of emplacement of the explosive, and yield of the explosive.

DEVELOPMENT OF PREDICTIVE THEORY

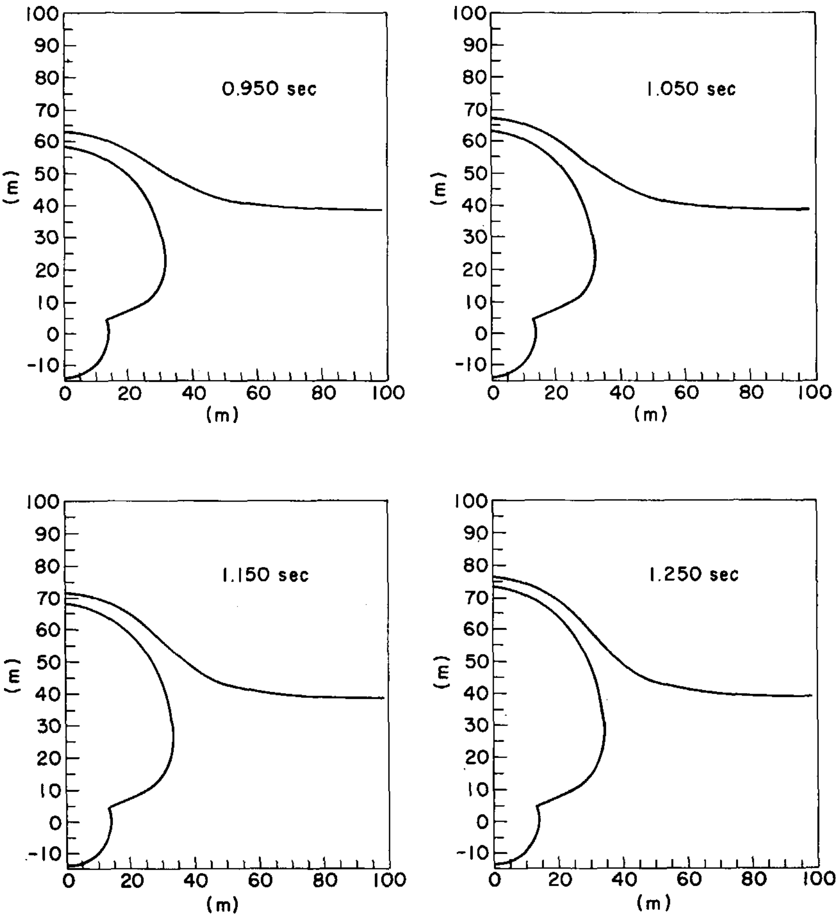
Beginning in 1963,[10] however, thousands of pieces of data have been collected from past experiments and organized with mathematical models so that the data can be handled in the large computers at the Lawrence Radiation Laboratory, Livermore. These calculational programs are then used to test the general theory by comparing its predictions for a specific situation against the observed results.

Computer Codes

A computer code, called SOC, developed in 1962, to calculate the effect of the shock wave and cavity expansion on earth materials, was refined and extended during 1965 with the data acquired from experiments in 1964, with the results of laboratory studies, and with further field measurements of rock properties. These calculations can now

[10] See pp. 211–213 and 219–220 of "Annual Report to Congress for 1963." For comparison, an example of the earlier empirical approach can be found on p. 246 of the "Annual Report to Congress for 1962."

predict with good agreement the measured results of detonations—the extent of explosion-induced fractures, cavity size, and earth motion. In the 1964 Salmon event of the Vela Uniform program, for example, measured peak pressure and peak velocity in the one to 600-meter range were within 20 to 50 percent of calculated results, time-of-arrival of the shock front was within 1 to 10 percent, displacement of the media at 300 meters was within 25 percent, and surface motion of the ground directly over the detonation was within 19 to 50 percent.



Cavity Formation. In a program to develop a detailed understanding and theory on which to base predictions for future experiments and applications, the AEC's Lawrence Radiation Laboratory, Livermore, has developed computer codes which can produce in a series of printouts, examples of which are shown here, reasonably close approximations to the formation and growth of the cavity formed by a nuclear explosion. Note the asymmetry which develops as the cavity grows toward the free surface. These calculations accurately reproduce the cavities made by several high explosive and nuclear detonations.

Two additional codes, called TENSOR and PUSH, were under development during the year. TENSOR is used for much more sophisticated predictions of the response in two dimensions of the medium to the shock wave. Among other things, TENSOR allows accounting for many of the nonuniform responses of the medium at different points. PUSH is used to predict in a similar way the response of the media to the late-time gas acceleration phase of the explosion. These codes are extremely useful in predicting the results of cratering detonations. In early trials during 1965, these codes were successful in predicting results which compare with previously observed surface motion behavior. Further refinement of these codes will be undertaken using data from laboratory studies, from further postshot investigations to obtain such data as is still available, and from Plowshare and other experiments.

Measurements of the spectrum of the ground shock from the 1964 Salmon detonation, which were obtained from the Plowshare add-on experiment,[11] were analyzed during the year and compared with the claims for damage which have been received. Although measured ground motion was in good agreement with predictions, the large number of claims suggested that further research to isolate and define the factors—such as geology, structural practices, foundation characteristics, and seismic wave properties—which contribute to structural damage should be undertaken. This research presently involves the instrumentation of some appropriate structures in areas near the Nevada Test Site.

The existing computer codes used to predict fallout from underground nuclear detonations which release, or may release, radioactivity were improved, updated, and checked against measured results of past experiments. Among the improvements to the code is an individual treatment for each radionuclide considered and a pictorial representation of the integrated, infinite dose pattern [12] to be expected with the actual wind conditions that exist at the time of detonation.

LABORATORY STUDIES

One very important area of research in the Plowshare program is concerned with the properties of rocks, especially as these properties vary over the range of conditions from the natural state to those of dynamic deformation at high pressure and temperature. Existing experimental techniques for determining these properties are often inadequate for Plowshare purposes and new techniques are developed

[11] See pp. 163–164, "Annual Report to Congress for 1964."

[12] A definition of infinite dose and examples of fallout patterns are shown on p. 211 of the "Annual Report to Congress for 1963."

by which new measurements can be made. During the year, a new experimental technique was developed to determine the failure characteristics of brittle material under stress. Measurements of various types of rocks using this technique have been factored into the computer codes, discussed above, and have greatly improved their accuracy in predicting the extent of explosion-induced fractures, cavity size, and free field earth motions.

Significant results were produced during the year by studies of the size of particles in fallout. With the increasing emphasis on a detailed understanding of the behavior of radioactivity released from nuclear explosions, it has become possible to describe, for many radioisotopes, the amount of radioactivity released in cratering detonations according to the physical form of the radioactivity (i.e., gaseous, volatile, or solid) and to relate this, where applicable, to the size of the particle to which the radioactivity adheres. This situation can be contrasted to the previous practice of describing the gross percentage of radioactivity released in terms of the amount in the fallout pattern. This work is being extended to additional radioisotopes, is being factored into the computer codes discussed above, and is planned to be extended into consideration of the biological availability, or non-availability in the case of chemically insoluble isotopes, of the radioactivity.

Another example of these laboratory studies is a very small-scale cratering detonation using two grams of high explosive or exploding wires in a plastic that has properties which simulate certain key properties or geological media. The transparency of this type of plastic, even with the shock wave passing through it, makes it possible to study and to make direct measurements of certain explosion phenomena. These results contribute to the evolution of explosion theory, provide data to improve computer codes, and suggest important phenomena to be studied in future full-scale experiments and ways to make measurements of these phenomena.

CONTAINED EXPLOSIONS

Studies of the effects of contained underground explosions and the relationship of the effects to possible Plowshare applications continued during 1965. Results in the areas of the size distribution of rock fragments in chimney rubble and the distribution of fractures in the rock surrounding a chimney are of particular interest. The results of theoretical and empirical analyses of both these effects have been used in analyzing proposed applications.

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POST-SHOT EXPLORATIONS AND STUDIES

Handcar Results

Post-shot investigations to date of Project Handcar,[13] a 10-kiloton explosion fired at a depth of 1,320 feet in dolomite on November 5, 1964, indicate that the gas generated was about the volume expected, and did not cause the release of radioactivity or add appreciably to cavity size. The cavity radius was about 69 feet, slightly less than that expected for a similar shot in granite. A major purpose of the experiment was to study the effects of a nuclear explosion in a carbonate medium that yields a large volume of noncondensible gas upon decomposition.

Collapse of the cavity occurred shortly after detonation, but data from post-shot drilling showed that the collapse was terminated by the bridging of large rock fragments at a point above the shot point. Further postshot exploration is expected to provide more information on chimney height and collapse phenomena.

Surface motion measurements within eight miles were in good agreement with theoretical calculations. Mockups of gas well-head equipment at ranges of 950 and 1,250 feet from surface zero survived the explosion without detectable damage.

Salmon Results of Plowshare Interest

Salmon was a five-kiloton nuclear detonation, conducted by the AEC for the Advanced Research Project Agency of the Department of Defense, at a depth of 2,716 feet in a salt dome near Hattiesburg, Miss., in October 1964.[14] The Salmon cavity did not collapse, and postdrilling indicates that the cavity diameter is about 112 feet, very close to the radius predicted on the basis of Gnome results. That the cavity would hold fluids or gases under pressure was indicated by the fact that the absolute gas pressure within the cavity upon re-entry by drilling was less than ⅓ atmosphere.

OTHER RECENT RESEARCH RESULTS

In Situ Retorting Advance

Recent studies at Lawrence Radiation Laboratory, Livermore, permit the prediction of the approximate particle size distribution in a

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[13] See p. 162 of the "Annual Report to Congress for 1964."
[14] See pp. 163–164, "Annual Report to Congress for 1964."

nuclear chimney. This information is essential to considering the technical feasibility of *in situ* retorting of the oil in the shale. With this knowledge, it will be possible to load a pilot-scale retort with particles which approximate those which would be found in a nuclear chimney and to study whether the heat flow around these particles would be sufficient to release enough oil to make the recovery economically attractive. Studies with the U.S. Bureau of Mines on appropriate oil shale formations in the western part of the United States for nuclear explosions were carried out during the year.

Water Resource Development

A summary and the principal conclusions of work which has been underway in the U.S. Geological Survey on water resource development applications for nuclear explosions were reported and published during 1965 as USGS Report No. TEI–857.[15] The current emphasis of this work is to locate and evaluate specific hydrological situations where nuclear techniques might be used.

Heavy Element Program

Plowshare program add-on experiments to weapons tests during the year studied the use of a heavier target (plutonium 242) and various improvements in design to increase the neutron flux in order to produce heavy isotopes, and possibly new elements. It was concluded that plutonium 242 would not be a suitable target and that substantial improvements in the flux through minor modifications were possible. A theory was evolved by the Los Alamos Scientific Laboratory which might lead to the selection of a better, more productive target than uranium 238 or plutonium 242.

[15] Available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va., 22151, price $4.

Chapter 13

ISOTOPES AND RADIATION DEVELOPMENT

During 1965, progress continued in the development and demonstration of new technology for uses of isotopes and radiation, important to the national economy and welfare; a new era of AEC-industry cooperation for expanding the commercial potential of isotopes and radiation appeared likely; and the AEC continued to withdraw from isotope production activities in favor of private industry.

PROCESS RADIATION DEVELOPMENT

To develop essential technology leading to commercial use of large radiation sources for processing of chemicals and other materials, an understanding of the complex effects of radiation on materials is required if useful chemical reactions or changes in the properties of materials are to be induced by radiation.

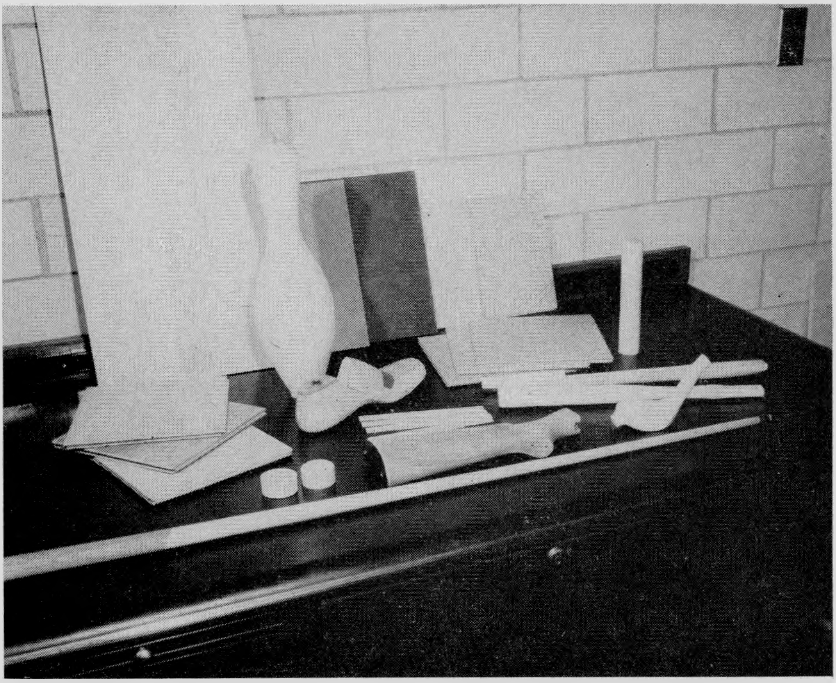
During the year, the AEC continued sponsorship of an extensive research program to determine the nature of significant chemical reactions through studies on the two major mechanisms of ionic and free radical transformations. Measurements of yields of potentially important radiation-induced reactions and the rates at which these reactions proceed are being determined. Research includes: (*a*) reactions between amines and olefins; (*b*) oxidation-reduction reactions in doped inorganic laser crystals; (*c*) emulsion polymerization of vinyl acetate; (*d*) effects of radiation on colloidal systems; and (*e*) radiation induced fluorination of hydrocarbons.

DEVELOPMENTAL APPLICATIONS

Where research has indicated a radiation-induced reaction is technically feasible, and where it is apparent that a commercially useful product can be obtained, engineering, economic, and development studies were carried out to determine the factors required to convert the reaction into a manufacturing process. Industry has been brought into each such project at the earliest possible time to maximize the utilization of the technology. Some examples of studies having potential industrial significance are summarized below.

Radiation-Processed Wood-Plastic Materials

The AEC's program for developing the process for wood-plastic materials production was significantly expanded during 1965. The material is produced by impregnating wood with a liquid monomer, and then irradiating it with ionizing radiation, such as cobalt 60 gamma rays. The radiation polymizes the plastic molecules and yields a solid wood-plastic composite which exhibits improvements in hardness, compression strength, moisture resistance, static bending



Wood-Plastic Uses. During the year, the AEC selected 78 companies to participate in a program for demonstrating the practical value of wood products which have been irradiation processed into a wood-plastic that is more desirable than the conventional wood product. Above are some products that have been fashioned out of radiation-processed wood-plastic material, and will be tested in their final product form. Included are production "blanks" for bowling pins, gun stocks, cue sticks, hammer handles, rulers, shoe lasts, floor tiles, and cutting boards. The wood-plastic combination is produced by impregnating wood with a liquid monomer and then irradiating it with gamma rays. The end product is many times harder than the original wood.

strength, impact strength, abrasion resistance, and toughness and yet retains its inherent natural beauty as a wood product—the material can be dyed throughout with natural "stains" or artificial colors.

These materials have promise in such markets as: furniture (indoor and outdoor), floors, window frames, sills and doors, tool handles, decorative trim, sporting goods, boat decks and fittings, and dies and jigs.

Process methods for producing wood-plastic materials have been steadily improved during the development effort of the past 3 years.[1] Experience with impregnation techniques, using various monomers (methyl methacrylate, vinyl acetate, acrylonitrile, styrene, and vinyl chloride), radiation doses, and catalytic additives has disclosed several shortcuts having economic significance.

Preliminary reports by an AEC contractor, Vitro Engineering Co., New York City, indicate that a production plant, designed to produce 3,000 pounds of wood-plastic material per hour on an 8,000-hour-per-year basis, could produce unfinished products at the following costs, exclusive of the wood itself: floor tile (9 x 9 x 1/4 inch)—12 cents; 2-inch diameter, cylindrical shapes (linear foot)—25 cents; shoe lasts—76 cents; salad bowls (15-inch diameter, 4-inch height)—57 cents; and bowling pins—88 cents. These costs were based on a hardwood/methyl methacrylate composition (0.7 lb. monomer/1.0 lb. of wood).

During the year, the AEC provided the wood products industry with samples of wood-plastic material for fabrication into specific products. In response to a solicitation, 180 firms expressed an interest for cooperative arrangements with the AEC in which their wood samples will be converted to wood-plastics by the AEC in return for the firm's evaluation of the material in its end-use application; 78 companies have been selected to participate.

Radiation-Produced Polyethylene and Copolymers

A process for the continuous production of polyethylene and ethylene copolymers has been under study at Brookhaven National Laboratory. The process seeks to replace conventional proprietary catalysts such as organic peroxides, with gamma radiation.

Earlier work was performed in small batch experiments. During 1965, a continuous flow apparatus was constructed to obtain more meaningful information on reaction kinetics. High conversion rates, comparable to commercial rates at conventional high pressure conditions, have been obtained for ethylene polymerization.

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[1] See pp. 197 and 199 of "Annual Report to Congress for 1963"; pp. 189–190, "Annual Report to Congress for 1964."

A wide variety of ethylene copolymer plastics have been formed using such monomers as carbon monoxide, sulfur dioxide, styrene, methyl methacrylate, vinyl acetate, acrylonitrile, allyl acetate, isobutylene, chlorotrifluoroethylene, trans-2-butene, methyl acrylate, isoprene, propylene, vinyl chloride, 1-butene, cis-2-butene, vinyl pyrrolidone, methyl vinyl ketone, and divinyl benzene. These have all been produced at room temperature. For the case of the ethylene-carbon monoxide copolymers, high molecular weight, high melting point products have been produced at 68° F. A crystalline melting point of 465.8° F. and an onset of decomposition at 482° F. were measured for a 50-percent carbon monoxide copolymer. These results indicate that several new plastics with important properties may be produced with radiation on an economical basis in the relatively near future.

The products have shown evidence of enhanced properties as compared to conventionally produced copolymers. Preliminary cost estimates indicate that the process should be economically attractive. These materials are part of a class of polymers which are produced in quantities of billions of pounds per year for the manufacture of molded plastic shapes, transparent films, and extruded forms.

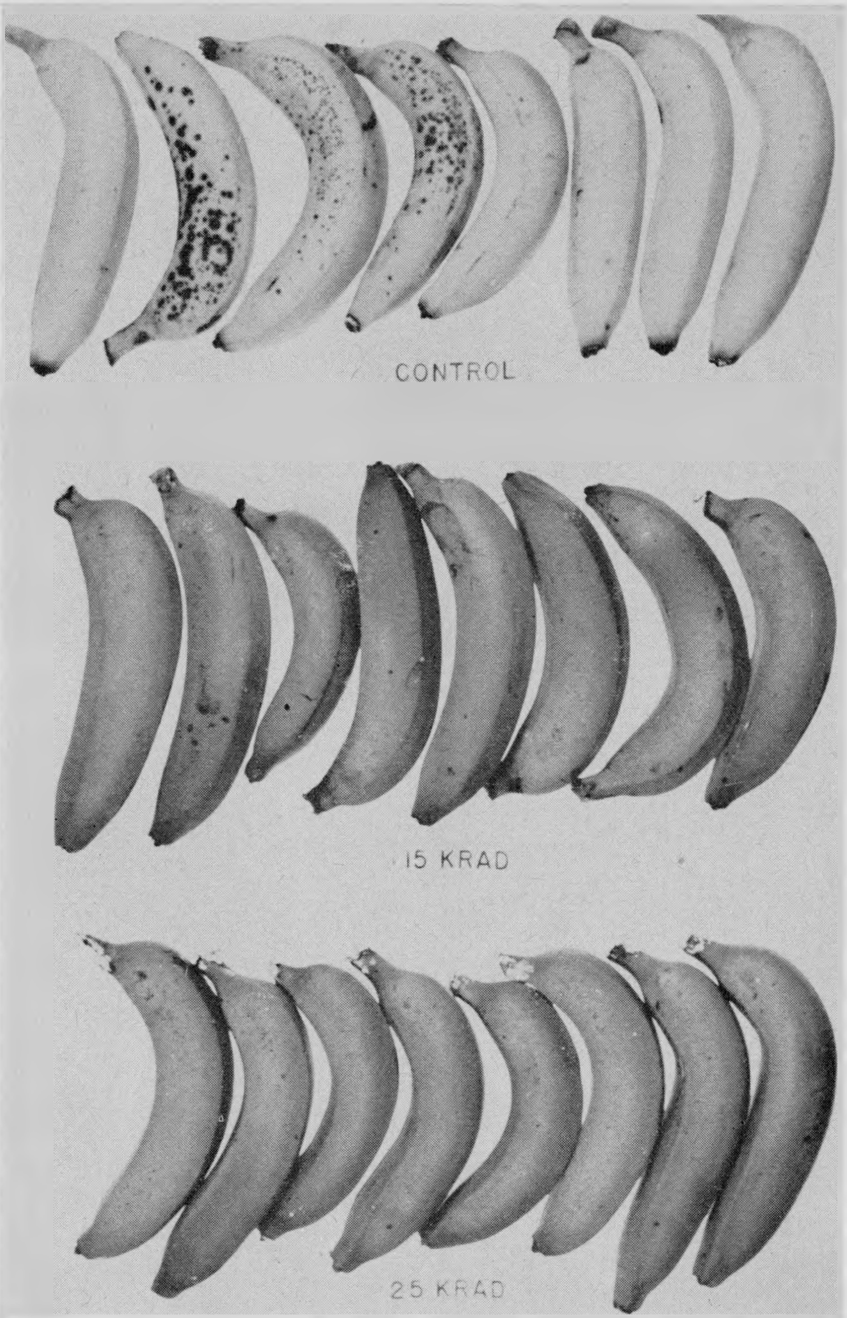
RADIATION PROCESSED FOOD

The development of necessary technology for extending the shelf life of perishable foods and for reducing insect and bacterial contamination of foods through the use of low doses of radiation continued through 1965.

Status of Research and Development

Five species each of seafoods (clams, haddock, shrimp, Pacific crab, and flounder) and fruits (strawberries, peaches, grapes, lemons, and oranges) were originally selected for initial study in the early phases of the program. Radiation preservation of the five species of seafoods continues to show promise for ultimate commercialization, and other seafoods (such as sole, ocean perch, pollock, and cod) have been added to the program. Some of the fruits (such as lemons and grapes) selected initially, however, have failed to respond well to radiation treatment and have been replaced by more promising candidates (such as bananas, papayas, and mangoes). Approximately 13 varieties [2] of

[2] Seafood: haddock, cod, ocean perch, flounder, sole, pollock, clams, crab, shrimp, oysters, halibut, hake, and fresh water fish.



Radiation Preservation of Fruit. Bananas, in particular, have been found to be beneficially affected by radiation from such sources as cobalt 60 in studies conducted by the University of California. Simple, inexpensive treatment delays ripening and extends the shelf life for two weeks. In the photo, the two-week-old control fruit (*top*) was a deep yellow; the irradiated fruit, which had been irradiated for five minutes at each of the two indicated levels, was still green with a few touches of yellow showing.

seafood and 15 varieties [3] of fruits, vegetables, and grains are now under intensive study. Recent work on bananas, for example, indicates that a low dose of radiation will delay the time of ripening. Subsequently, ripening can be induced at will by the standard ethylene treatment. The resultant savings in spoilage losses through shelf life extension should have major economic significance.

Food and Drug Administration (FDA) approval of radiation processed foods for general public consumption is a prerequisite for commercialization. No new approvals were made during 1965; bacon, wheat and wheat products had been approved in 1963, and potatoes in 1964. A petition was accepted for consideration by the FDA on September 8, 1965 which involves the clearance of six species of fish (cod, flounder, haddock, ocean perch, pollock, and sole), in connection with the work supported at the Bureau of Commercial Fisheries, Gloucester, Mass., and sites.

International activity in this field is beginning to gather momentum, and the AEC is providing support in the form of personnel and a large cobalt 60 source to the International Center for Food Irradiation at Seibersdorf, Austria, where a program on radiation pasteurization of fruit juices is receiving major consideration.

Demonstration Programs

Because of the good progress being made, increasing emphasis is now being directed to activities for early commercialization of the food irradiation technology. Cooperative projects with private industry involve large-scale shipping, storage, and market tests, and construction and operation of pilot facilities. These Government facilities are being offered for limited use and testing to private industry. A phase concerned with consumer acceptance is also being planned.

An AEC solicitation to industry in May for participation in the food irradiation program met with an enthusiastic response. Some 20 commercial fish processing companies are now using the Marine Products Development Irradiator at Gloucester, Mass., for large-scale testing of several marine products under cooperative arrangement with the AEC and the Bureau of Commercial Fisheries. None were using the facility prior to May. Further cooperative Government-industry projects in both the fish and fruit fields are being arranged at the AEC's other large-scale food irradiators.

The AEC expects to participate in a cooperative industry-Army-AEC project for the design, construction, and operation of a meat

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[3] Fruits, vegetables, and grains: strawberries, sweet cherries, plums, peaches, oranges, tomatoes (ripe), bananas, papayas, mangoes, figs, wheat, nectarines, prunes, pineapples, and potatoes.

radiation sterilization facility to demonstrate the process as an industrial operation. A solicitation of interest of firms was made on September 24 proposing construction of a facility with private funds. More than 40 meat packers and construction companies showed an interest in such a project. The Army intends to purchase a significant portion of the facility's output. The AEC plans to provide a radiation source (either cobalt 60 or machine) and may also provide other assistance. Indications are that the project may proceed rapidly in 1966.

Irradiators

The use of four AEC research cobalt 60-irradiators [4] and the Marine Products Development Irradiator (MPDI)—a pilot plant facility—are contributing materially to the success of the food program.

During 1965, the truck-mounted Mobile Gamma Irradiator (MGI) was completed by the Vitro Engineering Co. and will be sent to California for final checkout and field operation by the University of California. The mobile unit will be used for large-scale processing of fruit, including strawberries, bananas, and peaches, during the 1966 crop season.

The Grain Products Irradiator (GPI) located in Savannah, Ga., was nearing completion by the Vitro Engineering Co. and will be put into operation in late 1965. Although originally intended for insect disinfestation in grains, the GPI has drawn interest from processors of packaged mixes, cereals, and flours who have expressed a desire to cooperate in test irradiations of their products. The design of the irradiator has been modified to accommodate these uses.

Two shipboard irradiators were fabricated for the AEC by Nuclear Materials and Equipment Corp., Apollo, Pa. The first is to be on a U.S. Department of Interior fishing vessel working out of Gloucester, Mass. The second unit will be operational in early 1966, and operate in a similar manner out of Pascagoula, Miss. Irradiation of marine products as soon after catch as possible permits extended storage at quite low radiation doses. The 17-ton irradiators are versatile in their ability to handle a variety of products. A third such unit was ordered from Radiation Facilities, Inc., Lodi, N.J., and will be used cooperatively with selected segments of the poultry and fruit processing industries. Although the capacity of these shipboard irradiators is much less than the MPDI, they provide urgently needed additional units for scale-up testing beyond laboratory conditions, and are ideally suited for this purpose.

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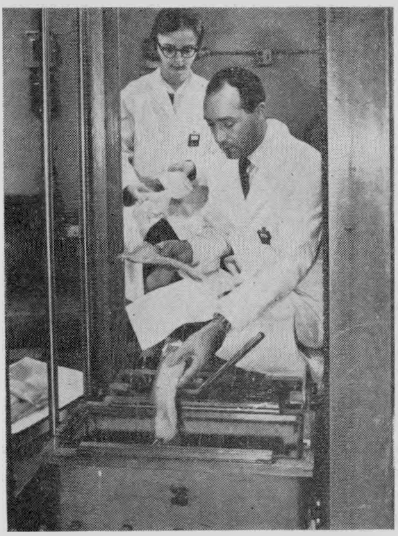
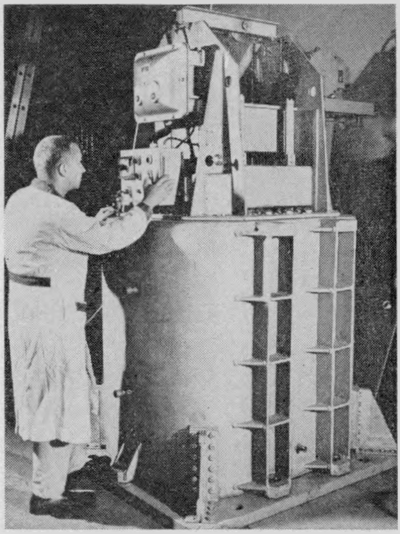
[4] See pp. 186–188, "Annual Report to Congress for 1964."





Preservation of Fish. Before any radiation-processed food can be made commercially available for general public consumption, it must be approved by the Food and Drug Administration (FDA). During September, the FDA accepted several species of fish for consideration. Photo on *left* shows fresh fish fillets being placed in the cobalt 60 irradiator at Massachusetts Institute of Food Technology in experiments to prolong the shelf life of fish by radiopasteurization. Photo on *right* shows a 30,000-curie, cobalt 60 on-ship irradiator being tested at Brookhaven National Laboratory. The 17-ton irradiator, which can handle 75 pounds of fish per hour at 200,000 *rads*, was developed at Brookhaven and constructed for the AEC by Nuclear Materials and Equipment Corp., Apollo, Pa. It will be used aboard fishing vessels so that fish can be processed immediately after they are caught.

Design work was begun in the fall by Nuclear Materials and Equipment Corp., on the Hawaiian Development Irradiator (HDI) to be located in Honolulu. Radiation preservation of tropical fruits for shelf-life extension, reduction of spoilage, and quarantine control will be done on a near-commercial scale when the HDI is completed in early 1967. Industry participation in the use of the irradiator will be invited.

ISOTOPES SYSTEMS DEVELOPMENT

The development and demonstration of radioisotope-instrumented systems during the year showed promising substantial benefits in solving problems of direct Government and industry interest.

TECHNICAL DEVELOPMENT

Helium 3 Activation Analysis

A new technique in activation analysis using nuclear reactions resulting from accelerated helium 3 ions has been further perfected for the AEC by General Atomic, San Diego, Calif. The technique was originally developed at the Lawrence Radiation Laboratory, Berkeley. The high sensitivity of this technique, especially for the measurement of oxygen and carbon in metallic surfaces, has drawn considerable interest from industry. Oxygen determinations have been made on stainless steel, tantalum, and platinum. Measurements of oxygen in stainless steel heated to high temperatures have revealed the usefulness of the method in degassing studies. Several industrial firms are currently developing small-size cyclotrons (weight about 14 tons) to meet industrial and governmental needs, both for this charged-particle activation analysis technique and for the production of small quantities of short-lived radioisotopes for use in such applications as medical diagnostics.

Alpha-Excited X-rays

Parametrics, Inc., Waltham, Mass., is working on the generation of monoenergetic, characteristic X-rays of various materials, without the usual Bremmstrahlung radiation present with beta irradiation. The X-ray yields of aluminum, titanium, copper, and vanadium have been measured and found to be significant. Spectra have been obtained for targets of all four elements, and results of the first three indicate that such sources can be used for highly sensitive X-ray fluorescence and absorption analysis application. Investigations are underway in conjunction with other agencies to determine the feasibility of applying this technique to lunar analysis and to analysis of wear products in aircraft engine oils.

SYSTEMS ENGINEERING

During the year, several isotope activated devices moved from the developmental stage to practical demonstrations of their applications.

Analytical Applications

Stable isotope measurement. A project at Tracerlab, Inc., Waltham, Mass., is directed to the development of a comparatively

Helicopter Formation Keeping. A Navy helicopter is shown testing variations in the response of an onboard radiation detector to a 100-millicurie cobalt 60 source mounted on the pole in the background. Industrial Nucleonics of Columbus, Ohio, is developing a radioisotope system for use by helicopters to permit safer formation flying and landing under conditions of limited visibility.

inexpensive microwave spectroscope to measure stable isotopes with very high sensitivity. In some instances, it is desirable to employ stable isotopes as tracers, rather than using radioactive isotopes, such as in medical diagnostic procedures in children. A prototype, which operates in the millimeter wavelength range, has been completed to measure such isotopes as nitrogen 15 with the highest possible sensitivity, in the temperature range of −80°C. to 300°C. The console unit, when completed, will be the size of a desk top, and easily transportable. The spectrometer was chosen by Industrial Research Magazine as one of the 100 most significant developments in 1965.

Gold detector. A radioisotope-activated, narrow-band X-ray gold detector, built by Tracerlab, Inc., has generated much international interest by gold prospectors, mine owners, and customs officials. The device is completely transistorized, rugged, portable, and has been tested by the U.S. Customs Bureau. It employs xenon 133 to activate gold X-ray lines and can measure the gold in samples containing 1 percent or more of gold, or a minimum of one-millionth of an inch thickness of gold, as a plating. Development of similar portable units for the measurement of other elements such as cadmium, copper, and tungsten in ores appears possible.

Ocean-bottom measurements. Tests conducted by the U.S. Navy Oceanographic Office at Panama City, Fla., with an ocean-bottom sediment density meter[5] exceeded expectations. The completely self-contained device, developed by Lane Wells Co., Houston, Tex., employs a cesium 137 gamma scattering technique, and can measure the density of ocean sediments to a thickness of 11 feet at any ocean depth and to within an accuracy of one percent. Further, it can make measurements at approximately 60 coring sites per 8-hour day; conventional coring techniques yield only 4 or 5 core measurements per day. The unit is to be modified by Lane Wells Co. to also permit measuring the moisture content of sediments via a neutron absorption-scattering technique.

Environmental Applications

Several projects were continued for solving problems in snow and watershed management, automatic calibration of high-head turbines, determination of source of water loss in large reservoir sites, and for pollution control of paper waste discharge into rivers.

Snow-water management. A long-term project is continuing with the U.S. Forest Service, Berkeley, Calif., to develop a snow-water management control system for the State of California. Efforts include the development of automated telemetry systems to transmit isotopic measurement of snow characteristics data, and the evaluation of hexadecanol as a means of retarding evaporation of water from the snow pack. The hexadecanol, either in powder or solution form, is applied by dispersion from an airplane and forms a film over the snow. The snow measuring unit consists of a portable source-detector employing the backscatter from neutron and gamma sources to determine snow characteristics in half-inch vertical increments with an accuracy of 95 percent or better. The hexadecanol study employs radioisotope tracers to measure the concentration and distribution of the microscopic covering of hexadecanol on the snow and to determine the efficiency of the protection from evaporation.

Turbine rater. An isotopic turbine rating technique, previously developed for low-head turbines (water drop of less than 200 feet), of the type found in the TVA complex, is now being extended to high-

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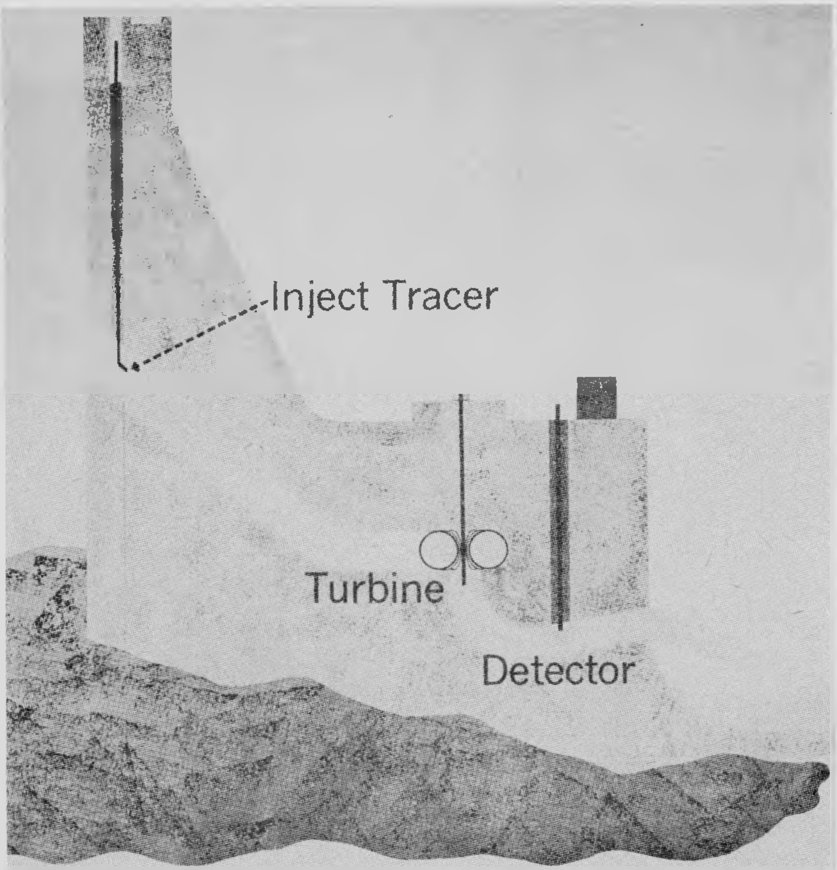
[5] See pp. 192–193, "Annual Report to Congress for 1964."

head turbines by the U.S. Bureau of Reclamation, Denver, Colo. The technique uses the isotope dilution principle (as shown in the schematic drawing).



Isotopic Turbine Rating. Under a joint project, the AEC and Department of Interior have developed a turbine calibrating system of highest precision and accuracy to permit a better control of water management and of production of electricity. The advantages of an isotopic system employing short half-life tracers such as gold 198 are (*a*) providing a precision of 1 percent in water volume measurement (as good or better than conventional methods); (*b*) providing immediate answers on volume flow (conventional methods require several months for data acquisition and analysis); (*c*) it can be used without shutdown of turbines (conventional methods require turbine shutdown); and (*d*) it provides the one and only unique method of automatic feedback control for waterflow (other methods are not compatible). As an example of what improved benefits in electrical power and water management control can mean, consider the fact that an error of 1 percent in water volume control can result in a loss of $1–$2 million per year per dam—such as Grand Coulee on the Columbia River.

More accurate turbine ratings help conserve water to achieve the greatest benefit from its uses. The basic principle of isotopic tracing with short-lived (64 hour half-life) gold 198 has already been established, but detailed studies are now in progress to design isotopic injection equipment for high pressures, and to obtain good measurement of activity under very rapid flow conditions. Comparative laboratory studies have been conducted on the mixing uniformity of injected solutions of salt, dyes, and tracers. Results indicate that under rapid flow conditions, a 95 to 97 percent lateral mixing occurs in a pipe length equal to 55 times the diameter. The final objective is to develop a remote command system which will permit the automatic calibration of individual turbines without shutting down the turbine.

THERMAL APPLICATIONS

During 1965, developments for direct utilization of thermal energy from radioisotope decay for applications in marine, terrestrial, and space environments progressed in several areas. Uses range from small auxiliary heaters to maintain stable operating temperatures in instrument components to large heat sources for propulsion purposes. Radioisotope heat sources, properly encapsulated and shielded, are safe for handling and offer simple long-life, dependable power.

HYDROSPACE USES

A survey,[6] conducted by Aerojet-General Nucleonics, San Ramon, Calif., of several hundred people in Government, industry, and academic institutions, to determine potential underwater (hydrospace) uses of radioisotopes, showed many potential applications. These included underwater sound generation, instrument electrical power supply, propulsion for small submersibles, electrical and thermal power for undersea platforms, and small heat sources. Several of these concepts are being explored, and in some cases, cooperative programs are underway with potential users.

Submersible Propulsion Engine

A design study is being conducted by Aerojet-General Nucleonics for the AEC to integrate an isotopic heat source with a turbine for propulsion of small undersea craft. The project includes conceptual

[6] Available in report No. AGN–8135, "Evaluation of Radioisotope Applications in Hydrospace," March 1965, from Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., 22151, for $5.

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design, detailed program planning, and initial research and development of a four-shaft horsepower proof-of-principle engine for specific hydrospace applications. Numerous engine cycles and power conversion concepts have been studied. A turbine Rankine-cycle using Dowtherm-A (an organic material) as a working fluid in a direct, single loop, regeneration system and a cobalt 60 boiler is proposed.

Swimsuit Heaters

A cooperative project is in progress with the Department of the Navy to develop a 300-thermal watt plutonium 238-fueled source to supply heat to underwater swimmers. The heat is transmitted, via a fluid, through vein-like tubes embedded in a diver's swimsuit, or a pilot's astronaut suit. This heating unit will permit the diver to extend his operating time for several hours—to the limit of his physical ability to perform work under water. It will be back-packed, weigh approximately 15 pounds, and the diver will be completely safe from radiation.

OUTER SPACE USES

Small Spacecraft Thrusters

Design has been completed by TRW-Space Technology Laboratories, Redondo Beach, Calif., on a radioisotope capsule to heat the catalyst bed of a monopropellant hydrazine engine. A Nuclear Isotope Monopropellant Hydrazine Engine (NIMPHE), to be used for propulsion of unmanned space vehicles, is capable of an unlimited number of startups and delivers excellent propellant performance over a wide range of duty cycles. The catalyst bed, however, is not capable of initiating hydrazine decomposition at ambient temperatures and must be heated. The radioisotope makes it possible to use a catalyst with unmatched physical and chemical properties at high temperature. The engine has had a test run of 2,000 starts using an electrical heater to simulate an isotope heat source.

Space Life-Support Systems

The AiResearch Manufacturing Division of the Garrett Corp., Los Angeles, Calif., has completed an evaluation of the applications of isotopes for life-support systems in manned spacecraft. These included water recovery, carbon dioxide removal, oxygen recovery, heating, cooling, and particle removal within the spacecraft. Radioisotope heat sources were evaluated against other conventional sources of power. The results indicate that the direct use of isotopic thermal energy offers distinct advantages over electricity-to-heat conversion systems for certain missions.

In a cooperative program with the Department of the Air Force, a conceptual design was completed by AiResearch of an integrated water system having the capability of recovering potable water from urine, condensate, and wash water; and heating, cooling, and dispersing the water and maintaining it in a pasteurized condition. Plutonium 238 is being evaluated by Mound Laboratory and promethium 147 by Pacific Northwest Laboratories as heat sources for this purpose.

TECHNOLOGY UTILIZATION

A specific effort is being made to translate isotopes technology into broad scale utilization by industry, Government, and research organizations. During 1965, major activities included visits with industry to determine trends and exchange information, collaboration with other Federal agencies, technology utilization meetings, an Isotopes Information Center (see Appendix 5) training films, lectures, preparation of books, and technical exhibits.

Industrial Utilization of Radioisotopes. Eastern Airlines, Miami, Fla., has developed a radiographic procedure, using 50 curies of iridium 192, for inspecting the compressor exit guide vanes during their routine maintenance program on jet engines. This method of inspecting the vanes has cut the time needed to inspect these critical parts which are deep inside jet engines from 125 man-hours to 5 man-hours, saving 120 man-hours per engine inspected.

Industry's Evaluation of Isotopes and Radiation

The Chairman of the Advisory Committee on Isotopes and Radiation Development (then Dr. Lauchlin M. Currie—see Appendix 2), and a member of the AEC's staff conducted interviews with officials of 40 firms representing a cross section of industrial users. The survey was designed to determine the extent of industrial development of isotopes and radiation, identify the factors that limit their use, and obtain recommendation of how the AEC might better help this portion of the atomic energy program.

Industrial response indicated a tremendous potential for expansion of routine applications of isotopes and radiation applications and predicted the present rate of growth in industrial uses of isotopes—considered to be about three to five percent per year—could reach 15 to 20 percent a year with more specific AEC assistance in critical areas. The consensus was that the AEC should:

(*1*) Actively seek joint funding projects for isotopes and radiation developments with industry;
(*2*) Set up procedures for loan or rental of large radiation sources;
(*3*) Broaden AEC patent procedures in connection with cooperative arrangements with industry for demonstration projects involving commercial or near-commercial size facilities;
(*4*) Extend the use of the general licensing provision of AEC regulations in light of past experience; and
(*5*) Adopt a more positive public information program to offset unfounded fears about isotopes and radiation.

The results of the survey (known as the "Currie Report") are being studied by the AEC. It is planned to make a followup study with the same firms in one or two years, after the recommendations in the report have had a chance to take effect, to assess the impact of any new policies and actions resulting from the 1965 survey.

Trends and Economics

A study of present industrial radioisotope usage, trends, and economics was completed in midyear by Arthur D. Little, Inc., Cambridge, Mass., under contract to AEC.[7] A similar study had been made by the National Industrial Conference Board in 1958. In both studies, 21 major industrial areas were surveyed, and case histories obtained on the use of isotopes and radiation.

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[7] The report, No. NYO–3337–16, "Isotopes in Industry, Trends in the Industrial Use of Radioisotopes and Ionizing Radiation, September 1965," is available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., 22151, for $1.50.

The results of the A. D. Little study are broadly encouraging for the future development of the industrial use of isotopes and radiation. For instance, significantly, isotopes seldom lose an application in which they have been found suitable, and new opportunities are continually being introduced. The study also showed the growth is slow but steady, and there seems to be every indication of an ample long-range return on investments which have gone into the development of isotopic technology.

RADIOISOTOPE PREPARATION AND MATERIALS TECHNOLOGY

As noted in Chapter 5—Source and Special Nuclear Materials Production, radioisotopes are made to meet national needs and continuous research and development conducted on preparation methods and radioisotope properties to provide these products in useful forms for tracer, thermal power, and radiation applications. There is increasing radioisotope preparation activity by private industry, resulting in the systematic withdrawal of the AEC from this area.

PREPARATION AND SALES

During the 11 months ending November 30, 1965, a total of 1,117,603 curies of processed radioisotopes were distributed from Oak Ridge National Laboratory. This represents a 95 percent increase in unit sales, mainly due to increased sales of cobalt 60, cesium 137, and tritium. An additional noteworthy shipment was 670,766 curies of cobalt 60 from the Savannah River Laboratory to Brookhaven National Laboratory for use in the High Intensity Radiation Development Laboratory.

Withdrawals from Preparation

The AEC withdrew from the preparation (for purposes of sale) of antimony 125, calcium 45, iron 59, selenium 75, tin 113, zinc 65, and strontium 85 during 1965. It is the Commission's policy to discontinue providing materials or services which are reasonably available from commercial sources.

AEC withdrawal from preparation and distribution of strontium 90, cesium 137, cerium 144, and promethium 147, is planned for late 1968. This action will coincide with commercial operation of the private Fission Products Conversion and Encapsulation plant to be constructed near Richland, Wash., by Isochem, Inc. (See "Fission Products Production" item, Chapter 5.)

Price Changes

The AEC reduced the prices on 12 radioisotopes and increased the prices on 52 others[8] during the early part of the year. The price increases were necessary to recover full costs of radioisotope preparation and distribution. Price reductions ranging up to 90 percent (effective November 10, 1965) were made on strontium 90, cesium 137, promethium 147, and cerium 144 in order to stimulate development of the market for these materials in the period before the privately operated Fission Products Conversion and Encapsulation plant goes into operation in late 1968.

Effective as of December 18, the AEC revised part of its price schedule on cobalt 60 which is widely used in medicine and industry. Two of the major changes in the new schedule reduced the cost to 40 cents (from 50 cents) per curie in the one to 15 curies per gram specific activity category, and increased—from the previous 30 curies per gram to 45—the maximum limit on specific activity of material which the AEC will supply.

Krypton 85 Enrichment

A thermal diffusion facility has been installed and tested at Oak Ridge National Laboratory for increasing the isotopic concentration (from 5 percent to 45 percent) of the fission product radioisotope, krypton 85 (Kr^{85}). This higher isotopic concentration will increase the usefulness of krypton 85 in commercial applications such as luminous signs and radioisotope density gages. With normal feed material (containing 5 percent radioactive Kr^{85}, and miscellaneous amounts of stable Kr^{82}, Kr^{83}, Kr^{84}, and Kr^{86}), an annual output of 3,000 curies of 45-percent Kr^{85} can be obtained through two thermal diffusion cascades containing 216 electrically heated tubes.

Technetium 99^m^ Generator

One of the more important recent advances in nuclear medicine has been the cooperative development by Brookhaven National Laboratory with Argonne Cancer Research Hospital of the methods for preparing and utilizing technetium 99^m (Tc^{99m}). The radioisotope is administered to the patient in special preparations, and localizes in organs such as the liver, brains, thyroid, spleen, and bone marrow. The organ is scanned with a sensitive radiation detector, and the radiation reading reveals anatomical details and information on the

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[8] A full list of prices is available from the Isotopes Sales Dept., Isotopes Development Center, Oak Ridge National Laboratory, Post Office Box X, Oak Ridge, Tenn., 37831.

function of the organ. Technetium 99 is formed by the decay of fission product, 67-hour molybdenum 99, which can be loaded onto a "generator" from which the metastable Tc^{99m} (6-hour half-life) is rapidly and easily "milked" at will by the user. The generator is a special apparatus containing an ion exchange resin manipulated to retain the "parent" radioisotope and release the "daughter" product. Such preparation of very short-lived radioisotopes makes it possible to use these materials in places remote from reactors or accelerators. Tc^{99m} generators are now routinely available from a number of commercial firms.

ISOTOPIC POWER FUELS DEVELOPMENT

Applications of the thermal energy from radioisotope decay are being developed as small power sources for space, terrestrial, and marine purposes. Radioisotopes provide a highly reliable energy source with a predictable life and a high power density.

Metallurgical Development

Major developmental efforts in 1965 were concerned with plutonium 238, polonium 210, strontium 90, curium 242, curium 244, promethium 147, and cerium 144, all of which are leading candidates for isotopic power fuels. Primary emphasis was on metallurgical development to achieve encapsulated sources capable of operating at temperatures up to 2,000° C. Other essential criteria include containment of the radioisotope under all conditions, except during re-entry from space where it may be desired to have the radioisotope source burn up and disperse in the atmosphere.

Plutonium 238. The plutonium 238 (Pu^{238}) isotope is currently one of those preferred for power generating devices where compactness, lightweight, low radiation fields, and long life (87.2 years half-life) are of importance. On the other hand, strontium 90 is the preferred radioisotope for terrestrial and marine applications because of low cost and ready availability. However, it is possible that certain specialized terrestrial and marine needs also will require the use of Pu^{238}. Production of Pu^{238} as a byproduct of current production operations[9] continued at Savannah River during the year. Such production results from the irradiation of the neptunium 237 recovered from plants at Savannah River and Hanford which perform the chemical processing of irradiated fuels. Forecast requirements

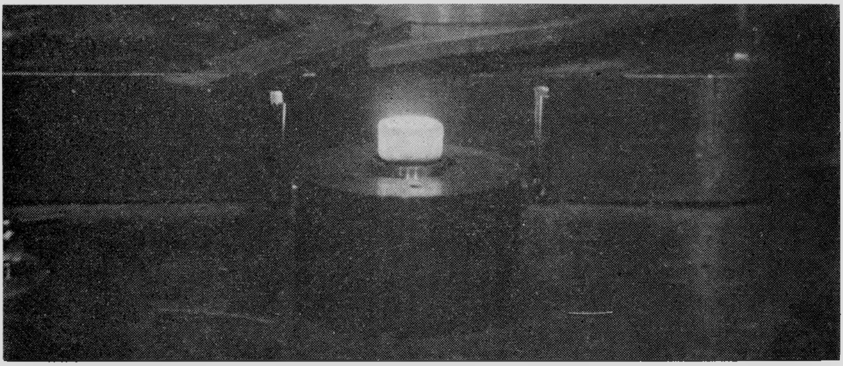
[9] See Chapter 5—Source and Special Nuclear Materials Production.

for Pu^{238} for the next decade exceed the routine production capabilities presently employed. As a result, new methods to increase production at Hanford and Savannah River are being considered. Primary efforts are directed toward necessary uranium 236 (U^{236}) concentration in the fuel. The U^{236} is reinserted in the reactor to generate neptunium 237 which is separated and irradiated as a target element to form Pu^{238}. Despite these efforts, inherent production limitations may be such that certain power applications will be required to use substitutes for plutonium 238, such as promethium 147, curium 244 and strontium 90.

Test quantities of fuel forms of Pu^{238} with melting points above 2,000° C. were prepared and characterization studies initiated at Mound Laboratory. Facilities for the fabrication and characterization of large sources for use as space power units are being installed with scheduled operation in 1966. The characterization studies emphasize encapsulation systems for long-term operation at high temperature and burn up upon re-entry from space, when desired.

Curium 242 and 244. Small amounts of curium 242 (Cm^{242}) were produced by the irradiation of americium 241 (Am^{241}) at Oak Ridge National Laboratory (ORNL). Long-term availability of significant quantities of Cm^{242} is limited by the availability of Am^{241} which is the decay product of plutonium 241 (half-life 13.5 years).

However, curium 244 can be made directly by the irradiation of Pu^{242} which is obtained by burning Pu^{239} in a nuclear reactor. A program to produce three kilograms of Cm^{244} for characterization purposes was begun by the AEC in 1964. The initial irradiations of



Curium 242 Heat Source. The above 10-gram curium 242 pellet is a source of heat so concentrated that it is incandescent while resting on a cool surface. It is a portion of the largest quantity of curium 242 ever purified and formed into a single pellet. It was processed at Oak Ridge National Laboratory.

Pu^{239} to produce Pu^{242} was completed in early 1965. Separated Pu^{242} was then fabricated into target elements which have been charged into a Savannah River reactor for further irradiation under high flux conditions (10^{15} $n/cm^2/sec$ range). Special facilities for chemical separation of the curium are being provided in the Savannah River Laboratory (SRL).

Gram quantities of curium 244 have already been obtained as a by-product of another program. At ORNL and SRL, curium work has included the acquisition of chemical and physical property data of the compound and source forms along with the development of encapsulation techniques. At ORNL, 10 grams of curium 242, the largest quantity ever processed, was purified. ORNL also has processed about 10 grams of curium 244 from SRL feed material. A 2.4-gram prototype source of Cm^{244} has been successfully fabricated; about 5 grams are being prepared for critical mass measurement, and the remainder is being used for properties studies.

Cobalt 60. A total of five million curies of cobalt 60 (Co^{60}) has been produced, and distributed, from AEC reactors since 1955. Nearly 16 million curies were being produced, or planned for production, at the end of 1965. This includes one lot of approximately one million curies at specific activities from 300 to 600 curies per gram, and will be the highest specific activity cobalt ever produced.

Savannah River Laboratory is developing Co^{60} isotopic fuels technology for applications requiring up to 400 kilowatts of thermal energy. The total energy available from cobalt 60 is about the same as polonium 210, and is large compared to that obtainable from any other radioisotope. The most immediate potential applications of these heat sources are to provide energy for propulsion of small submersible vessels and to provide heat and electricity for remote land-based and marine applications.

Polonium 210. The polonium 210 (Po^{210}) isotopes shares the desirable attributes of plutonium 238, but its short half-life (138 days) limits its use to missions of short duration. The Department of Defense and the National Aeronautics and Space Administration are interested in large-scale use of Po^{210} isotopic fuel for missions up to 90 days. Applications include both electric power generation and propulsion. During the years, detailed studies have been made of the production reactors for production of Po^{210} in thermal megawatt quantities. The high flux demonstration (see Chapter 5) provides the technical basis for producing polonium 210 at a concentration of almost 100 curies per pound of bismuth, thereby greatly increasing the potential capacity of the installed separations facilities.

At Mound Laboratory, in support of the radioisotopic space thruster program (see Chapter 8—Nuclear Space Applications), a prototype capsule was fabricated and operated at 1,450° C. for 72 hours. A number of polonium compounds can be used for applications in the temperature range of 1,600° to 2,000° C., and several compounds are being intensively studied for space applications. The properties of refractory metals and alloys are being examined to find more suitable materials to encapsulate the polonium fuel at these temperatures.

Chapter 14

FACILITIES AND PROJECTS FOR BASIC RESEARCH

During 1965, the AEC continued to expand its programs and facilities for conducting basic studies in the areas of biological, medical, environmental, and physical research. (This chapter summarizes only the progress made in new facilities, and two projects related to nuclear effects and civil defense. Noteworthy results of basic research conducted under the above areas are included in the supplemental report, "Fundamental Nuclear Energy Research—1965." [1])

BIOLOGY AND MEDICINE

Scientific knowledge needed to understand more fully the possible short- and long-term biological effects that may accompany nuclear energy applications, with emphasis on overcoming the attendant hazards, continues to be obtained. Discussed here are a nuclear effects research project to be conducted at the Nevada Test Site and the new Civil Defense Research Program at Oak Ridge National Laboratory. During the year, four new laboratory construction projects were completed to provide additional facilities for research on radiation effects on life.

NUCLEAR ENERGY CIVIL EFFECTS

Operation HENRE

The High Energy Neutron Reactions Experiment (HENRE)[2] which had been planned for field operations beginning in the first half of 1965 was rescheduled for 1966. Technical difficulties with the high voltage power supply for the linear accelerator which is to be used as the neutron source have prevented all but a few preliminary

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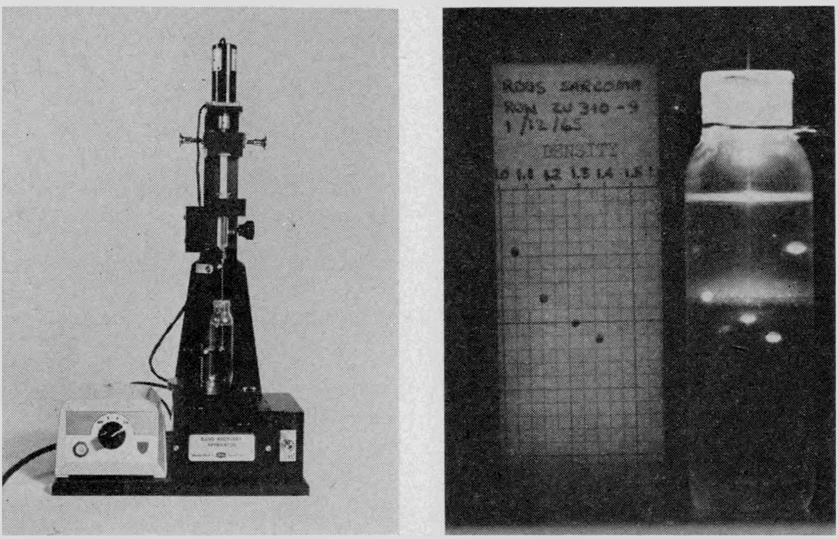
[1] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, for $2.25.

[2] See pp. 218–219, "Annual Report to Congress for 1964."

tests at Oak Ridge National Laboratory. The field operations at the Nevada Test Site are now planned for March 1966.

The Operation HENRE study, jointly supported by the AEC and the Defense Atomic Support Agency of the Department of Defense, is aimed at better defining the propagation of neutrons and gamma rays in the atmosphere. For this, an accelerator will be used as an intense source of monoenergetic neutrons. It will be installed on the 1,527-foot high BREN tower, which was used in 1962[3] for gamma ray angular distribution tests, at the Nevada Test Site. The source facil-



Recovering Virus Particles. The band recovery apparatus is one of a family of new instruments and equipment developed to attack the problems of concentrating, detecting, and recovering virus particles in a high state of purity. The motor-driven, syringe-type liquid-withdrawal instrument has a built-in light source, which is directed up through the bottom of the centrifuge tube, to distinguish the "band" of particles present by scattered light. Color-coded spherical beads of narrow, but known ranges of densities, help determine the density of the particles banded in a liquid whose density increases toward the bottom. The combination camera-band recovery unit provides a photographic record (right photo) which includes the tube, density beads, the band, and other pertinent information. The zonal centrifuge development program is sponsored jointly by the AEC and the National Institutes of Health (NIH) and is conducted at the AEC's Oak Ridge Gaseous Diffusion Plant and the Oak Ridge National Laboratory. The program began as a "technology spinoff" when, in 1963, technology attained during work on centrifuge methods to separate uranium isotopes led to development at Oak Ridge of a high-speed zonal centrifuge for the large-scale isolation and purification of viruses for use by the NIH in studying the role viruses play in the cause of such diseases as leukemia, cancer, hepatitis, and even the "common cold."

[3] See pp. 318–324, "Annual Report to Congress for 1962."

ity is designed to have a neutron yield of trillions of neutrons a second for exposure periods of four hours each.

Civil Defense Research Program

Organization of a civil defense research program, supported jointly by AEC and the Office of Civil Defense, was completed in 1965. The program was established at Oak Ridge National Laboratory in 1964 to evaluate the feasibility of various future national civil defense programs, taking into account both technical and social factors. Among the topics to be studied are effects of current and future weapons systems and the interaction of active and passive defense systems. Criteria will be developed for advanced shelter systems such as urban blast and fire protection. Human behavioral aspects and attitudes toward alternative systems will be studied. The research effort will also improve the understanding of preattack preparations for postattack recovery operations.

As an initial project, an improved method of urban sheltering has been devised consisting of blast-resistant tunnels, the so-called tunnel-grid shelter, which could be laid under the streets of a city with frequent entryways and underground emergency utility and life support compartments attached. A study of the installation of such a system in a 25-square-mile section of Detroit, Mich., was completed in June 1965.

NEW BIOMEDICAL RESEARCH FACILITIES

Molecular Biology Laboratory

At Oak Ridge National Laboratory, the new Molecular Biology Laboratory is now in use. The $330,000 laboratory provides 7,400 square feet of floor space, including a new intermediate floor of 2,800 square feet. The new facility is used for studies in the fields of viral genetics, immunology, and enzymology.

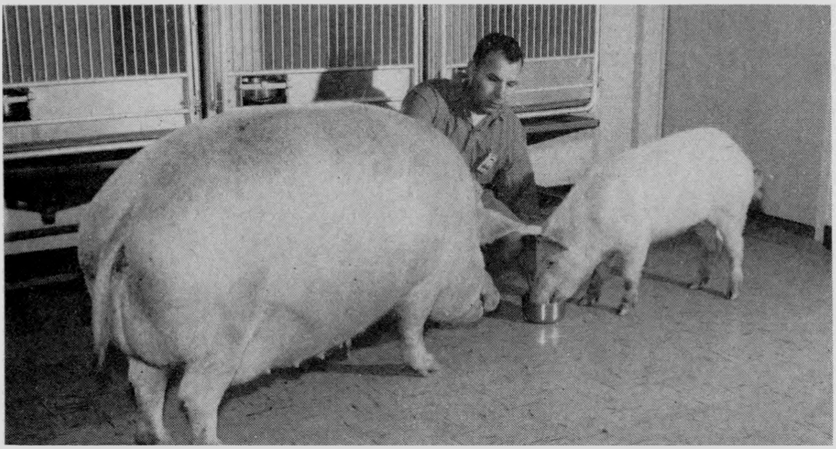
Agricultural Research Laboratory Addition

At the University of Tennessee-AEC Agricultural Research Laboratory, Oak Ridge, a new one-story and basement laboratory addition has been completed and is in use. This building addition, totaling 16,400 square feet, provides 14 new office-laboratory rooms in various combinations and with related facilities, including cold, preparation, counting, instrument, wash, storage, and photographic space. Small-animal rooms and a room for the laboratory's rat colony are also provided. The $685,000 addition is connected with the old, original laboratory by corridors.

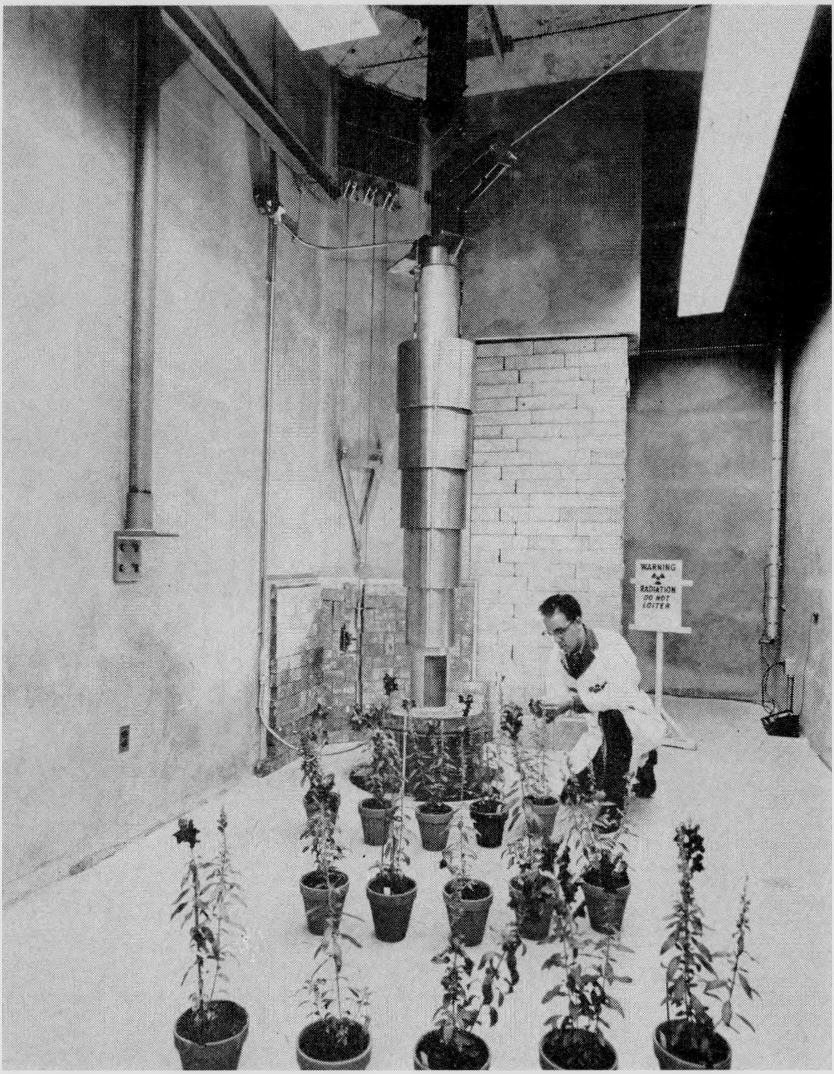
New Facility for Plant Research

Brookhaven National Laboratory has opened an extension to the existing biology laboratories to provide facilities for research with plants grown under precisely controlled conditions of light, temperature, humidity, and the amount of ionizing radiation.

The Controlled Environment Facility for Radiobotany has the double advantage of making it possible to grow almost any plant for research purposes at any time of the year, and ensuring that the plant is physiologically the same during a developmental period regardless



"Technology Spinoff" in Pigs. Because pigs eat almost anything, as man does, their gastrointestinal tracts are about the same as man's. So is their dental structure and skin composition (although thicker), and their bone mass and body mass approximate man's for a time. Thus, pigs are ideal for medical research except that as they mature, their weight becomes a problem. At six months of age, they weigh 160–180 pounds, about the weight of an average man. However, at maturity, pigs become hogs weighing 600 pounds or more—much too heavy for easy handling in medical research. About five years ago, the AEC's Hanford Laboratories (now renamed the Pacific Northwest Laboratory) began to develop a breed of pigs that would reach—and stay at—the average size of 160–180 pounds. Such pigs have proven to be invaluable in the study of radiation effects because of their close similarity to man's body structure. The photo compares a mature "Hanford Miniature" (*right*) with one of its parent stock, a huge Palouse white swine. A breeding herd of 100 has been kept at the laboratory to supply the increasing demand for the animals. At present, the demand threatens to surpass the supply as hospitals and universities find the miniature pigs useful in research applicable to humans ranging from dental braces and tartar formation to heart failure and consequent lung and respiratory changes.



New Plant Research Facility. Photo shows antirrhinum (snapdragon) plants being arranged at varying distances from the location of a 12,000-curie source of cesium 137, which will bombard the plants with gamma rays for 20 hours each day in the new Controlled Environment Facility for Radiobotany at Brookhaven National Laboratory. While biologists are in this shielded room, the source is lowered inside the pipe into a shielded container below the floor. The telescoping cover will allow the intensity of radiation to be altered to different desired levels. At a later date, a cesium 137 source of about 24,000 curies will be installed for use in this room. Controlling the environment in the laboratory will allow for growing plants at any time of year and under any reproducible environmental condition to study the effects of radiation on plants.

of planting time. Thus, the facility will increase the efficiency and decrease the ultimate cost of research with plants by allowing greater experimental accuracy with fewer plants permitting research throughout the year, and avoiding environmental changes. The new facility will not replace the existing greenhouses or outdoor fields.

The plant growth facilities will allow plants to be grown under continuous and controlled gamma radiation exposure under controlled and reproducible environmental conditions. The area includes a large room containing eight large (10 x 15 feet) and 10 smaller (4 x 8 feet) growth chambers equipped with fluorescent lamps which can provide varying light intensities up to 4,000-foot candles. Humidity can be controlled at any point from 40 to 90 percent and temperatures can be maintained from 40° to 95° F.

The basement of the building has six heavily-shielded rooms containing gamma sources ranging in intensity from 40 to 12,000 curies of cesium 137 (eventually, the largest source will be 24,000 curies of cesium 137). Acute and chronic irradiation experiments will be carried out at times in combination with controlled environment chambers.

The laboratory section of the new extension is in a two-story L-shaped structure. In addition to offices, instrument rooms, a small conference room, and service equipment rooms, there are eight laboratories variously equipped for studies in radiobiology, photobiology, cytology, genetics, ecology, plant physiology, and biochemistry.

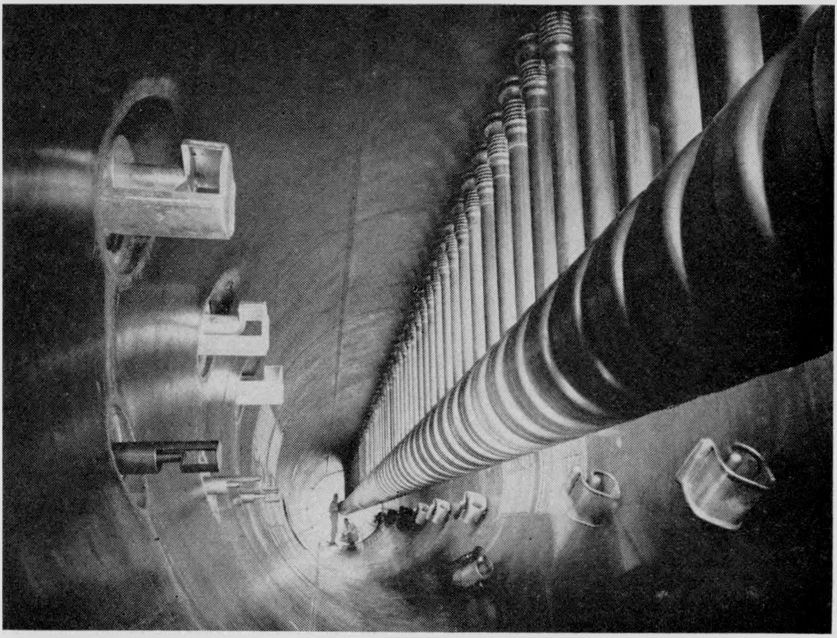
The total gross area of the facility is 33,300 square feet. Construction was begun in early 1963, and the cost was $1.8 million.

Fission Product Inhalation Laboratories

The balance of construction on the Fission Product Inhalation Laboratories at the AEC's Sandia Base, Albuquerque, N. Mex., was completed in February 1965. These facilities, operated as an AEC project by the Lovelace Foundation for Medical Education and Research, together with those furnished by the Foundation, now provide 99,810 square feet of space for research operations. The construction costs for the total facilities were $2,500,000. In addition, to support the requirements for data collection, storage and retrieval, a Burroughs B–5000 computer was purchased late in 1964 by the AEC at a cost of $506,470. The computer is located at Lovelace Foundation headquarters in Albuquerque.

PHYSICAL RESEARCH

The objective of the basic physical research program is to further the understanding of the basic laws of nature which influence the development, use, and control of nuclear energy. Inherent in such a program is the responsibility of providing adequate facilities to conduct such research. During 1965, three new reactors for the research program achieved criticality and design work was started for another research reactor. Construction was nearly completed on the Transplutonium Processing Plant and construction was started on the Transuranium Research Laboratory; both facilities are destined to



HILAC Interior. Photo shows the interior of the remodeled heavy ion linear accelerator (HILAC) at the Lawrence Radiation Laboratory, Berkeley. The $1.5 million remodeling and modernization program was initiated in 1963 and largely completed in the spring of 1965. It gives the machine the potential of accelerating particles continuously, in comparison to its earlier acceleration of particles in pulses with acceleration constituting 3 percent of operating time. The beam intensity (number of particles accelerated in a given time) has been increased by about 800 percent for heavy nuclei such as neon and argon, and about 2,000 percent for lighter nuclei such as carbon and oxygen. Suppression of unwanted radiation, which formerly swamped counters in some experiments, opens up new areas of experimentation with sensitive counters. The modification provides the potential of beam splitting and multiple experimentation for the first time, and a reduction by 8- to 20-fold in time required for a typical HILAC experiment. Central to the remodeling was installation of a new 7-megawatt power supply to replace the previous 1.4-megawatt unit. Associated modifications included a new cooling system, heavier shielding, and new electronic components. The photo looks in the direction of acceleration in the main accelerating chamber, with alinement of drift tubes.

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play vital roles in the National Transplutonium Production and Research Program. Satisfactory progress was made in the construction of the Stanford Linear Accelerator. A two volume report on the design of the proposed 200 Bev National Accelerator Laboratory was completed and now serves as the basis for the preliminary architect-engineering designs.

Ames Laboratory Research Reactor (ALRR)

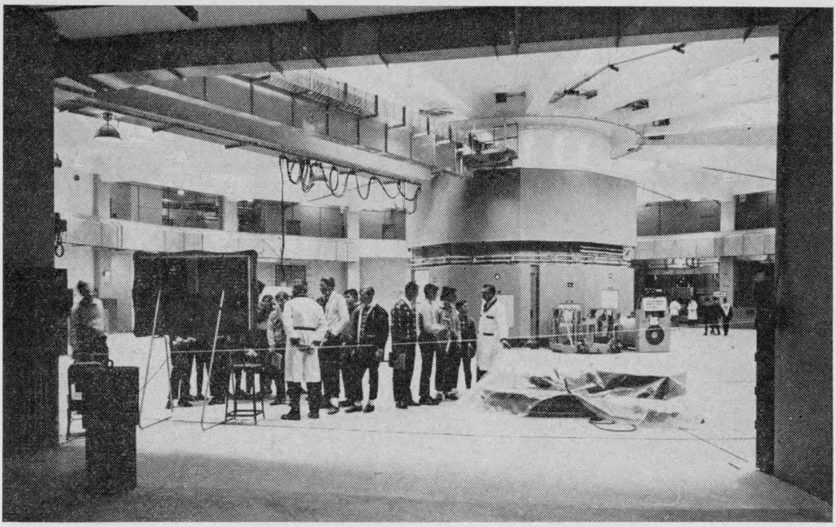
On February 17, 1965, the Ames Laboratory Research Reactor (ALRR) became operational; it achieved its full power level of 5 megawatts on July 12. The ALRR is a five thermal megawatt enriched uranium-fueled, heavy-water-moderated reactor located at the Iowa State University of Science and Technology, Ames, Iowa. It will be used as a source of radiation in the study of materials and other applications of radiation to problems in chemistry, physics, metallurgy, and engineering.

High Flux Beam Reactor (HFBR)

On October 31, 1965, the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory became operational. The HFBR, designed to operate at 40 thermal megawatts, is cooled and moderated by heavy water and contains a heavy water reflector. A feature of the experimental facilities at the HFBR is the multiple neutron spectrometer control system which is composed of eight spectrometers, each available to a different user group involved in independent research. All the spectrometers, however, will be under the control of a single digital computer with a 32,000-word memory. This computer will sequentially control the motion of all the axes of rotation and operate all the neutron detectors and monitors. In addition, it will handle all the computations, and accumulate and process the experimental data. The data are stored on a megnetic drum so that any run may be recalled at will for re-examination. This system will be most useful for many research experiments in such areas as nuclear physics, nuclear chemistry, solid state physics, and metallurgy.

Stanford Linear Accelerator Center (SLAC)

Construction of the Stanford Linear Accelerator, located at Stanford University near Palo Alto, Calif., was, at year's end, approximately 85 percent complete. Construction of all the buildings is essentially complete except for the cryogenic and experimental end station buildings. The two-mile-long accelerator tunnel portion is com-

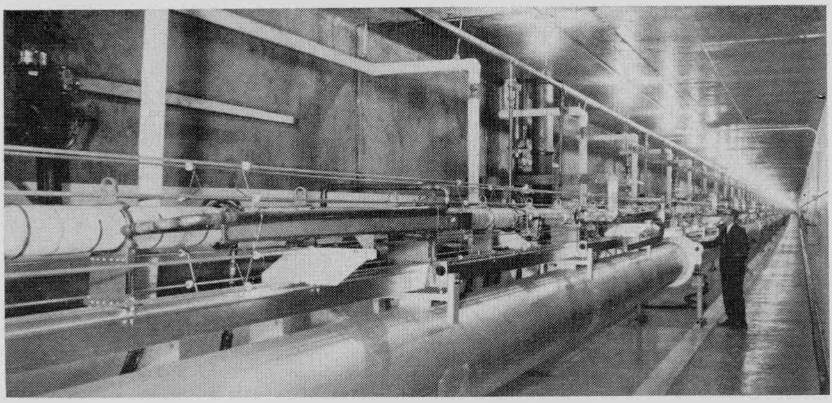


HFBR. Photo shows the experimental floor of Brookhaven National Laboratory's new high flux beam research reactor (HFBR) during a High School Visitor's Day tour in which 4,642 students from 172 schools toured Brookhaven. The reactor became operational on October 31. Three of the nine reactor ports (squares in reactor's faces) to provide external beams of neutrons can be seen. In addition, seven facilities for the irradiation of samples inside the reactor are also provided, making it possible to conduct a number of different experiments simultaneously. The new $12.5-million research reactor is housed in a three-story, circular, domed, gastight building. It is designed to provide the higher neutron fluxes required by the constantly improving experimental techniques in neutron research.

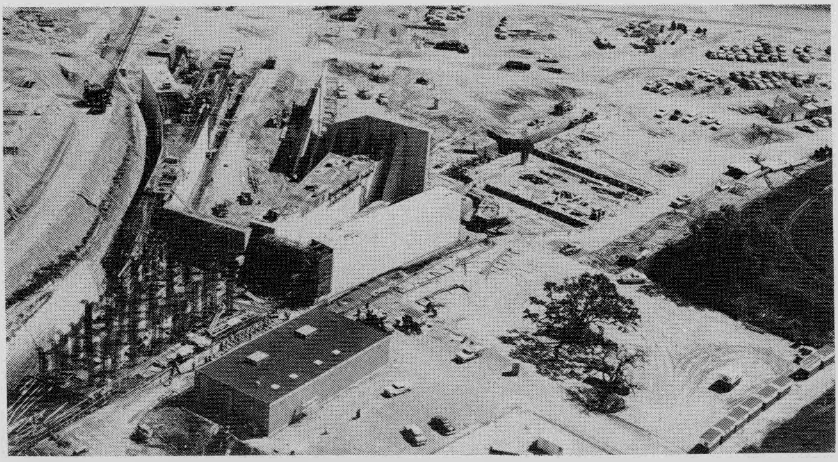
plete and more than 8,000 of the total 10,000 feet of accelerator tube and associated equipment have been installed. The first two sectors (666 feet) of the machine were successfully operated last spring, producing a 15-milliamp beam at 1.4 Bev. These two sectors are being used to test operating features of the machine. Completion of the $114 million accelerator is scheduled for the latter half of 1966.

Argonne Advanced Research Reactor (A^2R^2)

Advanced work in the fields of nuclear physics, nuclear chemistry, and solid state science has, in the past, been hampered by the lack of research facilities providing higher neutron fluxes. To help meet such research needs, the Argonne Advanced Research Reactor (known as the A^2R^2) will be built at Argonne National Laboratory at an estimated cost of $25 million. This research facility will consist of a high flux research reactor with an ultimate power level of from 100 to 240 thermal megawatts, and associated support and service buildings. Flux levels in excess of 5×10^{15} (five quadrillion) will be obtainable at power levels above 100 megawatts. Although primarily designed for research involving the use of high density neutron beams, a number of irradiation facilities will be provided affording advanced studies in such fields as transuranium element chemistry and metallurgy. The architect-engineer firm of Burns & Roe, New York,



SLAC. Completion of the $114 million, two-mile-long Stanford Linear Accelerator Center (SLAC) is expected in the latter half of 1966. Photo *above* shows a portion of the accelerator waveguide. The accelerator structure is constructed in 40-foot-long sections (240 in all) each of which sits on adjustable jacks to permit alinement. The round holes in the aluminum girder permit use of a laser beam for alinement purposes. Photo *below,* shows the beam switchyard under construction. The beam will enter the beam switchyard just off the picture at the lower left. Bending magnets in the beam switchyard will direct the beam to experimental apparatus in either of the two target buildings shown under construction in the foreground. The beam switchyard will be covered with 35 feet of earth.



started design work in June 1965, and field construction is scheduled to start in mid-1966. (See also Chapter 11—Advanced Reactor Technology and Nuclear Safety Research.)

NATIONAL TRANSPLUTONIUM PROGRAM

The national transplutonium production and research program is directed toward large-scale production of the very heavy elements (*i.e.*, plutonium 242, americium, curium, berkelium, californium) necessary for basic research. Currently, only very small quantities of these man-made elements are available for study.

High Flux Isotope Reactor (HFIR)

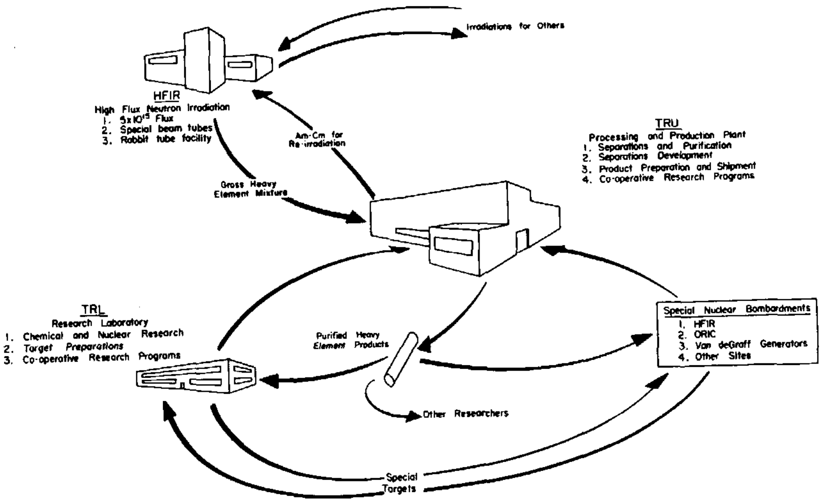
On August 25, 1965, the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory became operational. The reactor, rated at 100 thermal megawatts of power, will produce a thermal neutron flux of 5.5×10^{15} n/cm^2/sec. (5.5 quadrillion neutrons per square centimeter per second). This flux, to be reached next spring, will be available 90 percent of the time for production purposes; it is expected to be the highest flux of its kind in this country and perhaps in the world. The HFIR facility will be the prime producer of the very heavy elements which will be used in the nationwide transplutonium research program. In addition to the prime requirement for production of heavy elements, the reactor also includes high flux beam tubes and other ancillary irradiation facilities which will be used by physicists and chemists in a variety of advanced research programs.

Transplutonium Processing Plant (TRU)

The forthcoming completion of the Transplutonium Processing Plant (TRU) at Oak Ridge National Laboratory early in 1966 will mark the beginning of a vigorous program for the production, chemical processing, and recovery of large quantities of the very heavy man-made elements. These two facilities, HFIR and TRU, constructed for the large-scale production of a wide range of new elements and their isotopes needed for research purposes, will provide a major production capability for such purposes.

Transuranium Research Laboratory (TRL)

Construction started during 1965 on the Transuranium Research Laboratory (TRL) at Oak Ridge National Laboratory. This new



National Center. Oak Ridge National Laboratory (ORNL) is being equipped as the national center for production of transuranium elements. This production capability combined with other facilities at ORNL provides a unique center for research with the transuranium elements. The heavy manmade elements are produced by neutron bombardment in the high flux isotope reactor (HFIR) and are isolated by chemical processing in heavily shielded cells in the Transuranium Processing Plant (TRU). Basic research with the elements will be concentrated in a third facility, the Transuranium Research Laboratory (TRL) while the many other facilities at ORNL for nuclear and chemical studies with these elements greatly facilitate the research capability in this complex.

$1.8 million laboratory for research in the transuranium elements will provide special facilities and equipment necessary for progressive research with these elements. Individual laboratories are designed for chemical and nuclear studies of highly alpha-active isotopes in glove box and shielded glove box types of enclosures. Work areas will have up to three feet of concrete shielding for protection against neutrons emitted in spontaneous fission from quantities of transuranium isotopes under investigation. At year's end, design was complete and construction was about 40 percent complete.

PROPOSED 200 BEV ACCELERATOR

Preliminary Study

The Lawrence Radiation Laboratory's Berkeley staff submitted, at AEC request, a two-volume report[4] on their design study for the

[4] The report, "200 Bev Accelerator Design Study," is available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., 22151, at $10.25 for the 2 volumes. A summary, under the same title, is available for $2.

proposed 200 Bev accelerator to the Commission in June 1965. Incorporated in the report were preliminary design criteria for the accelerator, the physical plant, the associated experimental areas, support facilities, and an estimation of the operating staff and budgets. This is being used as the basis for the preliminary architect-engineer studies which were started in 1965 (see "Some Significant Developments" section of Chapter 1—The Atomic Energy Program—1965). The proposed accelerator is a 200 billion electron volt (Bev) strong-focusing proton synchrotron designed to provide about 30 trillion (3×10^{13}) protons per second, a beam intensity which would be 10 times greater than that obtainable from any present high-energy proton accelerator. The higher energy of this machine will provide the necessary experimental data for furthering the understanding of the nature of elementary particle physics and will provide the next step to a new range of particle energies.

Need Foreseen in Mid-1950's

The need for higher energy experiments in particle physics and the feasibility of extending the strong-focusing concept to higher energy accelerators were anticipated in the middle 1950's and became evident at the beginning of this decade, immediately after the CERN and Brookhaven strong-focusing proton synchrotrons came into operation. In February 1962, and again in December 1962, the Lawrence Radiation Laboratory submitted proposals to the Atomic Energy Commission requesting authorization to conduct a design study for a new accelerator in the range of hundreds of Bev. These and other proposals were considered in the context of the national program in high energy physics by a scientific advisory panel appointed by the AEC's General Advisory Committee and by the President's Science Advisory Committee (GAC/PSAC).

Recommendations Made

Among the April 1963 conclusions of the GAC/PSAC Panel was the specific recommendation that a high energy proton accelerator of approximately 200 Bev energy be authorized and constructed at the earliest possible date.[5] On February 26, 1964, while testifying before the congressional Joint Committee on Atomic Energy, AEC Chairman Glenn T. Seaborg was advised by the Committee that a national policy for high energy physics was considered imperative for the

[5] Report of the Panel on High Energy Accelerator Physics of the General Advisory Committee to the Atomic Energy Commission and the President's Science Advisory Committee, TID–18636, April 26, 1963. Single copies are available upon request from the Division of Technical Information Extension, P.O. Box 62, Oak Ridge, Tenn., 37831.

guidance of the Congress and the taxpayers. Later that year, the Joint Committee heard testimony, which included the need for the establishment of a national policy for the support of high energy physics, from Dr. Donald F. Hornig, Director of the Office of Science and Technology and Scientific Advisor to the President.

The Commission prepared a "Policy for National Action in the Field of High Energy Physics,"[6] and on January 26, this report was transmitted by the President of the United States to the Joint Committee on Atomic Energy, with his approval of the guidelines developed. The report became the primary subject matter for the High Energy Physics Research hearings before the Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy.[7] The first item in the national policy under the section entitled Specific Plans calls for "* * * construction of a high energy proton accelerator of approximately 200 Bev, in accordance with technical specifications developed by LRL, to be operated as a national facility. This machine should be authorized for design in fiscal year 1967, and for construction in fiscal year 1968. * * *" Actions initiated by the Commission in keeping with the national policy are discussed in Chapter 1 of this report.

[6] Policy for National Action in the Field of High Energy Physics, U.S. Atomic Energy Commission, Washington, D.C., January 24, 1965. Also reprinted as part of Report on National Policy and Background Information, JCAE, Congress of the United States, February 1965. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, at $0.55.

[7] Hearings before the Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy-Congress of the United States, 89th Cong., 1st sess., on High Energy Physics Research, March 2, 3, 4, and 5, 1965.

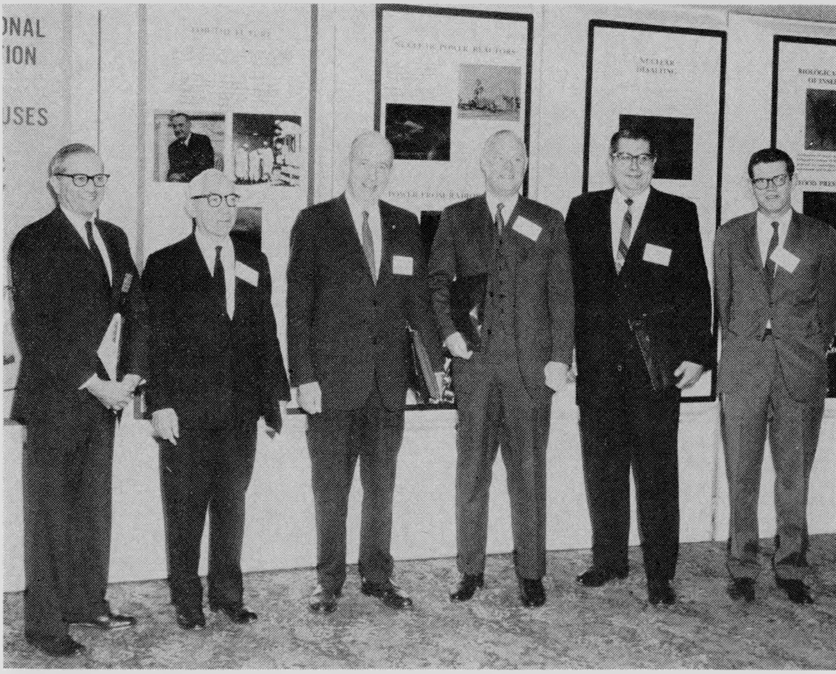
Chapter 15

INTERNATIONAL COOPERATION

The AEC's program for international cooperation in the peaceful uses of nuclear energy entered its second decade in 1965. The original objective of this program was to enable friendly nations abroad to share in the peaceful benefits of nuclear technology, under appropriate controls. Recent developments in the United States and abroad have placed increased emphasis on the export of enriched uranium for use in foreign power programs and on cooperation in the development of advanced nuclear technology. The two principal activities in the international program, the supply of nuclear materials and the exchange of technical information, involve resources created in the U.S. domestic program. With minor exceptions, the AEC's program does not include direct financial assistance to the atomic energy programs of other nations; assistance to nuclear power projects abroad has been funded by the U.S. Agency for International Development (AID) under established ceilings for aid to designated nations.

INTERNATIONAL COOPERATION YEAR

By Presidential Proclamation, the United States joined more than 100 other nations in the observance of International Cooperation Year, commemorating the 20th anniversary of the United Nations. A number of committees were established to review existing cooperative programs and consider areas for greater cooperation. The Private Committee on the Peaceful Uses of Atomic Energy submitted a report to the White House Conference on International Cooperation, held in Washington November 29–December 1, 1965. Among the areas in which the committee recommended expanded cooperation or increased emphasis were: international safeguards, nuclear power, nuclear desalting, biological control of insect pests, food preservation, and health and safety.



International Cooperation Panel. The White House Conference on International Cooperation, in late November, completed a U.S. review of existing cooperative programs as a part of the observance of International Cooperation Year. The members, above, of a Panel on the Peaceful Uses of Atomic Energy discussed recommendations for expanded international cooperation in nuclear energy matters. *Left to right* are: Dr. Robert Hasterlik, University of Chicago; Prof. I. I. Rabi, chairman of the panel and member of the United Nations Scientific Advisory Committee; Mr. William Webster, president, New England Electric System; Mr. W. Kenneth Davis, president, Atomic Industrial Forum; Mr. Alan Burch, AFL–CIO; and AEC Commissioner John G. Palfrey. Ambassador Henry D. Smyth, IAEA (not shown) was also a panel member.

AGREEMENTS FOR COOPERATION

The AEC's international program includes as one important aspect the implementation of Agreements for Cooperation [1] with the International Atomic Energy Agency (IAEA) and the European Atomic Energy Community (Euratom), and with 34 nations. These agreements are in two general categories: those which provide for transfer of limited quantities of material for research reactors and other small-scale research purposes, and those which provide much larger quantities of material for use in power reactors and related development work. Both provide for cooperative exchanges of information. U.S. Agreements for Cooperation include guarantees that nuclear

[1] See page 111 for summary on Mutual Defense Agreements.

equipment and materials supplied by the United States to other nations are used only for peaceful purposes, and safeguards to ensure compliance with this guarantee. These safeguards involve broad rights of verification, including on-site inspection. Safeguards are administered in some cases by the United States and in others by the International Atomic Energy Agency or the European Atomic Energy Community.

1965 Agreements Changes

During 1965, amendments to bilateral Agreements for Cooperation were negotiated and signed with Austria,[2] Israel, Korea,[2] and Turkey, and a superseding agreement was negotiated with Brazil,[2] to extend the period of the original agreements and to provide for the transfer of safeguards responsibilities to the IAEA. Negotiations were opened to extend the bilateral agreement with Indonesia.

Negotiations were completed with Switzerland and continued with Sweden on superseding power agreements. The proposed agreements would provide for transfer of safeguards to the IAEA, increased quantities of nuclear reactor fuels, and toll enrichment services beginning January 1, 1969. An amendment to the agreement with Spain, containing similar provisions, was negotiated and signed during the year.

The Agreement for Cooperation with Belgium, concluded in 1955 before the establishment of Euratom, was permitted to expire in July by mutual consent and special nuclear materials needed for Belgium's nuclear program will be made available under the U.S.-Euratom agreement. Direct technical cooperation with Belgium in areas of mutual interest will, however, continue. The civil uses agreement with the United Kingdom, scheduled to expire in July 1965, was extended in its present form for one year. (See Table 1, Appendix 5, for list of Agreements for Cooperation.)

TECHNICAL EXCHANGES AND COOPERATIVE PROGRAMS

INFORMATION EXCHANGES

The AEC conducts technical information exchanges with foreign governments, Euratom, IAEA, and the European Nuclear Energy Agency (ENEA). These exchanges, primarily in reactor technology, are intended to pool the benefits of foreign and U.S. technological developments. Major activities during 1965 are summarized on the following pages.

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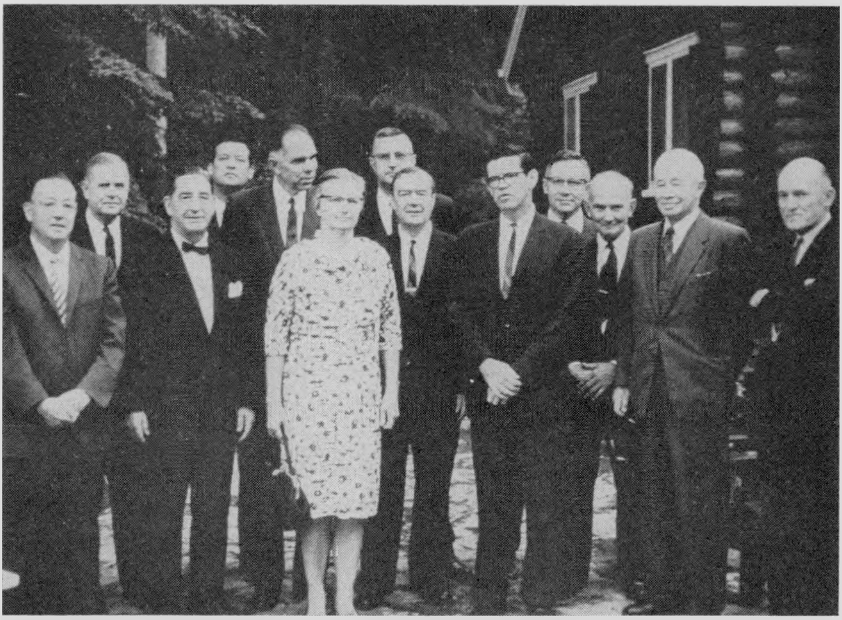
[2] To be effective upon ratification by these governments.

Signing of Agreements. During February, Dr. Glenn T. Seaborg, Chairman of the U.S. Atomic Energy Commission, and Sir William Penney, chairman of the United Kingdom Atomic Energy Authority, *above*, exchanged letters initiating a new 10-year information exchange program on fast reactor technology. The arrangement calls for exchange of research and development data on all types of fast reactors for civil, land-based power stations up to and including construction and operation of prototype reactors. Photo *below* shows the April signing of a memorandum by the United States and Israel concerning arrangements for a feasibility study of a proposed dual-purpose nuclear power desalting plant for Israel. Shown at the signing, *left to right*, are: Ambassador Abraham Harmon of Israel; Kenneth Holum, Assistant Secretary for Water and Power Development, U.S. Department of the Interior; AEC Commissioner James T. Ramey; and L. H. Oppenheim, vice president of Kaiser Industries, Inc., Oakland, Calif. The Kaiser firm was the prime contractor for the study.

Bilateral Exchanges and Programs

United Kingdom. An expanded fast reactor information exchange agreement was established in 1965 between the AEC and the U.K. Atomic Energy Authority to supersede the original 1956 agreement. The exchange covers all aspects of fast reactor research and development, including information on the construction and operation of prototype reactors. The five-year gas-cooled reactor exchange, covering the U.K.'s Advanced Gas Reactor (AGR) and the AEC's Experimental Gas-Cooled Reactor (EGCR) originally signed in 1959, was extended to July 1968.

Canada. The five AEC Commissioners visited Canada, during June 1965, for a meeting with senior officials of the Canadian atomic energy program to discuss the joint U.S.-Canadian heavy water reactor effort



Historic Meeting. Discussions with Canadian atomic energy officials and briefings on the Canadian program highlighted the visit of the Commission to Canada in June. It was the first time the five-member Commission had made a foreign visit as a group. *Left to right:* Commissioner James T. Ramey; Commissioner Gerald F. Tape; Mr. J. Loren Gray, president of Atomic Energy of Canada, Ltd. (AECL); AEC Division of International Affairs Director Myron Kratzer; AEC Chairman Glenn T. Seaborg; Commissioner Mary I. Bunting, whose term as a Commissioner ended in June; AEC General Manager Robert E. Hollingsworth; Dr. W. B. Lewis, vice president, AECL; Commissioner John G. Palfrey; Dr. Allen J. Vander Weyden, then AEC Deputy Assistant General Manager for Reactors; Charles Grinyer, AECL Board; R. L. Hearn, AECL Board; D. M. Stephens, AECL Board.

and other cooperative activities. A second joint meeting was tentatively scheduled for 1966 in the United States.

A new arrangement was reached between the United States and Canada in 1965 providing for cooperation in the development of the Heavy-Water Organic Cooled Reactor (HWOCR).

Germany. Over the past eight years, the United States and the Federal Republic of Germany (West Germany) have developed a close collaboration in several specialized areas of mutual interest. A new arrangement provides for German participation in AEC-sponsored nuclear superheat work being performed at Vallecitos, Calif., by the General Electric Co. Germany is contributing $3.5 million to this program and will provide the United States with information on its existing and future programs in the nuclear superheat field. An additional cooperative arrangement provides that fuel elements developed, fabricated, and purchased in the United States will be tested in the pebble-bed, high-temperature, gas-cooled reactor being constructed at Juelich in Germany. The United States and Germany will exchange information and visits as a part of this program. Germany is also participating in the Southwest Experimental Fast Oxide Reactor (SEFOR) project in Arkansas, construction of which started in September 1965. (See Chapter 7—Civilian Nuclear Power.)

The U.S. has entered into an arrangement with the GKSS, a nonprofit company supported by the German federal and state governments and Euratom, which is responsible for the development, construction and operation of the nuclear ship *Otto Hahn.* Under this arrangement, the AEC will lease fuel for the first core of the *Otto Hahn* and provide information on the NS *Savannah*, and in return will receive detailed information on the *Otto Hahn* project.

Italy. The United States and Italy, in November 1965, signed a contract under which "spent" thorium-uranium fuel elements from the U.S. Elk River, Minn., reactor will be reprocessed and refabricated by an Italian plant and subsequently reirradiated in the United States. This cooperative program will demonstrate the technology associated with the complete recycle of thorium-uranium fuel and will assist in development of information on the use of low-decontamination, remote fabrication fuel cycle technology.

Spain. The AEC and the Spanish Junta de Energia Nuclear have under consideration a prospective cooperative program in the development of heavy-water, organic-cooled power reactors including an exchange of technical information. Under this arrangement, and subject to congressional authorization, the AEC would loan the initial inventories of heavy water and enriched uranium for the Spanish

30,000-electrical kilowatt (ekw) DON prototype power reactor near Madrid. In return, Spain would provide the AEC with design, construction, and operating information on the DON reactor.

Sweden. In mid-1965, the AEC signed a cooperative exchange arrangement with Sweden on nuclear superheat reactors. Under this arrangement, the United States will receive information on the Swedish nuclear superheat effort which is centered on the Marviken reactor, a heavy water moderated and cooled, direct cycle, integral boiling superheating and slightly enriched fueled reactor some 130 miles south of Stockholm. In return, the AEC will provide information on its existing and future programs in nuclear superheat work and past programs relating to heavy water moderated and cooled reactors.

Soviet Union. The formal exchange of technical teams with the Soviet Union continued in 1965. Soviet delegations on reactor technology and radioactive waste disposal visited U.S. facilities, in return for similar U.S. visits to the U.S.S.R. in 1964. In December, a U.S. team of specialists in radioneurological research visited medical facilities in the Soviet Union, and a Soviet delegation of low-energy physics specialists visited facilities in the United States. Long-term reciprocal research assignments by specialists in the field of high energy physics were completed. The first phase (United States to the U.S.S.R.) of the long-term controlled thermonuclear reactions research specialists exchange was carried out in November when a U.S. physicist arrived at the Lebedev Institute in Moscow for a three-month stay and a U.S. scientist was placed at Kharkov in December for six months. The United States and the Soviet Union exchanged several delegations to conferences and scientific symposia during the year and continued the reciprocal exchange of recent scientific and technical reports.

Other Assistance to Foreign Programs

Cooperation with foreign governments has also taken the form of participation in international symposia, advisory visits to various countries, and information exchange in the fields of uranium exploration, mining, and milling. Twenty-three geologists and engineers representing Argentina, Australia, Canada, Egypt, France, Mexico, Pakistan, Peru, South Africa, Sweden, Turkey, United Kingdom, West Germany, and Yugoslavia, and Euratom visited AEC offices, and inspection tours of operating mines and mills were arranged for them. During the year, AEC geologists and engineers visited the following countries: Argentina, Brazil, Chile, France, Peru, Spain, Sweden, and the United Kingdom.

Cooperation With International Organizations

International Atomic Energy Agency (IAEA). The United States has continued its policy of giving strong support and cooperation to the IAEA, through the provision of cost-free experts, fellowships, equipment grants, and technical information. For the seventh successive year, the United States donated $50,000 worth of nuclear materials for use in the Agency's research and medical therapy projects. Materials under these offers have been donated in the past to Finland, Pakistan, Norway, the Congo, Mexico, Argentina, and Yugoslavia for use in research reactors. In December 1965, $39,268 worth of material was donated to the Agency for a Lockheed research reactor in Uruguay, and $10,732 worth of materials was added to the prior donation to Argentina.

U.S. experts participated in all of the meetings of the special group established by the IAEA Board of Governors to simplify and strengthen the Agency's safeguards system. In February 1965, the Board gave provisional approval to the revised system and, after consideration by the Ninth General Conference, final approval was given at a September meeting in Tokyo. The new safeguards system was put into effect on September 28.[3]

International Trilateral Agreement Signing. Agreements were signed in Tokyo in September, during the International Atomic Energy Agency's Ninth General Conference, under which the United States will transfer to Uruguay's Nuclear Research Center at Montevideo, a 100-thermal-kilowatt research reactor and the necessary nuclear fuel. The transfer will take place through the U.S.-IAEA Agreement for Cooperation, and the reactor and materials will be subject to the International Agency's safeguards. Shown signing the agreement, *left to right,* are: Professor Alfonso Frangella for Uruguay; Director General Sigvard Eklund for the IAEA; and AEC General Manager Robert E. Hollingsworth for the United States.

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[3] See also p. 233, "Annual Report to Congress for 1963."

European Atomic Energy Community (Euratom). The United States and Euratom have continued close cooperation in important development areas such as (*a*) fast reactors, (*b*) the Joint Research and Development Program which is devoted to improvement of the performance of U.S. light water power reactor types, including the lowering of fuel cycle costs associated with reactors built under the joint program, and (*c*) the Joint Power Reactor Program.

The AEC and Euratom have also agreed to undertake a joint critical experiment at the Oak Ridge National Laboratory related to the fast neutron burst, liquid metal cooled, source reactor, SORA, which would serve as a unique tool for nuclear measurements and which has been designed by Euratom.

European Nuclear Energy Agency (ENEA). The AEC cooperates with ENEA through information exchanges and participation in specific projects. The United States continued participation in the ENEA's Halden Boiling Water Reactor Project in Norway, and arrangements were completed for the exchange of nuclear data and computer programs with the ENEA Neutron Data Compilation Center at Saclay, France. The AEC's association with the ENEA Dragon high temperature, gas-cooled reactor project in the United Kingdom [4] and with Eurochemic (European Company for the Chemical Processing of Nuclear Fuels) continued during the year. In addition to participation in many ENEA study groups, the AEC is cooperating in the recently established food irradiation program at the Austrian Nuclear Research Center at Seibersdorf.

Inter-American Nuclear Energy Commission (IANEC). The IANEC joined with the AEC's Puerto Rico Nuclear Center in sponsoring an Inter-American Conference on the economic and technical aspects of nuclear power generation in Latin America, in February. Representatives from the United States and Latin American countries presented papers and participated in technical discussions.

RESEARCH ASSISTANCE

In support of research programs in the peaceful uses of nuclear energy in other countries, the AEC maintains 82 depository libraries of unclassified nuclear material abroad, has conducted atomic energy exhibits in 25 nations and at 6 international conferences, and has participated in 3 major international nuclear conferences at Geneva dedicated to the sharing of nuclear technology. Technical consultants and advisors have been sent abroad to assist the developing nuclear

[4] See p. 238, "Annual Report to Congress for 1963."

programs of cooperating nations, both bilaterally and through the International Atomic Energy Agency. Training and research opportunities in peaceful uses of atomic energy are afforded to citizens of Free World countries in AEC-operated laboratories and at the Puerto Rico Nuclear Center; since 1955, over 3,000 foreign nationals have been accommodated in AEC facilities. These foreign nationals may be sponsored by their own government, by the U.S. Agency for International Development, or by an international organization such as the IAEA. Nearly 400 foreign students and guests were accommodated in AEC facilities in 1965.

Research Reactors

More than 50 U.S.-built research reactors are operating or being built abroad under Agreements for Cooperation between the United States and other nations or international organizations, and several thousand radioisotopes shipments are exported annually for use in foreign medical, agricultural, and industrial research programs. The United States participates in IAEA-sponsored regional study groups to assist in developing sound programs in newly established research reactor centers in IAEA member states.

At the end of 1965, 22 of 26 grant commitments made between 1956 and 1962 had been paid to assist other nations to acquire U.S.-designed research reactors. The remaining commitments will be paid upon completion of the reactors. The deadline for submission of proposals under this program was in 1960.

"Sister" Laboratory Program

The first "sister" laboratory arrangement, between Brookhaven National Laboratory and the Cekmece Nuclear Center in Turkey, has been extended to June 30, 1966. Similar relationships have been established between the Argonne National Laboratory and the Institute for Atomic Energy, National Tsing Hua University in Taiwan during 1965, and with the Institute for Atomic Energy in Korea in 1964. In October 1965 a sister laboratory arrangement was established for one year between the Puerto Rico Nuclear Center and the Colombian Institute of Nuclear Affairs at Bogota, Colombia. A similar arrangement was being developed in December between Brookhaven and the Democritus Nuclear Center near Athens, Greece. Assistance is provided by the U.S. sister laboratory to these research reactor facilities by periodic visits of U.S. scientists, through the exchange of correspondence, and through provision of AEC publications and minor items of equipment.

INTERNATIONAL SAFEGUARDS

The United States has consistently supported the development of an effective system of international safeguards under the International Atomic Energy Agency. These safeguards are applied to the nuclear materials, and to equipment and facilities supplied by one nation to another to ensure against their diversion from peaceful nuclear programs.

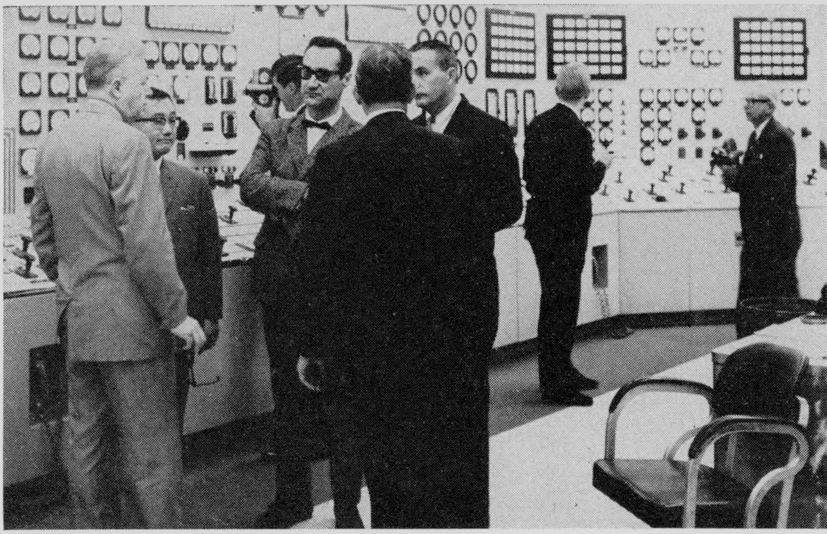
The Agency's 1965 General Conference adopted a U.S.-originated resolution to note with approval the revised safeguards system for nuclear materials and equipment which are subject to IAEA safeguards. Following approval by the General Conference, the system was put into effect by the IAEA Board of Governors. The revised system is substantially that which was earlier approved, though the language is less complex and precedures have been simplified. U.S. representatives contributed extensively through the working group established by the Agency to carry out this revision.

IAEA Inspections

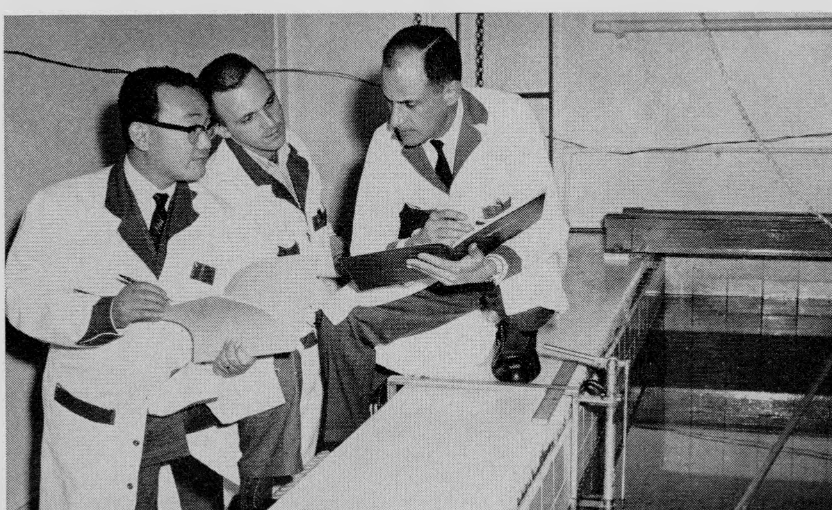
To encourage development of an effective and impartially administered international system, the U.S. has voluntarily placed two civilian prototype power and two research reactors under the IAEA system; one of the power reactors is the 175,00 ekw Yankee Nuclear Power Station at Rowe, Mass. This was done to provide additional experience for IAEA inspectors, to demonstrate the effectiveness of the system, and to support the U.S. position that these safeguards do not interfere with efficient operation of the reactors. During 1965, the IAEA conducted 10 inspections of U.S. reactors. The United States was joined in this demonstration program by the United Kingdom in June 1965, when the United Kingdom offered the 300,000 ekw Bradwell Nuclear Power Station for placement under IAEA safeguards.

Transfer of Bilateral Safeguards

The United States began in 1960 to seek the transfer of bilaterally administered safeguards to the IAEA. In September 1963, the first such transfer was accomplished by means of a trilateral agreement, signed by the United States, Japan, and the IAEA, providing for the administration of the Agency's system of safeguards over nuclear materials and equipment supplied by the United States to Japan. Arrangements have been completed for the IAEA to administer the safeguards applied to the nuclear materials, equipment, and facilities



IAEA Inspections. The privately owned Yankee nuclear power station, Rowe, Mass., was the first large power reactor to come under IAEA safeguards inspection and is one of four domestic reactors voluntarily placed under international safeguards by the United States. In *above* photo the inspection team is shown in the reactor control room of Yankee, *left to right:* John Downing, AEC Division of International Affairs; Yuzuro Motoda, IAEA inspector (Japan); Sloboden Nakicenovic, director IAEA Safeguards and Inspection Division (Yugoslavia); Charles Keenan and Herbert Waite of Yankee Atomic Electric Co.; and Robert Skjoeldebrand, IAEA inspector (Sweden). In the background, members of the inspection team's staff make photographic records of dial readings. Experience has shown that the IAEA inspections can be conducted without interference to efficient operation of the reactor. In photo *below*, Mr. Motoda (*left*) inspects the fuel element canal at the Brookhaven Graphite Research Reactor which, along with the Medical Research Reactor at Brookhaven National Laboratory, has been under IAEA inspections since 1962.



supplied by the United States to seven other nations. A number of other trilateral agreeements for transfer of safeguards have been signed. Negotiations continue for the transfer of remaining U.S. bilateral safeguards as other U.S. agreements approach expiration dates. Among the other supplier nations, Canada and the United Kingdom have entered into negotiations to transfer administration of specified bilateral safeguards to the IAEA. In October, the IAEA approved its assumption of safeguards over materials and technical equipment reciprocally transferred between Canada and Japan. Similar trilateral agreements were approved in 1965 covering safeguards on the United Kingdom agreements with Japan and Denmark.

Safeguards Advisory Panel Formed

To assist in the continued development of effective safeguards, the Commission authorized the formation of a Technical Advisory Panel on Peaceful Use Safeguards. The panel will advise the AEC on technical matters relating to the further development and implementation of improved safeguards procedures. Representatives with substantial experience in the various phases of nuclear energy from the nuclear industry and from AEC laboratories will constitute the panel.

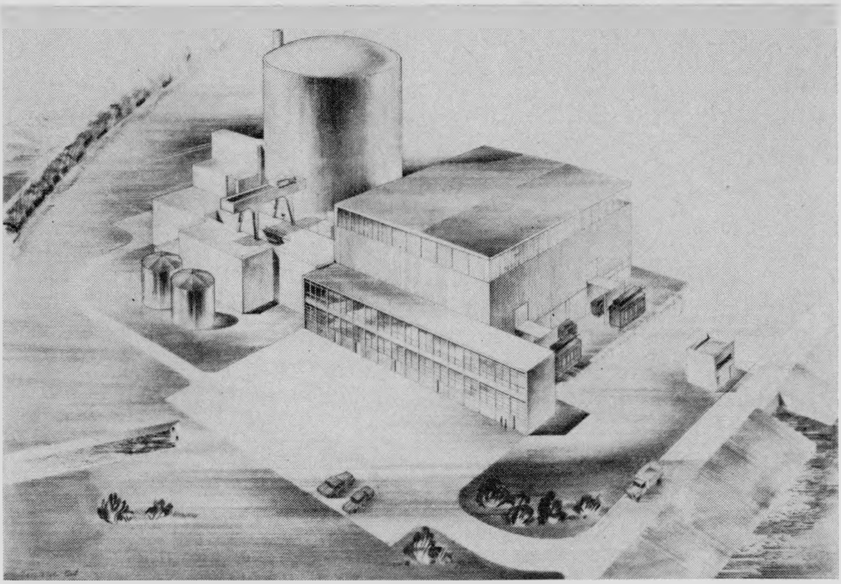
NUCLEAR POWER

The year was marked by increased international interest in the development and application of nuclear power reactors. Additional manufacturing experience, reductions in the capital costs of nuclear plants, and the passage of legislation providing for private ownership of nuclear fuel have combined to place the United States in a strong position with regard to foreign sales of reactors and nuclear fuels and materials. A total of 12 U.S.-type power reactors are completed or under construction in other countries and 3 more are in the planning stages.

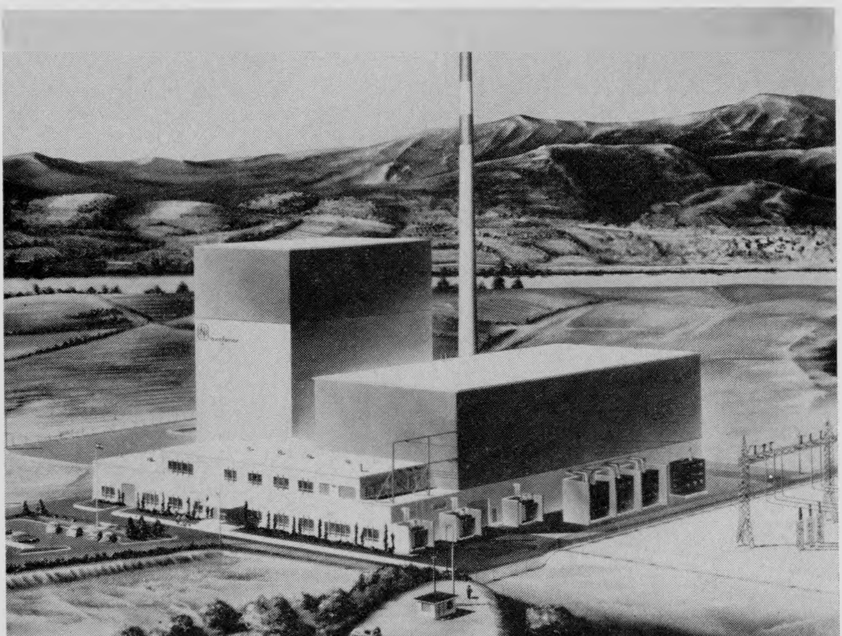
1965 Developments

Construction of India's first power reactor, the 380,000 ekw Tarapur plant designed by International General Electric, was approximately 22 percent complete late in 1965. The twin reactor plant, located north of Bombay, is scheduled for completion in 1968.

Northern Spain will be the site of a 440,000 ekw nuclear powerplant (Nuclenor), to be built by General Electric, expected to reach criticality in 1970. Spain's first nuclear powerplant, rated at 153,000 ekw, is now under construction near Madrid by Westinghouse, for Union Electrica Madrilena (UEM).



U.S.-Built Reactors. Drawing *above* shows the general configuration of the 350,000-electrical-kilowatt (ekw) pressurized water nuclear powerplant, Switzerland's first power reactor, which will be built by the Westinghouse Electric Corp. for Nordostschweizerische Kraft Werke A. G. (NOK), the largest electric utility in Switzerland, at Beznau near Baden on the Aare River. The artist's sketch *below* shows the 300,000-ekw boiling-water reactor to be built for Nuclenor, a Spanish utility, by the General Electric Co. The plant is to be located at Santa Maria de Garona on the Ebro River, in northeastern Spain.



Switzerland's first large-scale nuclear powerplant, a 350,000 ekw reactor (the NOK), will be built by Westinghouse in the Aar region. The plant is scheduled for completion by 1969.

In September, General Electric Co. was selected as the contractor for Japan's 325,000 ekw JAPCO No. 2, to be completed in 1969.

NUCLEAR DESALTING

The use of reactors for dual-purpose power generation and the desalting [5] of sea or brackish water is of strong international interest. President Johnson on numerous occasions has pledged the United States to share U.S. desalting technology with other nations. On September 9, 1965, he stated that:

> "Our Government is proceeding with an aggressive program of nuclear desalting. We invite all countries to join with us in this effort. What we learn from this program will be shared with the world."

"Water for Peace" Program

On October 7, the President announced initiation of a U.S. "Water for Peace" program to find solutions to man's water problems through a massive international cooperative effort. The announcement was made during the First International Desalination Symposium held in Washington, D.C., October 3–9. Delegates from 55 nations and 6 international organizations attended.

The AEC's foreign activities with other Government organizations are coordinated through the Interagency Committee for Foreign Desalting. This Committee, which is composed of representatives from the Departments of State and Interior, the Agency for International Development, the Bureau of the Budget, and the AEC, was formed early in 1965 to provide guidance on foreign desalting programs. The International Atomic Energy Agency serves as a focal point for U.S. cooperation abroad in nuclear applications to desalting.

Studies Underway

An agreement was signed on October 7 at the White House between the United States and Mexico providing for a joint preliminary study, under IAEA auspices, of the feasibility for a large nuclear power-desalting plant in Mexico near the Gulf of California. This agree-

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[5] See also Chapter 7—Civilian Nuclear Power, "Nuclear Desalting Applications" item for technical background.

ment was the culmination of a series of discussions and negotiations among the three interested parties which began in the spring of 1964.

The United States has participated in reviewing the needs and potential for nuclear desalting plants in Israel, Tunisia, and the United Arab Republic in cooperation with these countries. Discussions and consultations with many other interested nations have been held. A preliminary joint survey by the United States and Israel of Israel's water and power needs was completed in late 1964, and a jointly financed feasibility study with respect to a nuclear power desalting plant was nearly complete at year's end.

An arrangement for the exchange of technical information in the field of nuclear applications to desalting was concluded with the Italian National Nuclear Energy Commission; the IAEA is to receive reports exchanged under these arrangements. A reciprocal program is being conducted with the U.S.S.R. for the exchange of technical information in the desalting field, including the use of nuclear energy.

MATERIALS SUPPLIED ABROAD

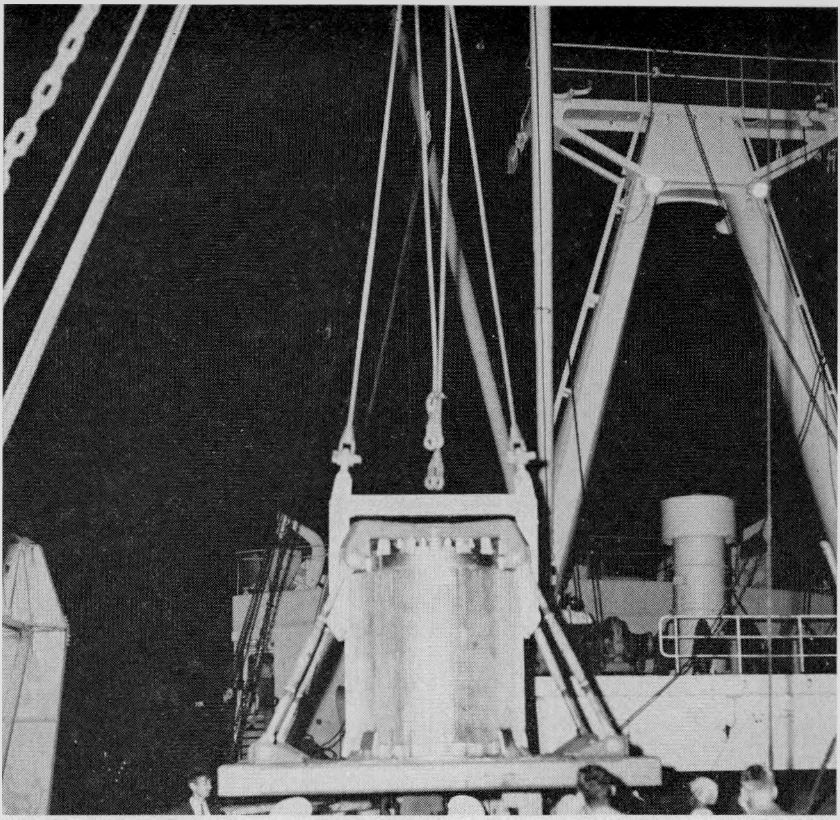
The AEC's policy for supplying enriched uranium and heavy water abroad has been to permit lease for research purposes, including research reactors, and to sell these materials when used for power reactor purposes. Pending the implementation of toll enrichment in 1969, the AEC is developing with several foreign users arrangements for the supply of enriched uranium under which natural uranium is accepted as partial payment. These arrangements are:

Power project	*Country or international organization*
UEM	Spain
VEW	Euratom
NOK	Switzerland
NUCLENOR	Spain
KRB	Euratom

Contracts may also be drawn in appropriate cases with foreign users providing for the deferral of payment for the initial inventory of enriched uranium fuel for a specified period, normally ten years, followed by repayment in installments during the following ten years.

Chemical Processing of Foreign Reactor Fuels

During the year, the AEC negotiated service contracts with France and Germany for the processing of Materials Testing Reactor-type spent fuel elements. A total of four countries—earlier contracts having been signed with Canada and Sweden—now obtain chemical proc-



Processing of Foreign Fuels. Spent reactor fuels from Sweden and France were shipped to the AEC's Savannah River Plant for chemical processing during the year. Photo shows one of two French fuel casks being unloaded from the Norwegian vessel *Georgia* at dockside in Charleston, S.C. The Savannah River plant is also a reprocessing center for heavy water and has received shipments from Canada, France, India, and Australia.

essing services from the United States. At the close of 1965, some 30 shipments of spent reactor fuel from abroad had been sent to the AEC's Savannah River Plant and the Idaho Chemical Processing Plant.

Exports and Imports of Special Nuclear Material

To assist in the return of U.S.-originated fuel for processing and eventual return of new reactor fuel, the AEC has cooperated by briefing officials of a number of U.S. ports on the shipment of irradiated fuels preliminary to obtaining local approval for such shipments, a requirement of U.S. Coast Guard regulations. During the year, 14 new ports were cleared bringing the total of U.S. ports cleared for the return shipment of highly radioactive materials to 35. The Southern Interstate Nuclear Board has undertaken a study for the AEC of measures designed to improve and encourage the return of foreign-irradiated reactor fuel to the United States for processing. The AEC, with the cooperation of domestic and foreign carriers, is continuing its efforts to bring the shipping costs of radioactive materials in line with other comparable commodities. Air transportation costs were reduced to about one-fourth of the earlier rate during 1965.

Value of Materials Distributed Abroad

As of mid-1965, the AEC had distributed through sale, lease and deferred payment sales, special nuclear and other materials abroad to the approximate total value of $141.7 million, resulting in dollar revenues to the United States of $84.6 million to date. (See Table 2, Appendix 5, for breakdown of U.S. nuclear material distributed abroad.)

Chapter 16

NUCLEAR EDUCATION AND INFORMATION

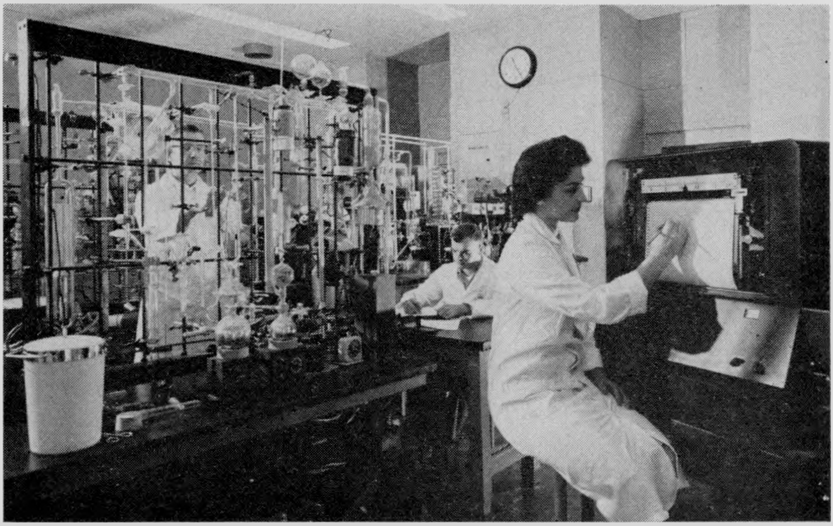
The AEC's cooperative education and training work with the Nation's schools continued to expand during 1965, and the amount and type of information about nuclear activities made generally available through exhibits, scientific and technical documents, films, and patents increased.

EDUCATION AND TRAINING

During 1965, the AEC continued to administer a wide variety of formal educational assistance programs primarily aimed at supporting and strengthening nuclear science and engineering education throughout the Nation's educational community. Major emphasis was upon graduate studies. The knowledge and experience of teacher-scientists was broadened and kept up to date by participation in AEC-sponsored research, postdoctoral fellowships, institutes, short topical conferences, and other specialized programs. AEC traineeships and fellowships provided universities with the means to attract capable graduate students into nuclear science and engineering. Grants for teaching equipment and loans of nuclear materials to colleges and universities made possible improved and expanded programs to increase nuclear knowledge. Secondary school curricula projects and institutes for secondary school faculty also received limited support. The AEC also supported a large number of research projects at colleges and universities under its various basic research and development programs. These research programs also provided educational and training opportunities for graduate students who served as research assistants to outstanding faculty members.

Reorganization

A reorganization of the AEC's nuclear education and training programs during July 1965 established two new branches, an AEC Laboratory Relations Branch and the University Relations Branch. The first provides increased emphasis for the direction and coordination of the AEC's expansion of cooperative educational programs between educational institutions and AEC multipurpose laboratories and other major research and development sites. The second administers nuclear education assistance programs conducted primarily at universities and colleges as distinguished from those at AEC laboratories and sites.



Graduate Fellows. Under the graduate fellowship program conducted for the AEC by the Oak Ridge Institute of Nuclear Studies, fellowships are awarded primarily to candidates working for the doctor's degree (Ph. D). The fellowship permits the students to conduct thesis research at one of the AEC's Oak Ridge, Savannah River, or Puerto Rico laboratory facilities. Photo shows graduate students working in a Chemistry Division laboratory at Oak Ridge National Laboratory.

UNIVERSITY-AEC LABORATORY COOPERATIVE PROGRAM

During 1965, the university-AEC laboratory cooperative program at selected AEC laboratories included activities such as faculty research training, faculty and student use of laboratory facilities, conferences, seminars, lectures, conduct of short-term specialized courses, temporary employment for faculty and students, and offsite educational services by AEC laboratory scientific and engineering staff members entailing part-time teaching, traveling lectures, and staff exchanges with university and college faculty.

Program Expansion

As a result of increased awareness of the unique contribution AEC facilities can make to colleges and universities, these cooperative activities expanded during the year. Factors contributing to this expansion were: (*a*) universities and colleges already in the program increased their interests in nuclear energy; (*b*) more and more institutions with rapidly expanding enrollments inaugurated graduate level education in science and engineering and found it advantageous to enter the AEC's program; (*c*) additional AEC laboratories in widely dispersed geographic locations became actively interested in these opportunities; and (*d*) several university and college associations were formed with the stated purpose of using AEC laboratories and other Government installations as an integral part of their curricular offerings.

Faculty and Student Use of AEC Laboratory Facilities

A wide variety of programs are available for cooperative research and education programs between the Nation's educational institutions and many AEC sites. The educational programs which may be activated at any given site are dependent upon the nature of the specific research and development mission of the AEC facility and the proximity of the site to educational institutions. Arrangements for university use of AEC facilities may be made through the related cooperative university associations [1] or, where such organizations do not exist, individual faculty members may make arrangements for themselves and/or their students on an individual basis with the directors of the participating AEC facilities. An estimated 700 faculty members and 2,500 students from 500 different institutions had some degree of participation in these various cooperative arrangements during 1965.

Faculty research participation. Through the use of educational funds, research training is being provided to a limited number of faculty members who are assigned to various laboratory facilities primarily for the research experience they will obtain. After several sessions of such research training, the faculty participant normally develops sufficient research capabililty to become eligible for support under the AEC's research and development program. Whether or not such support is developed, the faculty member is appreciably

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[1] The AEC "Annual Report to Congress for 1964" (pp. 239–241) identifies associations which continue to work with the respective AEC laboratories. In addition, during 1965, Central States Universities and Associated Colleges of the Chicago area became associated with the Argonne National Laboratory, and the Inter-University Committee expanded its cooperative endeavors with the Pacific Northwest Laboratory.

benefited by this experience. During 1965, 111 faculty members from 79 institutions received research training at 8 laboratories.

Student research participants. Selected undergraduate students in science who have completed at least their junior year are afforded opportunities to participate in research training, primarily during the summer months. This experience frequently results in their continuing their studies at the graduate level. During 1965, 273 students from 165 institutions participated in this program at 9 AEC laboratories.

On-the-job training. Training assignments for Health Physics Fellows are provided by all AEC National Laboratories, the National Reactor Testing Station, and the Puerto Rico Nuclear Center. During the 3 months at an AEC laboratory or site, extensive training is given in the practical aspects of health physics. A total of 29 fellows participated in this activity during 1965.

CONDUCT OF SPECIAL COURSES

Radioisotope Techniques Courses

The Oak Ridge Institute of Nuclear Studies (ORINS),[2] under contract with the AEC, has offered over 23 different types of courses during the 17 years of its existence to meet the needs of specialized groups. During 1965, 230 scientists, engineers, physicians, faculty members, and others have received training in the latest research techniques and analytical methods available in the application of radioisotopes. Even though many universities now give basic training in this area, they, as well as industry, still look to the AEC for leadership in this field. Thus, through the years these courses at ORINS have become more advanced and more specialized in new techniques, instrumentation, and course content. These and other ORINS courses are open to people from abroad also, if space is available.

Medical Qualifications Courses

The ORINS medical qualifications courses offer basic training and clinical experience in the safe handling of radioisotopes and are designed to train physicians in diagnostic procedures, thus preparing

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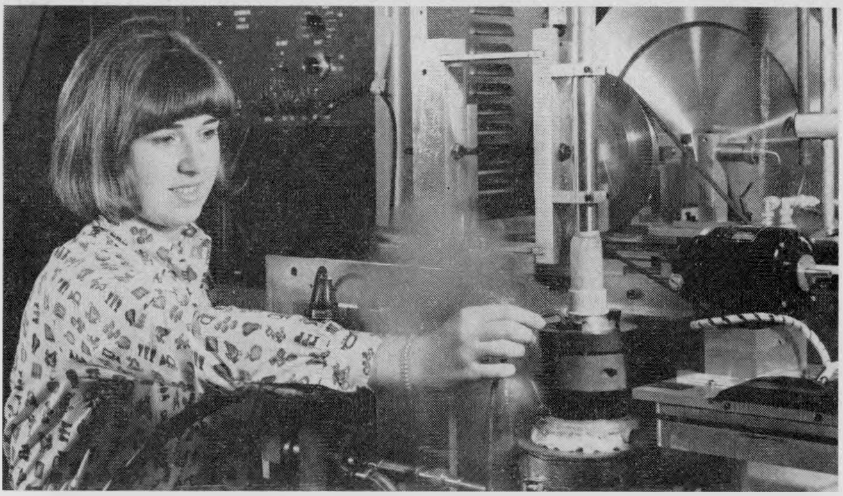
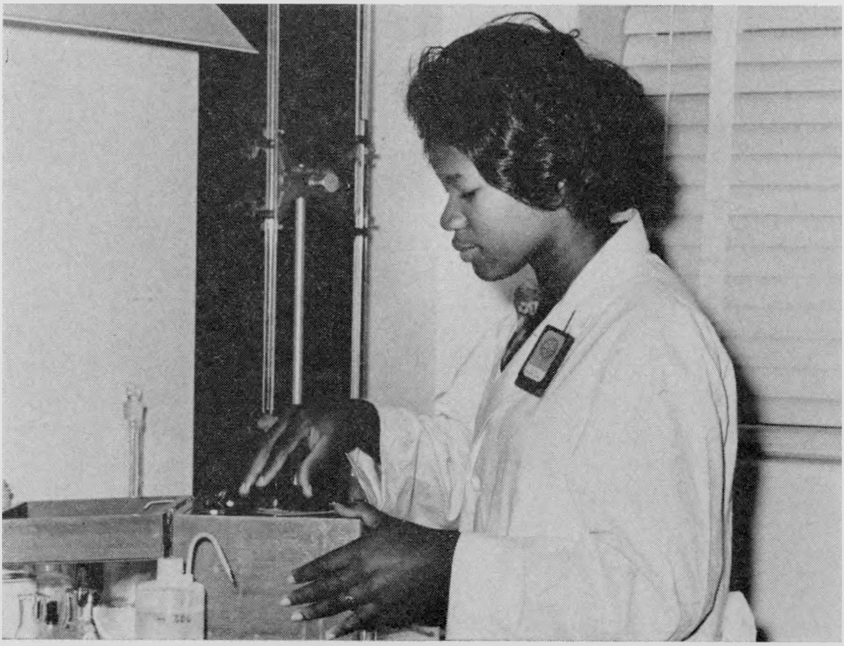
[2] Effective January 1, 1966, the corporate name of the Oak Ridge Institute of Nuclear Studies will be changed to "Oak Ridge Associated Universities." The Oak Ridge Institute of Nuclear Studies will remain an operating unit of Oak Ridge Associated Universities and will continue to function as a major avenue through which member colleges and universities participate in and support the Nation's nuclear energy programs.



Practical Training. In photo *above*, a senior from Knox College, Galesburg, Ill., uses liquid nitrogen during the course of a physics experiment at Argonne National Laboratory. She was 1 of 11 students taking part in the "Argonne Semester," a school-away-from-school program administered by the Associated Colleges of the Midwest (ACM). The program enables carefully selected juniors and seniors from ACM colleges to spend one academic semester at Argonne. Photo *below* shows a summer student trainee at the Medical Division of the Oak Ridge Institute of Nuclear Studies. This program permits college students in science who have completed their junior year to participate in research training during the summer months. The student shown is from Prairie View Agricultural and Mechanical College of Texas.



them to meet necessary AEC licensing requirements. Sixty-six physicians completed this course in 1965.

Mobile Isotopes Laboratory Courses

A third mobile laboratory was placed in operation during the year. These laboratories provide instruction and training in basic radioisotope techniques for both faculty members and students at small colleges which have limited staff and essentially no appropriate facilities. They also provide additional training support to some faculty institutes at universities conducted during the summer. During the year, a total of 29 colleges were visited for two weeks' special training at each.

Nuclear Reactor Courses Discontinued

Formal courses at the Oak Ridge School of Reactor Technology (ORSORT) at the Oak Ridge National Laboratory, and the Argonne Institute of Nuclear Science and Engineering (AINSE) at Argonne National Laboratory were discontinued in June 1965. Over a period of 15 years, more than 2,000 scientists and engineers from 50 countries received training in these programs. The programs were discontinued because of (*a*) the increased capabilities of domestic and foreign universities to provide advanced specialized programs in nuclear sciences and engineering; (*b*) the establishment of ORSORT-type schools by atomic energy agencies in several foreign countries for the training of their own students; and (*c*) increasing difficulties experienced by foreign students in obtaining financial support for training at the AEC schools. Although the formal programs involving the training of foreign students were discontinued, a variety of domestically oriented educational programs designed to meet the needs of the U.S. colleges and universities will be continued in the two AEC laboratories. Qualified foreign nationals will be permitted to participate in these programs providing they make their own financial arrangements for fees, living expenses, and travel.

Laboratory Staff Lecturers

Scientific and engineering staff members of AEC laboratories upon request schedule visits to colleges and universities to deliver lectures in their areas of professional interests to students and faculty. During the year professional personnel from eight of the AEC's laboratories presented approximately 650 lectures to over 250 colleges and universities.

In addition to on-campus visits, there is increased interest in the use of lecture-seminars taped by laboratory scientists with provisions for discussion sessions by an amplified conference call hook-up with several schools. During 1965, there were 19 lectures produced on tape with accompanying illustrated brochures by nine Argonne scientists in the field of radiobiology. Some 1,500 students and faculty from 54 colleges and universities in 12 States listened to an average of 10 of the lecture-seminars.

THE PUERTO RICO NUCLEAR CENTER

The Puerto Rico Nuclear Center (PRNC), operated by the University of Puerto Rico under contract with the AEC, is an important segment of the AEC's nuclear education and training program as well as its international program. The PRNC's facilities are located at Mayaguez and Rio Piedras where graduate research and education opportunties are provided in the nuclear aspects of the biological and physical sciences and engineering, and the application of nuclear techniques to agricultural and medical problems.

The PRNC programs are designed to serve the long-term interests of Latin America as well as the United States. They provide the type of graduate scientific and technical educational opportunities which are essential to the training and development of educational and industrial leaders, and also provide a locale where attention can be given to technological and scientific needs in a tropical environment. Research programs in marine biology, tropical ecology, food irradiation, and radiation effects, all of which are of programmatic interest to the AEC are also supported by the AEC at the center.

During the 1964–65 academic year, 47 graduate students were enrolled in advanced degree course work or research at PRNC and 341 students attended various individual courses involving the use of PRNC staff or facilities. Of these, 13 were non-U.S. citizens representing 9 countries.

EDUCATIONAL PROGRAMS AT UNIVERSITIES

Specialized Fellowships

To partially meet the Nation's need for well trained individuals in special nuclear fields, qualified graduate students who are U.S. citizens are granted specialized fellowships for advanced study at selected universities. Under this program, the AEC provides stipends for the individuals who select, from an approved list, the university at

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which they wish to study. Arrangements for admission to graduate school are made by the fellow. During the academic year 1965–66, 358 specialized fellowships were provided. Of this number, there were 203 in Nuclear Science and Engineering, 59 in Health Physics, 10 in Advanced Health Physics, 10 in Industrial Medicine, and 57 fellowships for thesis study at AEC laboratories. A highly selective Postdoctoral Fellowship Program, beginning with 5 fellowships in 1964, grew to 19 fellowships in 1965 involving 7 AEC laboratories and 4 universities. Research training beyond the Ph. D. degree is becoming the rule rather than the exception in American higher education and all major AEC laboratories offer many unique opportunities for such advanced study. Fellowships in Industrial Hygiene were discontinued, since they failed to attract enough well qualified applicants.

Traineeships in Nuclear Engineering

At additional centers of excellence not now participating extensively in the specialized fellowship program, AEC support is given directly to a university which, in turn, selects the students for participation in the traineeship program. Thus, participating universities are distributed throughout a broader geographical area. Trainees are currently selected by participating universities for graduate work only in nuclear engineering. Thirteen universities participating in the 1965 program selected a total of 50 trainees.

Faculty Training Institutes

Faculty training institutes include nuclear engineering, radiation and nuclear science, and specialized topics in the nuclear fields.

Nuclear engineering institutes. These institutes range from the short topical conference to 8-week seminars administered by the American Society for Engineering Education (ASEE) for the AEC. Such institutes are on current advanced nuclear topics of special interest to a growing number of engineering educators and practicing engineers. In 1965, an engineering institute was held on the topic, "Basic Nuclear Engineering," with 19 college faculty members enrolled. Short topical conferences were held on "Direct Energy Conversion," "Peaceful Uses of Nuclear Explosives," and "University Research Reactor Utilization." Plans for future programs include such topics as fast reactor physics, reactor kinetics, and water desalting.

Institutes in radiation and nuclear science. The AEC and the National Science Foundation jointly support institutes covering various aspects of atomic energy, such as radiation biology, radiation

Teachers' Visit. Dr. James Palotay, manager of comparative toxicology for the Pacific Northwest Laboratory, (*kneeling*) watches Maxine I. Miller, Lansing, Kans., as she feeds an African pygmy goat during a tour of Pacific Northwest Laboratory's Biology Department, by 31 high school and college science teachers attending the University of Washington's Summer Institute of Radiation Biology. Other visiting teachers looking on are: Okon A. Essiet, Orangeburg, S.C.; Sister Danile Keily, Bismarck, N. Dak.; and Margaret D. Raney, Seattle, Wash. Dr. Frank Hungate (*right*), manager of Plant Physiology and Agriculture Section, was coordinator for the visit. The laboratory is operated by Battelle Memorial Institute for the U.S. Atomic Energy Commission.

chemistry, nuclear physics, and reactor theory. These institutes stimulate high school and college faculties to teach the understanding of nuclear energy—its application, its effects and potential. In addition to learning the fundamental characteristics of radiation, participants also acquire safe handling techniques and laboratory procedures for the uses of radiation. The institutes are conducted at selected universities and AEC laboratories throughout the Nation in four types of sessions:

(*1*) Summer sessions for high school and college teachers, lasting 2 to 8 weeks, deal with subject matter at various levels of difficulty. In 1965, 40 of these programs were conducted, 20 enrolling 430 high school and 20 enrolling 369 college faculty.

(2) In-service sessions are offered in the evening and/or Saturday during the academic year. These sessions are primarily for high school science teachers and are normally held at universities located in the more populous regions. Nine programs were conducted, enrolling 190 high school science teachers, in 1965.

(3) Academic-year sessions for college and high school teachers require one year's leave of absence from teaching, to be devoted to full-time residence study at a major university or AEC laboratory. Two such programs were conducted in 1965, enrolling a total of 35 students.

(4) Research Participation Institutes for college teachers offer experience and training in research techniques to faculty members who have some previous nuclear science training. Working in small groups, faculty members serve as junior colleagues of experienced scientists at AEC laboratories and selected universities. Three such programs were conducted, enrolling 15 participants in 1965.

Training Equipment Grants and Materials Services

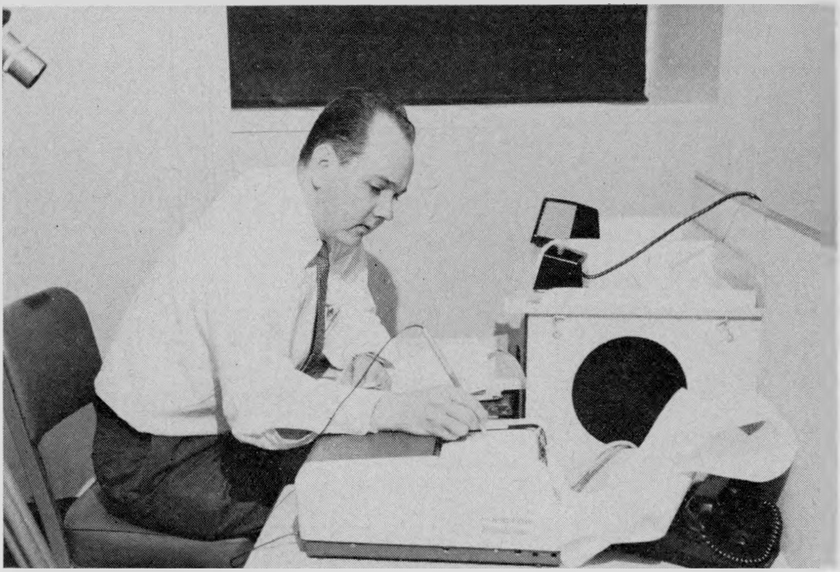
The AEC makes financial grants to U.S. colleges for the purchase of nuclear equipment for lecture and student-laboratory use. Grants must be used for teaching purposes, and may not be used for the purchase of conventional equipment or building construction. In 1965, a total of 139 grants in the amount of $1,722,719 [3] were made to 123 colleges. In addition to its equipment grants program, the AEC makes materials loans, without charge, to U.S. colleges and universities. Materials in this program include heavy water, graphite for subcritical facilities, neutron sources, and natural and enriched uranium from AEC stocks.

Financial assistance is also provided for the purchase and/or fabrication of commercially available materials to be used for educational purposes. In 1965, 44 colleges received loan materials valued at $765,000; related fabrication assistance totaled $125,116.

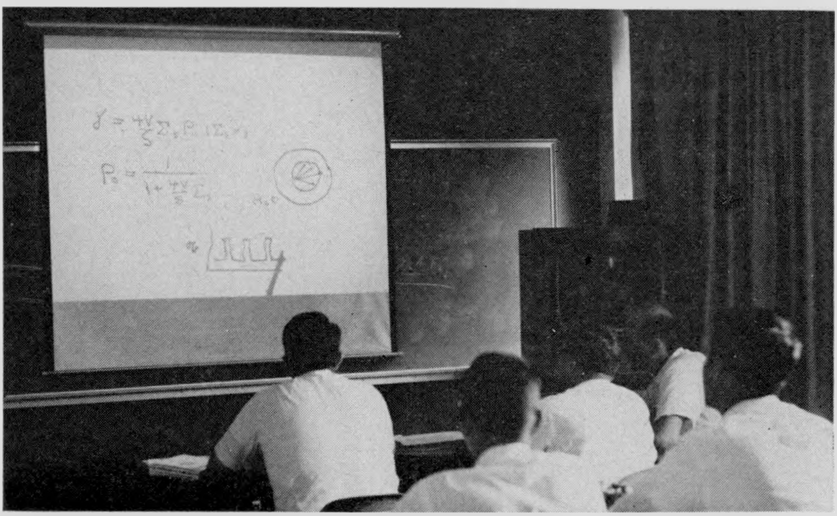
University Reactor Assistance

Since 1950, the AEC has assisted in the operation of U.S. university-owned nuclear reactors by loaning fuel materials without charge and providing funds or services without charge for fuel fabrication and reprocessing and neutron startup sources. Four university reactors received funds for fuel fabrication and/or shipment of spent fuel in 1965. The total value of such services for all schools was $414,000.

[3] Includes a round of grants totalling $652,573 in February 1965 which had been originally scheduled for grant in November 1964.



Remote Professor. From his office at the AEC's Savannah River Laboratory, Aiken, S.C., a physicist (*above*) teaches a course at Atlanta's Georgia Tech, 200 miles away. This is part of the university-AEC Laboratory cooperative program. Equations written on an "Electro-Writer" are displayed on a television screen in the classroom (*below*). Two-way voice communication and the visual display signals are carried by long distance telephone lines.



Lecture and Consultation Programs

A radiobiology lecture series, presented for colleges and high schools, is administered by the American Institute of Biological Sciences under contract with AEC. The traveling lecturers introduce nuclear science and technology into life science programs. During 1965, 32 speakers visited 30 colleges and high schools. The average lecturer spent two days on campus, giving lectures and providing consultation.

Conferences, Symposia, and Seminars

Table 1 shows examples of the numerous domestic educational conferences, symposia, and seminars sponsored or supported by the AEC during 1965.

TABLE 1.—DOMESTIC EDUCATIONAL CONFERENCES

Conference title	Conducted by	Location	Date	Number of participants
Sixth Annual AMU-ANL Nuclear Education Conference.	Associated Midwest Universities and Argonne National Laboratory.	Argonne National Laboratory, Ill.	Jan. 25–26, 1965	151
Third Annual Student Conference of the American Nuclear Society.	Air Force Institute of Technology	Dayton, Ohio	Apr. 4–11, 1965	229
Symposium on Nuclear Dynamics and Control.	University of Arizona	Tucson, Ariz.	Apr. 5–July 7, 1965.	129
Graduate Nuclear Engineering Design Seminar.	Purdue University and Associated Midwest Universities.	Lafayette, Ind	June 21–Aug. 13, 1965.	17
American Mathematical Society Seminar.	American Mathematics Society and Cornell University.	Ithaca, N.Y.	July 26–Aug. 20, 1965.	80
Radiation Biology Conference.	Oak Ridge Institute of Nuclear Studies.	Oak Ridge, Tenn.	Aug. 2–5, 1965	102
Fourth Faculty-Student Conference.	Associated Midwest Universities and Argonne National Laboratory.	Argonne National Laboratory, Ill.	Aug. 23–Sept. 3, 1965.	61

TEACHING-AIDS PROJECTS

During the year, the AEC sponsored a number of projects to provide guidance and instructional aids in various nuclear sciences for the high school and college levels.

Career Guidance

A series of films for career guidance and motivation is currently being produced in cooperation with the American Nuclear Society and the Army Pictorial Service. Completion is expected in 1966. The Association of State Universities and Land Grant Colleges is producing a 16-page brochure on "Nuclear Science and Engineering at State Universities and Land Grant Colleges." This brochure will catalog opportunities available for nuclear education among member institutions of the Association.

Experiment or Demonstration Materials

A laboratory manual, "Radioisotope Techniques in Biology," for teaching at the junior college level is being prepared and tested at the Montgomery County Junior College, Takoma Park, Md. This manual is the second part of a two-phase study started in 1964 and covers actual use and modification of experiments performed by students in the classroom.

The Lawrence Hall of Science at the University of California, Berkeley, has designed and developed a series of participation and demonstration learning devices. These devices are being tested in nearby high school and college instruction programs and will be made available to other institutions before they are placed in the Lawrence Hall of Science.

A joint pilot project was conducted with the Bio-Atomic Research Foundation and the Los Angeles Unified School District, starting in 1964. This project has developed experiments and materials for high school instruction in radioactivity. During 1965, these materials and experiments are being field tested and evaluated in selected high schools.

Teaching Materials

Rensselaer Polytechnic Institute, Troy, N.Y., is developing teaching materials for inclusion of radiation science within basic undergraduate science courses. To encourage nuclear education at the precollege level, Instructional Dynamics, Inc., Chicago, Ill., is developing a report entitled, "Stimulation of Nuclear Education at Pre-College Level."

TECHNICAL INFORMATION

In 1965, scientific discovery and technical development related to nuclear energy continued at an accelerated rate. This is reflected in the unprecedented volume of items carried in Nuclear Science Abstracts and in the record number of unclassified AEC reports released for public sale. To keep pace with the increasing volume of research and development, the AEC continued its development and refinement of means for communicating the resulting scientific and technical information, bearing in mind the range of interests of the various audiences involved, their degree of sophistication, the time they are able and willing to devote, and the communications techniques available. Thus, certain of the means employed were directed to the scientific and technical communities so that the information could be used effectively in further research and development; other devices were used to inform the young so as to provide inspiration and help toward scientific or technical careers; still others sought to provide the public at large with an understanding of the aims, methods and results of scientific inquiry so that policies and decisions in this field can be soundly judged.

PUBLICATIONS AND INFORMATION SERVICES

Reports Distribution

The volume of AEC-generated technical reports has continued to mount in step with the ever increasing applications of atomic energy for peaceful purposes. During 1965, the AEC made available some 7,100 new unclassified report titles for sale through the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., the largest total for any year to date.

To cope with the rising costs associated with the increased volume of reports, the AEC now distributes all of its reports to its depository libraries[4] in the form of microfiche, sheets of film which contain microimages of document pages. This practice is followed also in most of AEC's reports distribution to its contractors and those of other Federal agencies. Recipients of microfiche copies have the option, however, of purchasing enlarged copies from the firm which produces AEC's microfiche.

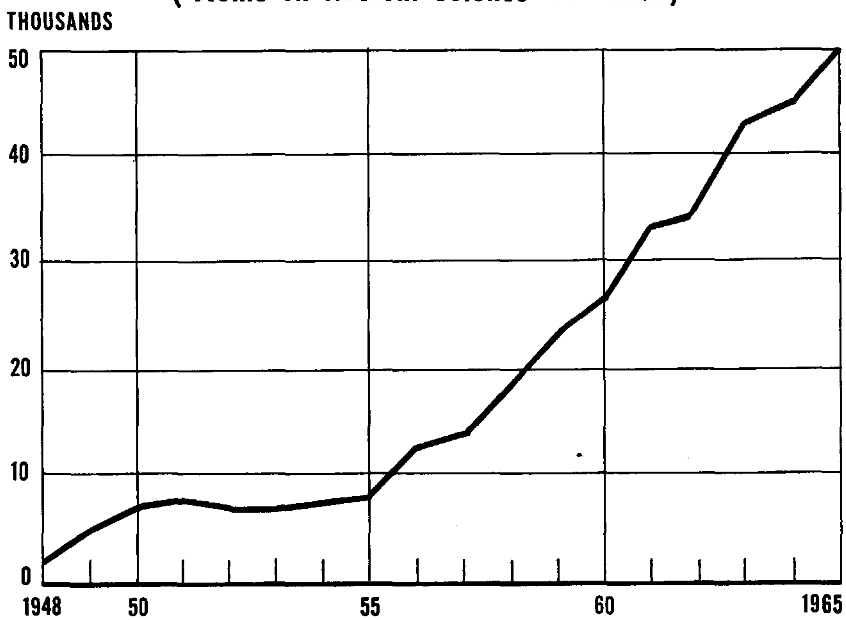
The AEC took a leading part in the development of Federal Microfiche Standards which assure that microfiche copies of research and development reports produced by all Federal agencies will be uniform in size and other important specifications so that recipients may interfile them and also read and reproduce them on uniform equipment. These standards were adopted for the entire Executive Branch in September.

[4] There are now 97 U.S. depositories located in 44 States and Puerto Rico and 82 located outside the United States in 55 countries and 5 international organizations. A document collection currently approximates 77,000 titles in a domestic depository and 65,000 titles in one abroad.

Nuclear Science Abstracts

AEC's semimonthly publication, Nuclear Science Abstracts (NSA), now in its 20th year, continues to be recognized internationally as the primary medium for announcement of the literature of nuclear science and kindred subjects. Of the approximately 50,000 abstracts carried in 1965, more than two-thirds were of journal articles and other short pieces of published literature, about 30 percent were of scientific and technical reports, and about 1 percent were of books. It is noteworthy that about 44 percent of the items originated outside the United States.

THE "EXPLOSION" IN NUCLEAR LITERATURE
(Items in Nuclear Science Abstracts)



Books and Monographs

To help meet the needs of scientists, engineers, and students for nuclear text and reference books, the AEC continued to foster the preparation of manuscripts for commercially published summary volumes which survey the main bodies of nuclear data. Nine AEC-sponsored books and monographs were published during 1965 (see Table 1, Appendix 6). Outstanding among these was the first volume, "Reactor Physics and Control," of the two-volume compendium, "The Technology of Nuclear Reactor Safety." Volume II is scheduled for publication early in 1966. In these volumes the lessons learned in 20 years of safety experience with nuclear reactors of all principal types are summarized, analyzed, and evaluated. The 31 authors represent the experience of AEC laboratories, industrial firms, and universities. The books and monographs published in 1965 brought to 186 [5] the number of AEC-sponsored scientific and technical volumes published since 1947. Manuscripts for 26 books and 34 monographs were in preparation at the year's end.

Technical Progress Reviews

The AEC's quarterly Technical Progress Reviews [6] completed their ninth year as recognized sources of summarization, critical analysis and comment on progress in large segments of reactor technology. In July, the Reactor Engineering Division of Argonne National Laboratory took over responsibility from Combustion Engineering, Inc. for the preparation of Power Reactor Technology.

Specialized Information Centers

Four new specialized information and data centers for nuclear science and technology were established by the AEC in 1965: An information center on Man-Made Radiation in the Biosphere at the Lawrence Radiation Laboratory, Livermore, Calif.; a rare Earths Information Center at Ames Laboratory, Ames, Iowa; an Atomic and Molecular Processes Information Center at Oak Ridge National Laboratory, Oak Ridge, Tenn.; and a Radiation Chemistry Data Center at the University of Notre Dame's Radiation Laboratory, Notre Dame, Ind. The latter two are sponsored jointly by the AEC and the National Bureau of Standards and are components of the National Standard Reference Data System. Two previously established centers, the Neutron Cross-Section Compilation Activity and the Reactor Cross-Section Evaluation Program, both at Brookhaven National Laboratory, were combined to form the Sigma Center.

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[5] Descriptions of works published or being prepared are presented in the booklet, "Technical Books and Monographs," available without charge from the U.S. AEC, Division of Technical Information Extension, P.O. Box 62, Oak Ridge, Tenn., 37831.

[6] Annual subscriptions to the Technical Progress Reviews are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, at the following prices:

Journal	*Prepared by*	*Subscription price*
Nuclear Safety	Oak Ridge National Laboratory	$2.50
Reactor Materials	Battelle Memorial Institute	2.50
Power Reactor Technology	Argonne National Laboratory	2.50
Reactor Fuel Processing	do	2.50
Isotopes and Radiation Technology	Oak Ridge National Laboratory	2.00

The function of the centers is to collect, evaluate, and compile scientific and technical information in specific fields and to make it available in such forms as data tables, handbooks, critical state-of-the-art reviews, summaries of research and development programs in progress, answers to technical inquiries, and specialized bibliographies. Table 2, Appendix 6, lists the 19 centers currently supported in whole or in part by the AEC.

During 1965, several specialized information centers began participating in a cooperative international exchange of nuclear data information and nuclear energy computer programs under an agreement between the AEC and the European Nuclear Energy Agency (ENEA). Under this agreement, the exchange points are as follows:

(*1*) The Sigma Center at Brookhaven National Laboratory and the ENEA Neutron Data Compilation Centre at Saclay, France, for neutron cross-section data;

(*2*) The Argonne Code Center, at Argonne National Laboratory, and the ENEA Computer Programme Library, Ispra, Italy, for nuclear energy computer code information and computer programs;

(*3*) The Radiation Shielding Information Center, Oak Ridge National Laboratory, and the ENEA Computer Programme Library, Ispra, Italy, for radiation shielding computer code information and computer programs; and

(*4*) The Computer Index Nuclear Data (CINDA) program at the AEC's Division of Technical Information Extension, Oak Ridge, Tenn., and the ENEA Neutron Data Compilation Centre, Saclay, France, for bibliographic references to nuclear cross-section data.

Scientific and Technical Conferences

The AEC continued, in 1965, to play an active role in scientific conferences in fields related to its programs. These included 15 conferences convened by the International Atomic Energy Agency (IAEA), for which AEC organized U.S. participation. Among the most important of these were the second IAEA Conference on Plasma Physics and Controlled Nuclear Fusion Research, held at Culham Laboratory, England, in September, and the IAEA Symposium on Exchange Reactions, held at Brookhaven National Laboratory, May 31 to June 4. AEC also gave financial support to a number of topical conferences convened in the United States by professional and academic organizations. The support not only helped defray costs of conducting the conferences, but also insured prompt publication of the proceedings by the conference sponsors.

Educational Literature

During the year, the AEC and its major contractors answered over 140,000 requests from students and others for educational and informational materials. In most instances the inquiry was satisfied, at least in part, by sending one or more of the booklets in the "Understanding the Atom" series.[7] Titles added to the series during the year were "Isotopes in Industry," "Microstructure of Matter," "Nondestructive Testing," "Radioactive Wastes" and "Research Reactors."

Total distribution of these booklets since they were originated in June 1962 reached 2,500,000. Also published during 1965 was a 68-page booklet with 115 illustrations entitled "The USAEC, What It Is, What It Does."

Mechanization of Information Systems

The sheer volume of scientific and technical information appearing in written form has overwhelmed traditional handling methods. The introduction of methods using electronic digital computers and automated data processing equipment for information handling consequently continued at an accelerated pace in AEC installations.

A computer-based system for storing and retrieving nuclear science information continued to be developed under cooperative arrangements with the European Atomic Energy Community (Euratom). As part of this system, Nuclear Science Abstracts was indexed in depth, using an average of 15 keywords per abstract. This information was placed on magnetic tape. Copies of the tapes were then provided to Argonne National Laboratory and Lawrence Radiation Laboratory for use in experimental systems by which information is disseminated automatically to selected scientists based on their expressed scientific interests. A further development planned is to have decentralized input of technical abstracts from a number of contributing nations and international organizations.

AEC's information systems development program resulted in the introduction during the year of two significant improvements in techniques for library mechanization. Both systems are now in use in AEC's Headquarters Library. They could be adapted for a large number of technical libraries and several expressions of interest in them have been received. The first system involves 16 computer programs stored on magnetic tape for recording journals and other serial matter received at the Library. The tapes can automatically and

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[7] The full list of titles currently available is shown in Table 3, Appendix 6. Single copies are available without charge from U.S. AEC, Division of Technical Information Extension, P.O. Box 62, Oak Ridge, Tenn., 37831.

rapidly produce a variety of library products and services, ranging from serials holdings lists to routing slips. The second system consists of a computer program for storing and retrieving information on legislative matters of interest to the AEC. Descriptions of legislative literature are recorded on punched paper tape. This record, which includes thousands of items (House and Senate Bills, Committee Reports, Executive Orders, Congressional Record, etc.), is fed into a computer which, in a matter of minutes, organizes all the information to produce catalogs of the documents, as well as subject and legislative history indexes.

"Technology Spinoff"

Experimentation continued on various means to facilitate the application to nonnuclear industrial use of the results (processes, techniques, materials, instruments, equipment, etc.) of AEC research and development.

One approach has been the operation of Offices of Industrial Cooperation at Argonne and Oak Ridge National Laboratories. In addition to answering industrial inquiries and arranging industrial consultations and visits, each office sponsored industrial conferences in 1965. The Argonne Office, in collaboration with the Small Business Administration, sponsored a series of conferences on "Mechanical Developments" for representatives of smaller enterprises. The Oak Ridge Office sponsored a further information and demonstration meeting on "Zonal Liquid Centrifuges," following up two 1964 meetings on the same development.

An experimental case study, initiated in 1964, on the "Transference of Non-Nuclear Technology to Industry" was completed by a group of AEC-industry teams. They examined AEC-developed technology in the selected areas of fluorine technology, materials development, and mechanical developments for the purpose of making recommendations as to the most effective and expedient ways of accelerating the "spin-off" of technology. Results of the study were published under the title "Transference of Non-Nuclear Technology to Industry," ORO–629.[8] Contractors participating were the General Electric Co., the Goodyear Tire and Rubber Co., the National Lead Co., and the Union Carbide Corp.

DEMONSTRATIONS AND EXHIBITS

In April, the management of the "Atoms in Action" demonstration centers abroad, the domestic exhibits program, the coordination of

[8] Available for $2 from Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., 22151.

AEC's participation in scientific and technical conferences, and AEC's technical publications activities were merged into one organizational unit. This was done to improve the coordination of AEC's presentations to the scientific and technical communities.

"ATOMS IN ACTION" DEMONSTRATION CENTERS

Three successful presentations abroad of AEC's "Atoms in Action" demonstration centers were held in 1965 with the collaboration of scientists and Government officials from the host countries. The presentations were in San Salvador, El Salvador; Guatemala City, Guatemala; and Lisbon, Portugal. Attendance at the public portions of the 3 showings (San Salvador, 95,000; Guatemala City, 69,000; Lisbon, 65,000) brought to over 6 million the number of people who have visited these AEC presentations since their inception in 1958.

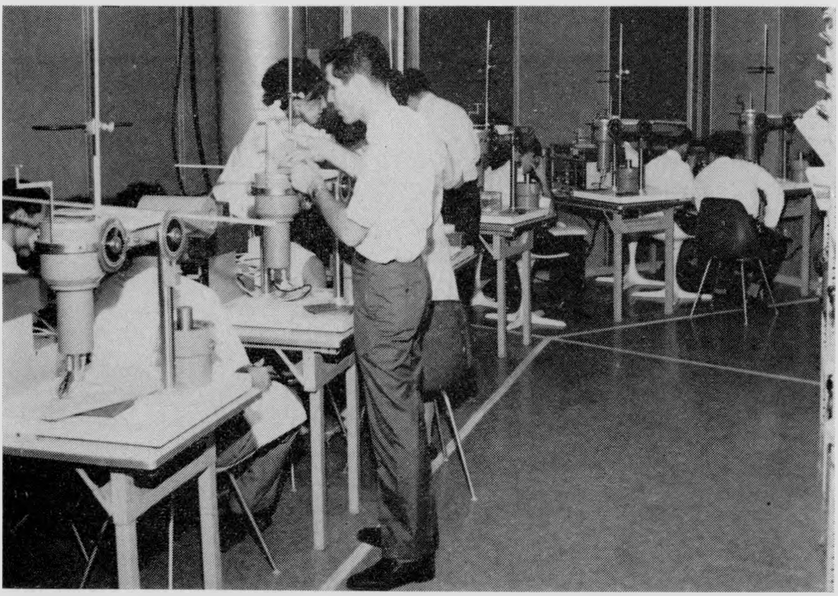
In addition to the public section, where university students of the host countries conducted lecture-demonstrations, each of the presentations included: (*a*) classroom demonstrations for high school students and their teachers; (*b*) research projects using a gamma irradiation facility and other nuclear equipment to seek solutions to practical problems of importance to the host countries; (*c*) a technical information center where AEC films were shown and where AEC publications and U.S. textbooks were made available for use; and (*d*) advanced lectures and seminars conducted by a U.S. staff. Science fairs for high school students were also held locally in conjunction with each of the presentations. These were organized by Science Service, Inc., Washington, D.C., under contract to the AEC.

Latin American Showings

For the first time, the two Latin American showings also presented demonstration courses of four-weeks' duration for physicians (diagnostic uses of isotopes), research personnel (research uses of isotopes), and technicians (maintenance and repair of nuclear instruments). These courses were filled to capacity in both San Salvador and Guatemala City.

San Salvador. The public attendance of 95,000 at San Salvador was particularly remarkable, amounting to some 33 percent of the city's population. The high school lecture demonstrations were attended by 5,458 students, comprising all third- and fourth-year high school students in the Nation, and their teachers. Research projects in the San Salvador center concerned the use of gamma radiation for such purposes as increasing the germination life of stored coffee

Latin-Amcrican Presentations. A new 10,000-square-foot building (*above*) was used for the first time to house the San Salvador and Guatemala City presentations of the AEC's "Atoms in Action" demonstration centers. Octagonal in shape, following the configuration of the ancient Mayan calendar, it is covered by a circular roof consisting of twin layers of fabric held rigid by a cushion of air. The Latin-American presentations of "Atoms-in-Action" demonstration centers featured courses for scientists of the host countries utilizing U.S. equipment. The Guatemalan scientists shown *below* were learning about research applications of radioisotopes.



seeds, mass sterilization to eradicate damaging insect pests, preserving fruit, and mutation breeding of basic food products. One result of the demonstration center in El Salvador appears to have been a resurgence of interest in nuclear research. Most research projects begun at the center were carried forward.

Guatemala City. The gamma facility used in Guatemala City contained, in addition to four irradiation tubes, a large-diameter fruit irradiator which was refrigerated to handle samples at between 28° and 35° F. So many research projects were undertaken that the facility operated 24 hours per day, 7 days a week, throughout the 4 weeks, the first time such round-the-clock operation has been required in any of the "Atoms in Action" presentations. The facility treated 973 samples with a total dosage of 181.8 million *rads.* Several local or regional groups participated in the irradiation experiments. They included members of the agronomy faculty from the University of San Carlos (use of the sterile male technique for eradicating insect pests); the Nutrition Institute of Central America (irradiation of stored food to reduce insect damage); the National Coffee Association of Guatemala (use of radiation to improve coffee taste); and the Ministry of Agriculture (mutation crop breeding studies). The stimulus provided by the "Atoms in Action" center was so great that, following the center's close, the Instituto Centroamericano de Investigacion y Technologia Industrial (ICAITI), a regional organization with headquarters at Guatemala City, established a long-range nuclear research and development program for all of Central America. To assist in this program, the demonstration center's gamma facility, along with the fruit irradiator and most of the associated laboratory equipment, was purchased and donated to ICAITI by the U.S. Agency for International Development. The facility will remain in Guatemala City and the Guatemalan Atomic Energy Commission will be responsible for the safety aspects of its operation.

Lisbon Presentation

The European "Atoms in Action" demonstration center uses for research a 10-kilowatt swimming pool training reactor and a whole-body counter in addition to a gamma irradiation facility and other laboratory equipment. Experiments conducted at Lisbon included investigation of the applicability of the wood-plastic irradiation impregnating technique[9] to Portuguese woods and cork; and the use of gamma irradiation to preserve basic Portuguese food products, improve characteristics of food packaging material by poly-

[9] See Chapter 13—Isotopes and Radiation Development.

merization, accelerate the aging of wines, prevent mold in coffee, and sterilize pharmaceutical supplies. The whole-body counter was used to measure fallout contamination in milk and wine and to measure the thorium body burden in 18 patients who had been injected about 20 years earlier with Thorotrast (a chemical solution containing thorium) for X-ray contrast studies.

1966 Schedule

The 1966 schedule for "Atoms in Action" demonstration centers calls for spring presentations in San Jose, Costa Rica, and Utrecht, The Netherlands, and for autumn showings in Managua, Nicaragua, and Dublin, Ireland.

DOMESTIC PRESENTATIONS

The year was a very active one for the domestic exhibits program. While the AEC's two exhibits were setting attendance records at the New York World's Fair, three new exhibits for professional and industrial audiences, and four new exhibits for the general public were developed.

Professional and Industrial Presentations

An exhibit on "Nuclear Energy for Water Desalting" was presented for the first time early in October at the First International Symposium on Water Desalination in Washington, D.C. It was shown again in mid-October at the annual meeting of the American Institute of Planners in St. Louis, and in November and December at the main office of the Metropolitan Water District of Los Angeles. This exhibit presents information on AEC's program for development of economic nuclear power sources for plants which will simultaneously generate electricity and produce fresh water from sea or brackish water.

"Partners in Protection" was exhibited for the first time at the U.S. Public Health Association's meeting at Chicago in mid-October. A joint undertaking of the AEC and the U.S. Public Health Service, the exhibit informs viewers about the Federal assistance available to States expecting to establish their own programs for regulation of radiation-related activities.

"The International Nuclear Information System" is an exhibit which portrays the emerging pattern for worldwide cooperation in handling unclassified nuclear information. It was shown first in

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Washington, D.C., during October at the joint meeting of the International Federation for Documentation and the American Documentation Institute.

Presentations for the General Public

AEC's two exhibits at the New York World's Fair, "Radiation and Man" and the children's exhibit "Atomsville, U.S.A." were seen by more than 2,500,000 visitors during 1965. In the early part of 1966, they are scheduled to be shown at the California Museum of Science and Technology, Los Angeles, and at the Chicago Museum of Science and Industry, respectively.

"The Vision of Man," a 5,000-square-foot museum exhibit designed to acquaint viewers with the Federal Government's science and engineering activities, was opened at the Smithsonian Institution, Washington, D.C., by President Johnson in late April, moved to the Federal Pavilion of the New York World's Fair in May, and to the Los Angeles Museum of Science and Industry in November. The U.S. Civil Service Commission coordinated the design effort, while the AEC joined with nine other Federal agencies in supplying concepts and content.

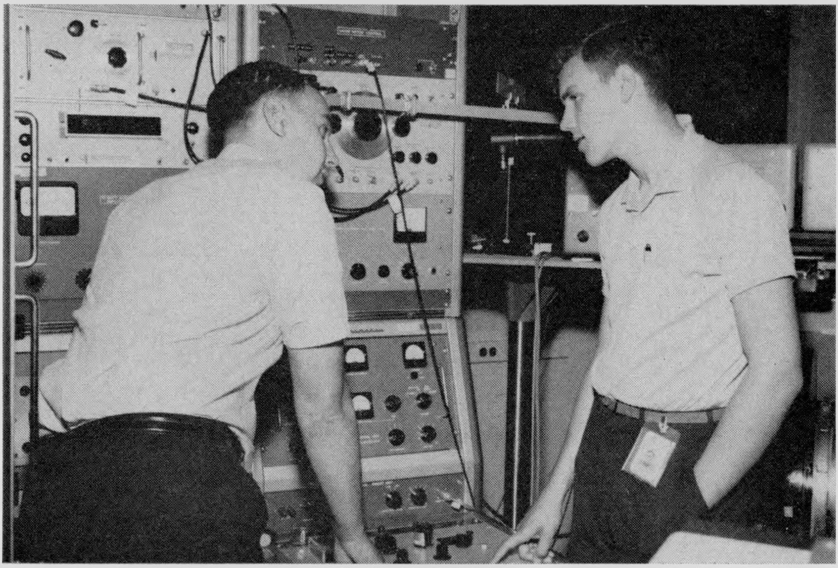
"Power Unlimited," a 12-panel unmanned package exhibit explaining the achievements and promise of U.S. nuclear power programs, was completed during the summer. It was designed for the AEC by the Oak Ridge Institute of Nuclear Studies (ORINS) for display at schools, small fairs, and similar exhibit locations. During the last five months of the year, two "Power Unlimited" units were viewed by an estimated two million persons at 12 locations.

The "Atoms at Work" exhibit combines a three-screen motion picture with a live demonstration of nuclear energy principles and applications. It was shown in August in a theater of the Chicago Museum of Science and Industry.

Three units of a new single-panel exhibit which shows titles available in the AEC's "Understanding the Atom" series of educational booklets are being made available for showings in schools and libraries. The exhibit is based on one which was well received at the New York World's Fair.

At the Chicago Museum of Science and Industry, the "Microworld Theater," formerly devoted exclusively to biological demonstrations, was modified to accommodate a companion program of atomic energy films. An associated "Nuclear Science" exhibit is managed for the AEC by Argonne National Laboratory.

The American Museum of Atomic Energy at Oak Ridge, Tenn., which serves also as the operational and developmental base for AEC traveling exhibits, received some 125,000 visitors during the year.



Science Fair Winners. The 15th National Science Fair-International held in St. Louis, Mo., in May, produced the first non-U.S. winner of an AEC special award for exhibits on nuclear-related subjects. As part of this award, George Beal of Aldershot High School, Burlington, Ontario, *right* and his teacher-sponsor, W. Bruce Page, won a "Nuclear Research Orientation Week" at Argonne National Laboratory. They are shown *above* in one of Argonne's chemistry laboratories. Ronald Bailey, a senior at Evans County High School, Claxton, Ga., also won a "Nuclear Research Orientation Week" at Argonne for his exhibit which was entitled "Effects of Radiation on Zea Mays as Counteracted by Microbial Products." Bailey is shown *below* in an Argonne laboratory with his teacher-sponsor, Ralph E. Roberson.

Presentations for Students

The AEC's ten "This Atomic World" high school demonstration units were all modified during the year to improve and update their content. These very successful assembly programs were presented in 1,600 secondary schools in 23 States before an estimated 1,400,000 students and teachers. They were also tried out at 10 civic meetings before an estimated 500 civic leaders.

DECLASSIFICATION OF INFORMATION

AEC conducts a continuous review of Restricted Data and AEC classification guides to determine which information useful to science and industry may be declassified without undue risk to the common defense and security. A number of declassification actions were taken during the year, two of which are mentioned below.

New Declassified Subjects

Among the subject areas declassified during the year were the high flux design and operational details of the Savannah River Plant's "C" reactor. The declassification action permits maximum use by the scientific community of the information acquired from the reactor which has been operating at an unprecedented high flux to produce transplutonium elements and high specific-activity radioisotopes. Operational details of the Hanford "N" reactor such as power level, total steam available, pressures, and temperatures were declassified. This action was important to the Washington Public Power Supply System because it made possible the unclassified operation of the associated power generating system.

Document Declassification

In addition to review of Restricted Data and AEC classification guides, the AEC conducts a continuous review of previously classified documents so that when changes in classification rules permit, as many as possible may be declassified making the information available for use by science and industry. During the year, some 68,000 documents were declassified. A large percentage of these reported research and development work on materials and compact reactors.

PATENT MATTERS

The AEC, as a part of its program of dissemination of technical information and data to the public, has made inventions and patents available through the issuance of the patents and the republication of abstracts and summaries through various media. In addition, copies of U.S. patents are available from the U.S. Patent Office. AEC has prepared abstracts of the patents, furnished listings of issued patents, and distributed press releases not only of U.S. AEC-owned patents but also AEC foreign-owned patents.[10]

1965 Issuances

During the period November 24, 1964 to November 23, 1965, the U.S. Patent Office issued 252 U.S. patents to the AEC. As a result, the portfolio of AEC-owned U.S. patents administered by AEC and available for licensing now number 3,661 domestic patents. The AEC portfolio of foreign patents increased during this period by 424. This included 68 British patents, 59 Belgian patents, 79 Canadian patents, 47 French patents, 30 German patents, 49 Japanese patents, and 20 Swedish patents. The balance of AEC-owned foreign patents issued during this period were by 15 other foreign countries. The total portfolio of AEC-owned foreign patents numbers 2,624.

During 1965, the AEC granted 44 nonexclusive licenses on Government-owned patents. At present, 1,093 nonexclusive licenses have been issued on 595 of the 3,661 Government-owned patents administered by the AEC. In addition, 595 nonexclusive licenses have been retained by contractors. Contractors have retained exclusive licenses in fields other than atomic energy in 368 patents. In 405 instances, the title and rights in the patents are vested in the contractor, subject to a nonexclusive license in the Government for governmental purposes.

Private Atomic Energy Applications

Referrals by the Commissioner of Patents to the AEC of privately owned U.S. Patent Applications in the atomic energy field under section 152 of the Atomic Energy Act of 1954, as amended, numbered

[10] Listings published as AEC press releases during 1965: No. IN–553 (Japanese patents), January 11; No. IN–556 (British patents), February 16; No. IN–563 (French patents), March 4; No. IN–572 (German patents), March 31; No. IN–578 (U.S. patents), April 20; No. IN–587 (Australian patents), May 18; No. IN–594 (U.S. patents), June 24; No. IN–596 (Italian patents), June 25; No. IN–606 (U.S. patents), August 13; No. IN–617 (Spanish and Portuguese patents), September 13; No. IN–620 (South African patents), September 23; No. IN–622 (Swiss patents), September 24; No. IN–626 (Canadian patents), September 29; No. IN–629 (South American patents), October 1; No. IN–631 (U.S. patents), October 7; No. IN–638 (Denmark, Norway and Sweden patents), October 21.

825 in the past year. This shows an increase over the previous annual periods and evidences an ever-growing industrial interest in the atomic energy field. The AEC filed 22 directives with the Commissioner of Patents with respect to the question of rights during the year, bringing the total number of directives filed under section 152 of the Atomic Energy Act of 1954, as amended, to 155. The AEC has acquired rights in 84 applications, and in 56 cases after completion of investigations the directives were withdrawn without acquisition of rights. Thirteen applications are pending, 2 having been abandoned.

PUBLIC INFORMATION

During 1965, the AEC continued to conduct a broad information program to give the news media and the general public a better understanding of the many uses of nuclear energy. Working through its information officers at 13 field offices throughout the United States and through its headquarters public information staff, the AEC makes every effort to keep the news media, private industry, and educational and research organizations apprised of its widespread activities. Considerable effort is made, both in the field and at headquarters, to arrange visits to AEC laboratories and facilities for newsmen and tours for science students along with an opportunity to confer with scientific personnel.

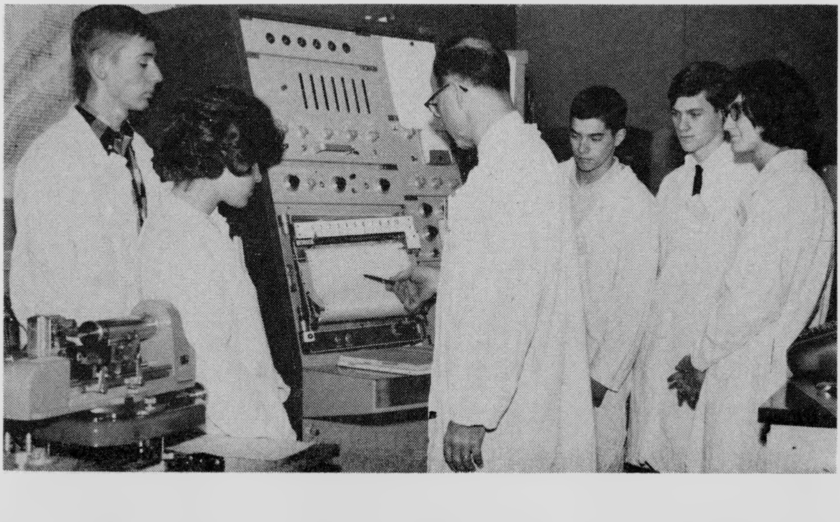
YOUTH ACTIVITIES

Edison Day Tours

More than 5,000 high school science students and teachers visited AEC projects at 12 installations to help commemorate the 118th anniversary of the February 11, 1847, birth of Thomas Alva Edison. The AEC has participated each year since the Thomas Alva Edison Foundation inaugurated the international celebration in 1957.

Junior and senior high school science students and their teachers visited facilities this year at Argonne National Laboratory, Argonne, Ill.; Battelle Memorial Institute, Columbus, Ohio; Brookhaven National Laboratory, Upton, L.I., N.Y.; Hanford Works, Richland, Wash.; Los Alamos Scientific Laboratory, Los Alamos, N. Mex.; Mound Laboratory, Miamisburg, Ohio; National Reactor Testing Station, Idaho; Nevada Operations Office, Las Vegas, Nev.; Nuclear Rocket Development Station, Nev.; Oak Ridge Operations Office, Oak Ridge, Tenn.; Sandia Laboratory, Sandia Base, Albuquerque, N. Mex., and Savannah River Plant, Aiken, S.C.

Edison Day Tours. For the ninth consecutive year, the AEC helped commemorate the February 11 birthday of Thomas Alva Edison by providing tours of its facilities to high school science students and teachers. Some 2,000 students and their teachers from Idaho, Montana, Wyoming, Utah, and Oregon spent a day touring the National Reactor Testing Station. Photo *above* shows a small group learning about nuclear fuel elements. At the AEC's Pacific Northwest Laboratory, 166 students and teachers from 24 high schools split up into small groups and spent a day "on the job" with a scientist or engineer. The group *shown* below is learning about an X-ray spectrometer which can identify all the elements in a chemical solution and measure the quantity of each.



FILMS

Stocked with prints of more than 300 popular and professional-level films during 1965, the AEC's 10 domestic film libraries loaned prints for some 174,000 showings which were viewed by an estimated 8,300,000 persons in high schools, colleges and universities, industrial organizations, labor organizations, scientific and engineering groups, service clubs, etc. Television audiences, estimated at about 50 million, also viewed many of these films through educational and commercial channels. The film libraries and the geographical areas they serve are listed in Appendix 6.

International Aspect

Loans of approximately 189 motion pictures, largely on a professional level, were made from the AEC's liaison offices in London, Tokyo, Brussels, and Buenos Aires, the latter 2 supplying French and Spanish versions of about 75 of these films. The use of AEC films by foreign scientific, industrial, and educational organizations has greatly increased during the past year with Australia, Israel, and Mexico leading the list. Production services were provided to make Dutch- and Japanese-language versions of selected films, and to TV and film producers from England, Italy, and Germany in providing atomic energy information, stock film footage, and arranging for new photography.

The depository of atomic energy films, both English and French versions, at the National Science Film Library of Canada (in Ontario) is serving increasing needs of Canadian scientists, industry, universities, and scientific and educational organizations. The AEC continued to supply films to the American Film Library in The Hague, the film library of the International Atomic Energy Agency in Vienna, and to the U.S. Information Service office in Stockholm for use throughout Scandinavia.

New Films

The Commission added 27 films to its motion picture libraries during the year (see Appendix 7).

Film Festivals and Awards

Twenty films were entered in 11 foreign and one domestic film festival; included were the "Atoms in Action" film at the 18th Edinburgh International Film Festival, and "Transcurium Elements," "Man and Radiation" and "Snapshot" in the XII International Nuclear Rassegna in Rome. "Pax Atomis" won a best-in-class statuette in the Industrial Awards competition by Industrial Photography Magazine.

Part Two

Regulatory Activities

Chapter 1

LICENSING AND REGULATING THE ATOM

Major steps were taken in the AEC's regulatory program during the past year to improve the regulatory process to accommodate current and prospective long-range growth of the nuclear industry. The goal of the Commission's regulatory program is to assure through a program of licensing and regulation that the use, transport and disposal of radioactive materials, and the operation of reactors and other nuclear facilities are conducted in a manner consistent with public health and safety.

HIGHLIGHTS OF 1965

- Four utilities submitted applications to construct large nuclear power reactors during 1965, and there was a marked increase in the number of firms conferring with the regulatory staff on sites and plans for other nuclear powerplants.
- The most significant development of the year affecting the regulatory program was a study and report by a Regulatory Review Panel appointed by the Commission. Its recommendations, directed toward improving and expediting the overall regulatory process pertaining to nuclear facilities, covered licensing procedures and policies and the decision-making process.
- Another important event was the passage of legislation extending for 10 years the Price-Anderson program for indemnifying nuclear facilities against public liability claims in the event of a nuclear accident. At the same time, the insurance industry announced that the amount of private third-party liability insurance available to the nuclear industry would be increased in 1966.
- An excellent radiation safety record was compiled during the year by the more than 7,000 AEC materials and facility licensees. Of the eight radiation incidents of sufficient significance to justify investigation, five involved human overexposures to radiation, and there were no fatalities. In general, AEC licensees have corrected promptly those safety deficiencies identified in AEC inspections.

- Progress was made in development of general design criteria for nuclear powerplant construction permits.

These highlights of the AEC's regulatory effort in 1965 are described in more detail below. Developments in the licensing of reactors and other nuclear facilities are reported in Chapter 2 of Part Two, and programs of controlling radioactive materials are described in Chapter 3.

REGULATORY REVIEW PANEL STUDY

The Regulatory Review Panel, appointed by the Commission in January 1965, conducted an exhaustive study of the regulatory process and its policies and procedures relating to nuclear facilities. Members of the panel [1] were appointed from outside the Government. From January through June, the panel met with the Advisory Committee on Reactor Safeguards (ACRS) and numerous other interested individuals and groups in the Government and in industry. It also consulted extensively with members of the regulatory staff, the Director of Regulation, and other key staff members throughout the AEC.

The panel's study was conducted under a charter encompassing two principal areas of inquiry. The first area was concerned with overall policies applied and being developed to administer the AEC's licensing and regulatory responsibilities. The objectives were an appraisal of the general approach to the safety evaluation effort which characterizes the licensing and regulation of reactors, and recommendations leading to the more expeditious handling of these matters.

The second principal area of inquiry was concerned with the decision-making process in the AEC regulatory program, with emphasis upon the respective roles played by the regulatory staff, the Advisory Committee on Reactor Safeguards, the Atomic Safety and Licensing Boards, and the Commission itself. This part of the panel's charter emphasized review of the experience gained since the 1962 amendments to the Atomic Energy Act, and the panel attempted to identify possible improvements in the decision-making process under the existing legislation, rather than suggest a major legislative program.

REVIEW PANEL RECOMMENDATIONS

In July, the panel submitted its report to the Commission. Key recommendations included:

(*1*) "In the discharge of the Commission's regulatory responsibilities, the primary element in the safety review of every reactor project

[1] See footnote 5, Chapter 1 of Part One (p. 18) for list of panel members.

should be the analysis conducted by the staff of the Director of Regulation."

(*2*) "The statutory requirement that the ACRS review and report on all applications for a license under sections 103 and 104 of the Atomic Energy Act should be modified. The ACRS should be informed of each new license application, and should be privileged to undertake a review on its own initiative if it feels this to be desirable. * * * The talents and time of this uniquely qualified group should be reserved for the more difficult and novel reactor safety problems * * *."

(*3*) "The AEC should define more precisely and realistically the scope of information to be supplied by the applicant at the construction permit stage."

(*4*) "The AEC should continue and intensify its efforts, in cooperation with industrial and professional groups, to develop criteria, standards and codes for nuclear reactors."

(*5*) "Technical specifications should be limited to those aspects of the reactor system which bear a direct relation to public safety, rather than a detailed description of all components of the reactor such as is suggested in Appendix A of Part 50 of the Commission regulations."

(6) "The function of the Atomic Safety and Licensing Board in facility licensing cases should be redefined specifically to recognize that a board cannot undertake, *de novo*, an independent technical review of the safety of a proposed facility."

(*7*) "The Atomic Energy Commission should establish a mechanism, which should include a Reactor Safety Research Committee, to coordinate the Commission's program of research on reactor safety, and to ensure that the needs of the Director of Regulation for experimental information to be used in developing reactor safety criteria and in evaluating the safety of reactor projects submitted for licensing will be met."

The AEC regulatory staff, with active participation by the Commission, concentrated on implementation of the panel's recommendations in the latter half of 1965. Some of the recommendations, relating to areas in which work already was underway, were carried out during the year. For example, the establishment in July of the Steering Committee on Reactor Safety Research to coordinate programs of research and reactor safety, was in line with a panel suggestion. Other actions recommended by the panel were longer-range in character, and will require changes in legislation or rules, and other steps. (Details of implementation are covered in "The Decision-Making Process" section in Chapter 2 of Part Two.)

NUCLEAR FACILITY INSURANCE AND INDEMNIFICATION

Important developments also occurred in the field of nuclear liability insurance and indemnification in 1965, highlighted by extension of the Price-Anderson Act.

PRICE-ANDERSON INDEMNITY ACT

The Commission completed a comprehensive study of operations under the Price-Anderson indemnity legislation since its enactment in 1957.

This legislation provided Government indemnity against public liability up to $500 million for each incident over and above the amount of private financial protection required of licensees. The two principal objectives of the legislation were (*a*) to assure the availability of funds to satisfy public liability claims in the event of a catastrophic nuclear accident, and (*b*) to remove the deterrent to industrial activity in atomic energy presented by the threat of enormous liability claims if such an accident were to occur. The AEC study concluded that the second objective was clearly being achieved, but that achievement of the first objective cannot be demonstrated with the same assurance since, as expected, no catastrophic accident has occurred. The study further indicated that the need to remove the deterrent to industrial participation still existed, thus warranting extension of the legislative authority beyond its original August 1, 1967, termination date. The report, recommending extension of the Price-Anderson Act, was transmitted to the Congressional Joint Committee on Atomic Energy (JCAE) by the Commission.

Federal Indemnification Program Extended

Congress, following hearings by the JCAE, extended the Price-Anderson Act 10 years beyond its expiration date of August 1, 1967. The amended Act (Public Law 89–210) was signed by the President on September 29, 1965. In extending the law, Congress provided that the amount of Federal indemnity shall be reduced by the amount that the private financial protection required exceeds $60 million—the maximum amount of private insurance available through 1965. While not reducing the total amount of protection available to the public, this action enlarges the role of private insurance in the nuclear industry.

Private Liability Insurance Increased

At the Congressional hearings on extension of the Price-Anderson Act, the Nuclear Energy Liability Insurance Association (NELIA) and the Mutual Atomic Energy Liability Underwriters (MAELU) announced that the maximum amount of private nuclear liability insurance would be increased from $60 million to $74 million as of January 1, 1966. These two syndicates had been formed by the stock and mutual companies in 1957 to enable the insurance industry to assist and participate in the expansion forecast for civilian nuclear activities.

Licensees of nuclear facilities, except nonprofit educational institutions and Federal agencies, are required to have private financial protection, which is usually provided in the form of liability insurance. The statutory requirements in section 170 of the Atomic Energy Act of 1954, as amended, for financial protection require licensees of power reactors having a rated capacity of 100 electrical megawatts (Mwe) or more to obtain the maximum amount of available insurance. Thus, as of January 1, 1966, the three licensees [2] currently operating reactors with capacity of 100 Mwe or more increased their basic financial protection from $60 million to $74 million, and the amount of Government indemnity extended to them was reduced proportionately.

Amendments to the AEC's regulations to implement the new Price-Anderson legislation and to reflect the increase in privately available insurance were issued late in 1965. At the same time, the Commission published in the *Federal Register* for public comment a notice that it is considering whether to effect a proportional increase in financial protection requirements for licensees of smaller power and test reactors. (Summary of effective and proposed rules appears in Appendix 9.)

INDEMNITY AGREEMENTS

As of December 31, 1965, the AEC had 80 indemnity agreements in effect with licensees. Coverage included the operation of 11 power reactors, 4 test reactors, 68 research reactors, and 17 critical experiment facilities; storage only of nuclear fuel at 6 reactor sites; 2 construction permits; storage only of fuel at the chemical processing plant of Nuclear Fuel Services, Inc., at West Valley, N.Y., and the operation of the NS *Savannah* by First Atomic Ship Transport, Inc. Also, following the Commission's determination of August 19, that the

[2] Consolidated Edison Co., Commonwealth Edison Co., and Yankee Atomic Electric Co. Of the reactors currently under construction, four will be required to have the increased maximum amount of private insurance protection. They will be operated by Southern California Edison Co., Connecticut Yankee Atomic Power Co., Niagara Mohawk Power Corp., and Jersey Central Power & Light Co.

Fission Product Conversion and Encapsulation Plant proposed to be built at Hanford, Wash., is a "utilization facility" within the scope of section 11aa of the Atomic Energy Act, steps were being taken to determine financial protection levels for its operation.

The AEC charges, as required by statute, an annual indemnity fee of $30 per thermal megawatt for licensed reactors, subject to a minimum annual charge of $100. Thus, the Commonwealth Edison Co.'s Dresden-1 plant at Morris, Ill., with an operating level of 700 thermal megawatts, is subject to an annual indemnity fee of $21,000, and its proposed 2,300-megawatt Dresden-2 reactor would require an annual fee of $69,000. During the 12 months ended November 30, 1965, the AEC had received a total of $87,180 from indemnity fees. To date, there have been no claims under licensee indemnity agreements.

Two amendments to the Commission's regulations in 10 CFR Part 140, "Financial Protection Requirements and Indemnity Agreements," were issued during the year. A summary of these amendments appears in Appendix 9.

A listing of indemnified licensees and their financial protection levels is shown in Table 1.

RADIATION SAFETY RECORD OF LICENSEES

An excellent radiation safety record was compiled during the year by the more than 7,000 AEC materials and facility licensees.

In the 12-month period ending November 30, 1965, eight radiation incidents were reported [3] of which five resulted in radiation exposures in excess of the limits specified in the AEC regulation 10 CFR Part 20.

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[3] Licensees are required to report to the AEC significant radiation incidents which occur in licensed operations, each of which is investigated. Under 10 CFR Part 20, immediate notification is required if any incident involving licensed materiel may have caused or threatened to cause:

(1) Exposure of the whole body to 25 rems or more of radiation; exposure of the skin of the whole body to 150 rems or more of radiation; or exposure of the feet, ankles, hands or forearms to 375 rems or more radiation; or
(2) The release of radioactive material in concentrations which, if averaged over a 24-hour period, would exceed 5,000 times the limits specified for such materials in Appendix B, table II; or
(3) A loss of 1 working week or more of the operation of any facilities affected; or
(4) Damage to property in excess of $100,000.

Notification within 24 hours of any incident involving licensed material is required by 10 CFR Part 20, if it may have caused or threatens to cause:

(1) Exposure of the whole body to 5 rems or more of radiation; exposure of the skin of the whole body of any individual to 30 rems or more of radiation; or exposure of the feet, ankles, hands, or forearms to 75 rems or more of radiation; or
(2) The release of radioactive material in concentrations which, if averaged over a 24-hour period, would exceed 500 times the limits specified for such materials in Appendix B, Table II; or
(3) A loss of 1 day or more of the operation of any facilities affected; or
(4) Damage to property in excess of $1,000.

Licensee reports on all such incidents are filed for public inspection in the AEC's Public Document Room, 1717 H Street NW., Washington, D.C. 20545

TABLE 1.—INDEMNITY AGREEMENTS

[As of December 31, 1965]

Organization	Thermal Power Level	Private Financial Protection Required
Commonwealth Edison Co	700, 000 kw	$74, 000, 000
Yankee Atomic Electric Co	600, 000 kw	74, 000, 000
Consolidated Edison Co	615, 000 kw	74, 000, 000
Pacific Gas & Electric Co	240, 000 kw	43, 200, 000
Consumers Power Co	240, 000 kw	36, 000, 000
First Atomic Ship Transport, Inc	80, 000 kw	None
Carolinas-Virginia Nuclear Power Associates, Inc	65, 000 kw	9, 800, 000
General Electric Co	33, 000 kw [1]	7, 000, 000
Saxton Nuclear Experimental Corp	23, 500 kw	4, 300, 000
Northern States Power Co	20, 000 kw	3, 600, 000
The Babcock & Wilcox Co	6, 000 kw [1]	3, 500, 000
Industrial Reactor Laboratories, Inc	5, 000 kw	2, 500, 000
Union Carbide Corp	5, 000 kw	2, 500, 000
Battelle Memorial Institute	3, 000 kw [1]	2, 500, 000
Lockheed Aircraft Corp	3, 000 kw	2, 500, 000
General Dynamics Corp	1, 500 kw [1]	2, 500, 000
Northrop Corp	1, 000 kw	1, 500, 000
Power Reactor Development Co	20, 000 kw	3, 500, 000
Aerojet-General Nucleonics	250 kw [1]	1, 500, 000
IIT Research Institute	75 kw	1, 500, 000
Westinghouse Electric Corp	10 kw [1]	1, 000, 000
North American Aviation, Inc	200 w	1, 000, 000
United Nuclear Corp	100 w	1, 000, 000
Martin-Marietta Corp	50 w [1]	1, 000, 000
Allis-Chalmers Manufacuring Co		1, 000, 000
Nuclear Fuel Services, Inc		5, 000, 000
Philadelphia Electric Co		1, 000, 000
53 educational institutions and Federal agencies		None

[1] More than one indemnified licensed activity; power level shown is highest level for that license.

Eight persons were involved, and there were no fatalities. Seven of the incidents involved radioactive materials licensees, and are described in Chapter 3, of this Part Two under "Radiation Incidents." The eighth, resulting in the temporary shutdown of a reactor, is described in Chapter 2 of Part Two under "Compliance Inspections of Facilities."

Enforcement Activities

The AEC compliance field staff, decentralized in five regional offices—in New York, Atlanta, Chicago, Denver, and San Francisco—conducts inspection programs to ascertain compliance of licensees with

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AEC requirements and to identify any safety problems. Any unusual occurrence or condition receives prompt attention to determine its safety significance. If the preliminary information gathered indicates the possibility of noncompliance with regulatory requirements or an unsafe condition, an investigation is conducted to determine the cause of the occurrence or condition, the degree of hazard involved, and the timeliness and adequacy of measures which the licensee is taking to protect its employees and the public.

During 1965, approximately 80 percent of the cases in which inspection disclosed noncompliance were handled by the Compliance Regional Offices. The remainder which involved more serious and complex questions of noncompliance were referred to Headquarters for disposition. No case arose in which it was necessary to issue an order for license suspension or revocation. On the whole, the record of AEC licensees in complying with requirements of their licenses has been excellent.

Chapter 2

REACTORS AND OTHER NUCLEAR FACILITIES

During the year, steps were taken to improve the licensing process for reactors and other nuclear facilities, and safety reviews were initiated on construction applications for four large power reactors which would more than double current installed nuclear electrical capacity. Of particular significance to the future conduct of the licensing program were steps initiated to implement recommendations of the Regulatory Review Panel, most of which were directed at facilitating procedures and practices at the construction permit stage in light of the projected growth of the nuclear power industry. (See Chapter 1 of Part Two.)

THE DECISION-MAKING PROCESS

A principal area of inquiry of the Regulatory Review Panel was the decision-making process in the regulatory program, with emphasis on the respective roles played by the regulatory staff, the Advisory Committee on Reactor Safeguards (ACRS), the Atomic Safety and Licensing Boards, and the Commission.

Function of Safety and Licensing Boards

The panel concluded that the practice of conducting public hearings before Atomic Safety and Licensing Boards (ASLB's), which include members with technical backgrounds, is an effective means of obtaining public participation in reactor licensing proceedings, as was the intent of Congress in the 1962 amendments to the Atomic Energy Act. However, the panel recommended redefinition of the function of boards "specifically to recognize that a board cannot undertake, *de novo*, an independent technical review of the safety of a proposed facility." It proposed focusing of the board's adjudicatory and technical expertise on appraising the adequacy of the regulatory staff's safety review, the general sufficiency of technical and other information supplied by the appellant and other parties, and the adjudicating of controversy expressed in contested cases. Other panel recommendations were directed at prehearing conferences, conduct of hearings, jurisdiction of the boards, and board composition.

Commission Actions

The Commission in the latter part of 1965 discussed the role of the boards with members of the Atomic Safety and Licensing Board Panel, the ACRS, the regulatory staff, and the Atomic Industrial Forum and considered the experience gained in the conduct of public hearings by the boards since 1962. The Commission enlarged the membership of the ASLB Panel near the end of the year to assure an adequate number of members to accommodate an increasing volume of cases, and began the practice of designating a third technical member of boards as an alternate to facilitate future proceedings as recommended by the Regulatory Review Panel.

Another recommendation of the Review Panel, designed to expedite Commission review of regulatory decisions, was implemented with publication in the *Federal Register* on November 5, 1965, of a proposed amendment to its regulations which would simplify procedures for filing appeals from initial decisions of hearing examiners or Atomic Safety and Licensing Boards. The amendment would eliminate the necessity of filing petitions for Commission review.

CRITERIA, STANDARDS, AND CODES

An important action during the year was the development of proposed general design criteria for the safety evaluation of applications for nuclear powerplant construction permits, which were issued with a public announcement on November 22,[1] seeking comment from the industry and other interested persons. This was a key recommendation of the Regulatory Review Panel, which urged intensified efforts to develop criteria, standards, and codes.

General Design Criteria for Construction Permits

The proposed criteria represent an effort to set forth design and performance requirements for reactor systems, components and structures which have evolved over the years in the licensing of nuclear powerplants by the AEC. The 27 criteria, covering the facility, the reactor, engineered safeguards, and radioactivity control, reflect the

[1] AEC press announcement H–252, Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C., 20545.

predominating experience to date with water reactors, but most are generally applicable to other reactors as well.

While it was recognized that further efforts would be necessary by the AEC regulatory staff and the ACRS to fully develop the criteria, they were considered sufficiently advanced to issue for public comment and to give interim guidance to applicants and reactor equipment manufacturers. The AEC plans to confer with nuclear industry organizations, and to issue from time to time explanatory information on each criterion, and subsequently to develop and publish criteria used as a basis for evaluation of applications for nuclear powerplant construction permits. Meanwhile, it is recognized that there may be instances where one or more of the proposed criteria may not be applicable, and also that additional criteria may be needed in other cases. Application of the criteria to specific designs continues to involve a considerable amount of engineering judgment.

Establishment of criteria for the construction permit stage was a key recommendation of the Regulatory Review Panel, which viewed them as a vehicle by which the licensing process "could be simplified, shortened, and made more exact and predictable, with attendant improvement in the time-efficiency of the regulatory staff."

Industry Code Goal

The proposed criteria are part of a longer-range Commission program to develop criteria, standards and codes for nuclear reactors. The ultimate goal is the evolution of industry codes based on accumulated knowledge and experience, as has occurred in various fields of engineering and construction.

Progress also was made by the AEC during the year in developing (*a*) technical specifications guidelines defining more precisely the vital areas of reactor safety that must be covered by the technical specifications accompanying a reactor license, and (*b*) a safety analysis report guide which will more clearly specify the information needed by the AEC to conduct required safety reviews.

NUCLEAR SAFETY RESEARCH PROGRAMS

Coordination of the AEC's nuclear safety research programs was strengthened in July by the formation of the Steering Committee on Reactor Safety Research, with high-level staff representation from both the General Manager and the Director of Regulation. The committee will work to assure that the experimental information developed in the AEC's extensive program of reactor safety research is keyed to the needs of the continuing development of the nuclear industry and to the requirements of the Commission's regulatory program. During the latter half of 1965, the committee held meetings with industry representatives to obtain their views on safety matters that should form an important part of the research program.

Liaison during the year with groups carrying out the nuclear safety research programs emphasized the regulatory staff's interests in results of planned major accident tests. Programs of particular, cooperative interest were Loss-of-Fluid-Test (LOFT), Containment Systems Experiment (CSE), Special Power Excursion Reactor Test (SPERT), Nuclear Safety Pilot Plant (NSPP), and the Reactor Containment Handbook and the course of proposed future programs such as the Core Spray System Experimental Program and the Five-Year Fast Reactor Safety Program.

MAJOR REACTOR LICENSING ACTIONS

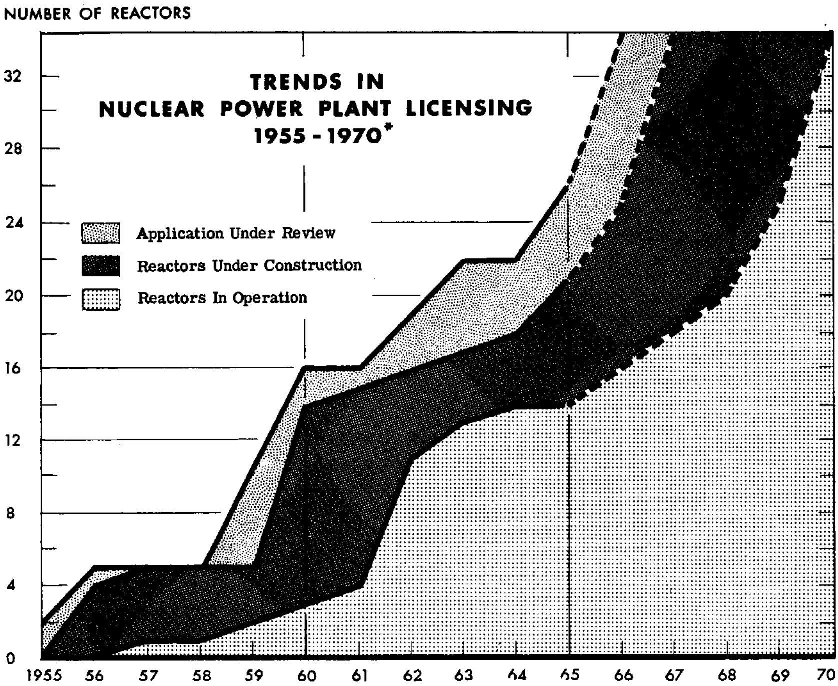
Applications were received during the year for four large power reactors representing an aggregate electrical capacity of nearly 2,600,000 kilowatts—more than double the current installed capacity of all licensed power reactors. Two of the proposed projects are the largest powerplants yet submitted for licensing: A pressurized water reactor proposed late in the year by the Consolidated Edison Co. for its second nuclear unit at its Indian Point, N.Y., site with a design capacity of 873,000 electrical kilowatts (ekw); and the Dresden-2 unit proposed by Commonwealth Edison Co. at its Morris, Ill., site which is designed for initial production of 715,000 net ekw.

More than a dozen other utilities either conferred informally with the AEC's regulatory staff during the year or requested preliminary site reviews for powerplants tentatively planned for operation in the early 1970's. Major actions completed during the year included the issuance of full-term operating licenses for two power reactors and one test reactor; construction permits for two power reactors; a three-year operating license for the NS *Savannah;* and a safety review of Commonwealth Edison's application for construction of its Dresden-2 plant.

Licensed facilities at the end of 1965 totaled 105, as follows: 16 power reactors, mostly operated by privately owned public utilities; four test reactors, three owned by industrial firms and one by a Federal agency; 17 critical experiment facilities, primarily industrial; and 68 research reactors, mostly owned and operated by universities and other educational research groups.

In addition, at the end of 1965, 16 construction permits and authorizations were in effect for the construction of seven power reactors, one test reactor, 11 research reactors, and one chemical separation facility.

The growth in licensed nuclear power facilities in the past decade, and projected into 1970, is shown in the chart—Trends in Nuclear Power Plant Licensing, 1955–1970.



*At the end of 1965, there were 14 operating licenses and seven construction permits in effect for nuclear power reactors, and construction applications were under review for five others. Projections beyond 1965 indicate potential new applications for power reactor construction permits in 1966 and estimated total number of operating power reactors by 1970 if all applications currently under review and those projected for 1966 are approved. Licensed reactors continue under AEC surveillance throughout their lifetimes.

POWER REACTORS

Significant licensing actions and private reactor operation experience, as well as the status of new applications received in 1965, are summarized below. (Significant operating experience of AEC-owned reactors operated by utilities under the Power Reactor Demonstration Program is reported in Chapter 7 of Part One even though the reactors are licensed.)

Construction Permit Applications in Process

Dresden Nuclear Power Station No. 2. The Commonwealth Edison Co. of Chicago on April 15 submitted an application to construct a large single-cycle, forced circulation, boiling water reactor at the 953-acre site of the original Dresden unit at Morris, Ill., about 50 miles southwest of Chicago. The company announced that the General Electric Co. will build the Dresden-2 reactor, designed for initial operation at 2,300 thermal megawatts and production of 715,000 net electrical kilowatts (ekw), but with an expected ultimate capacity of 793,000 ekw.

Following regulatory review of the application, an Atomic Safety and Licensing Board [2] conducted a prehearing conference on November 9 in Morris, and held a public hearing December 7–8 at the same location. The board's initial decision, announced December 29, 1965, authorized the issuance of a provisional construction permit.

Brookwood Power Plant. The Rochester Gas & Electric Corp. on November 1 submitted an application to build a pressurized water reactor at its Brookwood site on the shores of Lake Ontario, Wayne County, N.Y., about 16 miles east of Rochester. Westinghouse Electric Corp. was named designer and prime contractor for the proposed facility, designed for a capacity of 1,300 thermal megawatts and 420,000 ekw, and scheduled for full commercial operation by mid-1969.

Millstone Point Nuclear Power Plant. Application for construction of a 1,730 thermal megawatt boiling water reactor with a net output of 549,200 ekw was filed November 15 by the Connecticut Light & Power Co., the Hartford Electric Light Co., the Western Massachusetts Electric Co., and Millstone Point Co. (an affiliate of the other three companies). The 500-acre site is located at Millstone Point, Waterford, Conn., on the north shore of Long Island Sound, 3.2 miles from New London. The utilities announced award of a contract for designing, furnishing and erecting the plant to the General Electric Co., and scheduled operation to begin by mid-1969.

Indian Point Unit No. 2. On December 6, the Consolidated Edison Co. of New York proposed the largest nuclear powerplant yet submitted for licensing—a pressurized water reactor with a design capacity of 2,758 thermal megawatts and net electrical capacity of 873,000 ekw. The facility would be located at the site of the original Consolidated Edison nuclear powerplant, now designated Indian Point Station, Unit No. 1, on the Hudson River. The utility announced award of a "turn-key" contract to the Westinghouse Electric Corp. and plans for power operation by mid-1969.

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[2] The Atomic Energy Act of 1954 was amended in 1962 to authorize the Commission to establish such boards to conduct public hearings for proceedings involving the granting, suspending, revoking, or amending of licenses or authorizations. The three-member boards are drawn from a panel of AEC Hearing Examiners, AEC-contractor employees, and private citizens (see pp. 426–427, "Annual Report to Congress for 1962").

Malibu Nuclear Power Plant. An Atomic Safety and Licensing Board began a public hearing in Santa Monica, Calif., on March 23, 1965, regarding the application by the Los Angeles Department of Water and Power to construct a large power reactor in Corral Canyon, near Malibu. Five intervenors participated in the proceeding in addition to the applicant and the regulatory staff. The hearing, protracted by extensive testimony and cross-examination on matters of geology and seismicity, concluded November 5, after five different sessions involving a total of 41 days. Prehearing and interim conferences also were held. The board established a schedule for submittal of proposed findings and conclusions, and briefs which expires April 20, 1966, after which the case will be decided upon by the board. The proposed Malibu plant is a pressurized water facility, designed to operate at 1,473 thermal megawatts and to produce 462,000 net ekw.

Reactors Under Construction

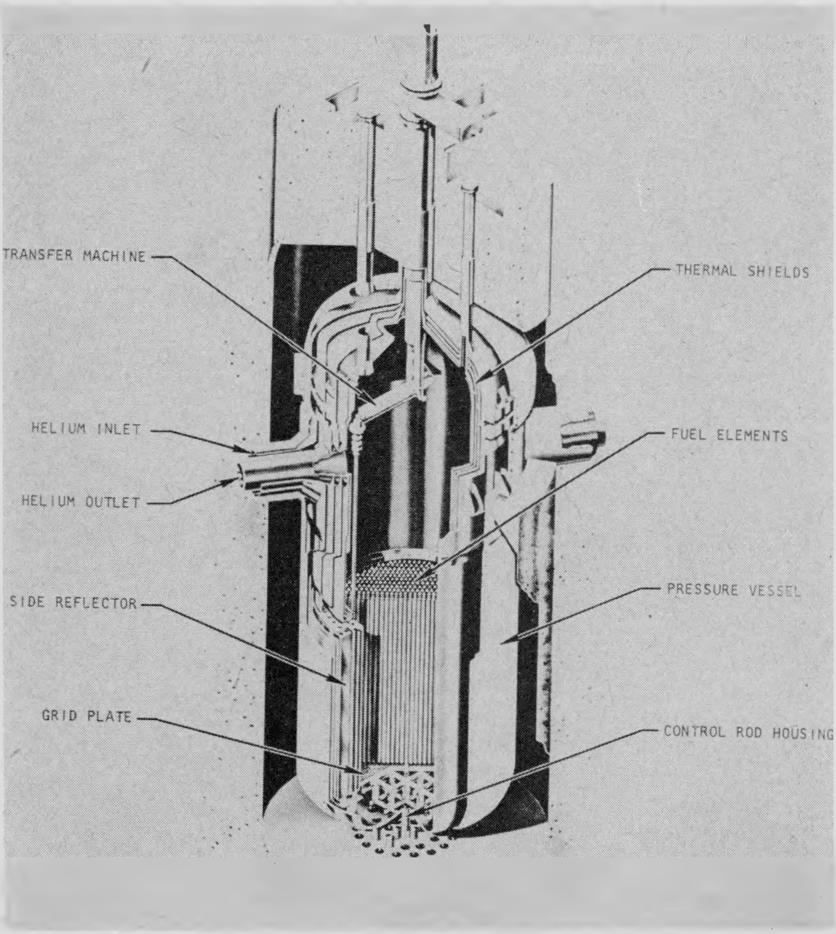
Peach Bottom. On February 2, 1965, a notice of proposed issuance of a facility license was published in the *Federal Register* which would authorize operation at one thermal megawatt of the Philadelphia Electric Co.'s prototype high-temperature, gas-cooled reactor at Peach Bottom, Pa. On February 3, 1965, a fire, believed to have been started by a spark from a welder's torch, caused considerable damage to electric cables and deposited a coat of soot on surfaces inside the reactor's containment shell. There were no personnel injuries and no radioactive materials were involved in the fire. After repair of damage from the fire, construction of the plant was essentially completed and all preoperational testing was completed except for fuel handling equipment.

In December, cracks were discovered in tubes of the reactor's steam generators, and repair will be necessary before operation at significant power levels. However, it appeared that the plant would be ready for fuel loading in January 1966, with low-power testing to follow. The Commission, at the company's request, issued an order extending to January 31, 1966, the latest completion date specified in the construction permit. The reactor is designed to produce 40,000 net ekw at full power.

Nine Mile Point. Following a public hearing in January before an Atomic Safety and Licensing Board, a provisional permit was issued to the Niagara Mohawk Power Corp. on April 12, for construction of a boiling-water nuclear power reactor. The plant, under construction with the assistance of the General Electric Co. at Nine Mile Point on Lake Ontario near Scriba, N.Y., about seven miles northeast of

Oswego, has a design reactor power rating of 1,538 thermal megawatts with an approximate output of 500,000 net ekw. As of December 31, physical construction of the facility was about 35 percent complete, and the reactor was scheduled to achieve initial criticality by the fall of 1967. Power operation is planned for early in 1968.

SEFOR. A provisional construction permit was issued September 21 for the 20-thermal-megawatt Southwest Experimental Fast Oxide



Peach Bottom Reactor. The Philadelphia Electric Co.'s prototype high-temperature gas-cooled reactor at Peach Bottom, Pa., is now scheduled to go into operation about mid-1966. A February 1965 fire damaged electrical cables and left a layer of soot within the reactor containment shell which, while not damaging the reactor, required that a thorough cleanup job be conducted before the reactor fuel could be loaded. Diagram shows the main components of the reactor, which will use graphite fuel elements containing carbon-coated uranium-thorium fuel particles.

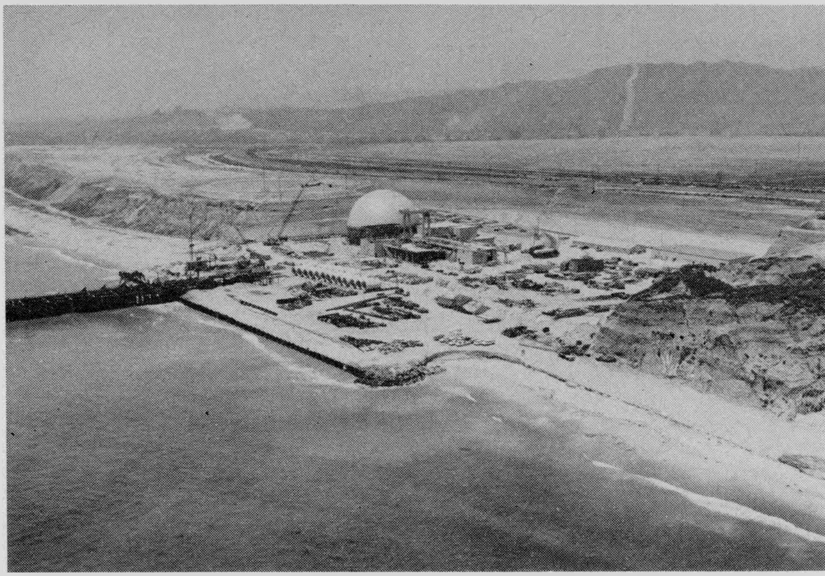
Reactor (SEFOR) project, now under construction at a site near Fayetteville, Ark. An Atomic Safety and Licensing Board, following a public hearing at Fayetteville, June 29–July 2, specified in its initial decision that certain supplemental information be supplied by the applicants during the construction stage. The reactor, which is not planned for electricity generation, is a joint project involving the Republic of West Germany, Euratom, Southwest Atomic Energy Associates, the General Electric Co., and the AEC.

Oyster Creek. On January 5, construction began on the Jersey Central Power & Light Co.'s boiling water reactor powerplant near Toms River, on Oyster Creek, about 40 miles north of Atlantic City, N.J. By the end of 1965, construction of the plant, which is being built for the utility by the General Electric Co. on a "turn-key" basis, was about 30 percent complete and on schedule. It is designed to produce 515,000 net ekw initially (and ultimately more than 600,000 ekw), and is planned for operation late in 1967.

LaCrosse. In August, the Allis-Chalmers Manufacturing Co., which is constructing the 50,000 net ekw LaCrosse Boiling Water Reactor near Genoa, Wis., for the Dairyland Power Cooperative, requested a provisional operating authorization. However, completion of the plant was delayed by late delivery of several components.

San Onofre. The Southern California Edison Co., San Diego Gas & Electric Co., Bechtel Corp., and Westinghouse Electric Corp. in December filed the final safety analysis report and applied for a provisional operating license for the San Onofre Nuclear Generating Station Unit No. 1 at Camp Pendleton, in southern California. The 1,347 thermal megawatt, pressurized water reactor, now about 50 percent completed, is designed to produce 450,000 net ekw, with Bechtel as the construction contractor and Westinghouse as nuclear contractor. The application is under review.

Connecticut Yankee. Construction of the Connecticut Yankee Atomic Power Co.'s 462,000 net ekw nuclear powerplant at Haddam Neck, Conn., is proceeding on schedule. By the end of the year, shipment of the steam generators fabricated by Westinghouse in South Philadelphia, Pa., had started, with the last of the four units scheduled for delivery in April 1966. The reactor vessel was expected to be shipped from Combustion Engineering's Chattanooga, Tenn., shops in February 1966, and delivery of all other major components was on schedule. The pressurized water reactor facility is planned for completion early in 1967 and for regular power operation by October 1967.



San Onofre. Located on the Pacific Ocean shoreline 60 miles south of Los Angeles, the 450,000 ekw San Onofre Nuclear Generating Station is scheduled to be in operation by early 1967. The Westinghouse-built pressurized water reactor will be supported in concrete within the massive steel containment sphere; the turbine-generator will be mounted on the concrete pedestal structure to the right of the dome. In the background are the main north-south highway and railroad between Los Angeles and San Diego, and the Santa Margarita Mountains. The plant is being built for the Southern California Edison and San Diego Gas and Electric Companies by the Bechtel Corp. of Los Angeles and San Francisco.

Operating Reactors

Enrico Fermi. Operation of the Power Reactor Development Co.'s Enrico Fermi Atomic Power Plant at levels up to 200 thermal megawatts was authorized December 17 by amendment to the provisional operating license following the initial decision by an Atomic Safety and Licensing Board on December 7. A public hearing was conducted by the board at Detroit, Mich., August 30–September 2, 1965.

The sodium-cooled, fast breeder-type reactor is located at Lagoona Beach, Mich. Throughout the year, a nuclear test program was conducted to determine the reactor's "characteristics," and it was operated periodically for operator training and nonnuclear testing purposes. Operation at full power level of 200 thermal megawatts would produce 60,900 ekw.

Carolinas-Virginia Tube Reactor. A full-term operating license replacing the provisional license was issued in April to the Carolinas-Virginia Nuclear Power Associates (CVNPA) for its heavy water-moderated and cooled pressure-tube reactor at Parr, S.C. For the major portion of the year, CVNPA operated the plant at an authorized level of 44.3 thermal megawatts without major problems, and losses of heavy water were below design expectations. In September, the license was amended to permit an increase in operating power to the design capacity of 65 thermal megawatts, and a stepwise increase in power was begun. By the end of the year, the reactor had achieved its full power level of 17,000 ekw (with oil-fired superheater).

Elk River. A full-term operating authorization replacing the provisional authorization held by Allis-Chalmers was issued to the Rural Cooperative Power Association in June for operation of the Elk River, Minn., reactor. The maximum power level authorized for this boiling water reactor is 58.2 thermal megawatts (producing 22,000 ekw).

Humboldt Bay. Following the successful completion of a series of stepwise power-increase experiments in the fall of 1964, the Pacific Gas & Electric Co. was authorized in May 1965 to increase, from 165 to 240 thermal megawatts, the power level of its Humboldt Bay boiling water reactor plant near Eureka, Calif. However, the reactor was not operated at this higher level because its old core did not have sufficient reactivity to attain it.

In September, the company was authorized to replace the stainless steel-clad fuel, which had been used in the past two years of operation, with Zircaloy-2 clad fuel assemblies. During the shutdown begun September 20, the facility was modified and about 25 percent of the new core was loaded. The remainder will be loaded in 25-percent increments at approximately eight to 12-month intervals until a complete fuel change has been accomplished. The utility subsequently was authorized to operate at a steady-state power level of 240 thermal megawatts with the new fuel assemblies, and startup operations began in November.

Pathfinder. The Northern States Power Co. was authorized on December 2, 1965, to increase the power level of its Pathfinder Atomic Power Plant at Sioux Falls, S. Dak., from one thermal megawatt to the full rated power of 190 thermal megawatts, which would produce about 58,500 ekw.

BONUS. An application for transfer to the Puerto Rico Water Resources Authority (PRWRA) of the provisional operating authorization for the Boiling Nuclear Superheat Reactor (BONUS) at Punta Higuera, Puerto Rico, now jointly held by PRWRA and Combustion Engineering, Inc., is pending. Review of the application, which was received in December 1964, was deferred by the regulatory staff pending a report on operation of the reactor at full power of 50 thermal megawatts (producing 16,500 ekw).

Indian Point No. 1. In October, the Commission issued an amendment to Consolidated Edison's provisional operating license for its Indian Point-1 plant to permit replacement of the original uranium-oxide and thorium-oxide core with a low-enrichment uranium-oxide core of modified design, and an increase in steady state operating power level from 585 thermal megawatts to 615 thermal megawatts. Full power with the new core would produce about 270,000 net ekw, including conventional superheating of the steam, compared with 255,000 net ekw with the first core. The pressurized water reactor was shut down in October for refueling. It is scheduled to be back in operation in early spring of 1966.

Yankee Nuclear Power Station. On August 9, the Yankee Atomic Electric Co.'s pressurized water reactor at Rowe, Mass., was shut down for annual refueling and maintenance. This ended a total of 3,857 consecutive hours of power generation. At the time of shutdown, the fourth core, which had been in operation since September 6, 1964, had a total electric generation of 1,309,058,800 kilowatt-hours.

The fuel assembly which had been discharged from the first Yankee core and reinserted into the reactor with Core II and again with Core IV for additional irradiation, was examined and found to be in excellent condition. The assembly, which achieved an estimated peak burnup of 46,000 megawatt-days per metric ton of uranium, is currently undergoing destructive examination at the Westinghouse Post-Irradiation Facility at Waltz Mill, Pa.

During the shutdown, the full core and the core barrel were removed to permit inspection of the core support structure and the interior of the reactor vessel. No problems were found in the core support structure, but modifications were made to assure proper core support in case structural failure did occur. Two penetrations of the reactor vessel cladding in the region of the lower vessel head were discovered. Several failed bolts in a vertical seam of the thermal shield also were discovered. Modifications were made to provide for the use of clamps on the vertical seams of the thermal shield, thereby eliminating the need for bolts. Evaluation of the cladding defects indicated that vessel integrity was not affected and that reactor operation could be resumed.

During reassembly of the core, one-half of the 76 fuel assemblies were replaced. After the containment vessel was leak-tested and general plant maintenance work was performed, the reactor was returned to power operation on its fifth core in mid-November.

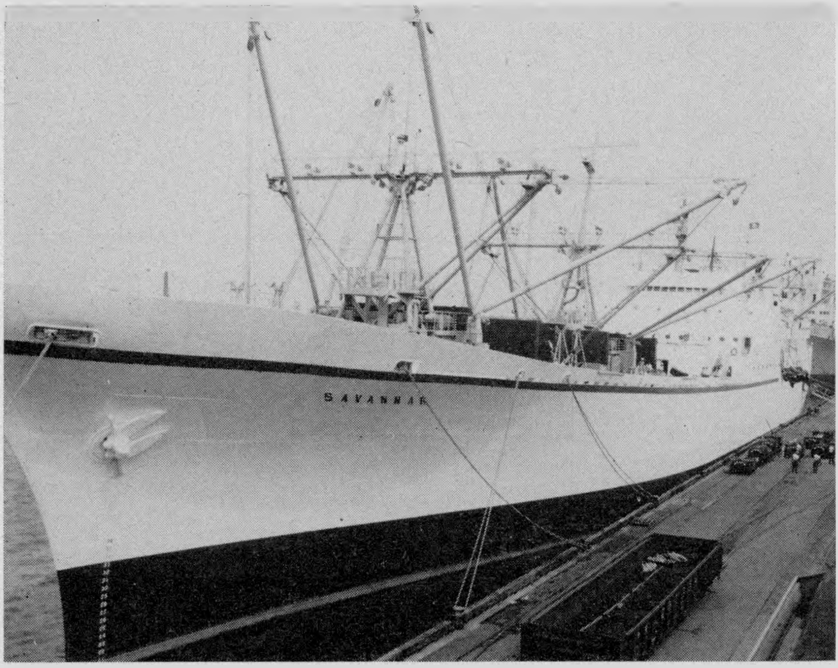
Dresden-1. On May 29, the 200,000 net ekw boiling water Dresden-1 reactor of the Commonwealth Edison Co. at Morris, Ill., returned to normal load-following (*i.e.*, adjusting the energy output of the reactor to meet the load requirements of the utility system at any time) power operation after a nine-week shutdown which started on March 28. About half of the shutdown period was for refueling, and the rest was for routine testing and maintenance. During this third reloading, 200 of the reactor's 464 fuel assemblies were replaced.

Tornadoes near the Dresden-1 plant on November 12 disabled all five of the connecting power lines to the facility. Reactor scram and main turbine trip from full load conditions followed the complete loss of outside power, and continuous local power then was supplied by the building's emergency diesel generator set. Outside power was restored in 1½ hours and the reactor was returned to service on the following day. All safety systems responded as designed.

Big Rock Point Nuclear Power Plant. The Big Rock Point, Mich., boiling water reactor plant of Consumers Power Co. returned to operation on September 4 after having been shut down since September 18, 1964. Soon after the reactor was shut down, several bolts that attach the thermal shield to the reactor vessel were found to be sheared off. The bolt failure apparently resulted from a thermal shield vibration problem which was finally resolved in July. As a result of cold flow tests, it was determined that the vibration was caused by excessive primary coolant flow between the shield and the reactor vessel wall. Modifications were made to the thermal shield mounting and a seal was installed at the top of the shield to control the coolant flow. Following replacement of core internals and fuel assemblies, the plant resumed operation and reached full power of 70,400 net ekw on September 10. Since then it has been operating on a normal load-following schedule.

NS *Savannah.* First Atomic Ship Transport Inc. (FAST) received a three-year license on August 5 to operate the pressurized water nuclear reactor aboard the NS *Savannah*, pursuant to an initial decision by an Atomic Safety and Licensing Board following a public hearing at Germantown, Md., on June 7. The reactor is licensed to operate at 80 thermal megawatts. Built as a joint project of the Maritime Administration and the AEC, the *Savannah* had been operated for the Government since June 1964 by American Export Isbrandtsen Lines, Inc. (AEIL), as general agent. In December 1964, the Maritime Administration had applied for a license to operate the *Savannah*, but withdrew the application in January 1965.

Subsequently, FAST, a wholly-owned subsidiary of AEIL, was created for the sole purpose of operating the *Savannah* under charter from the Maritime Administration in the regular freighter service of AEIL. FAST has reported performance of the vessel's reactor plant highly satisfactory since taking delivery of the ship on August 20, enabling the licensee to meet schedule obligations and to complete three voyages under full cargo conditions with satisfactory revenue. Two of the voyages were to Northern Europe, and the third was to Mediterranean ports. The AEC approved 22 port reviews for the *Savannah's* visits in 1965 since issuance of the license in August. FAST plans about eight voyages annually—six between the U.S. North Atlantic Coast and European ports, and two to the Mediterranean area.



First Commercial Cargo. The NS *Savannah*, the world's first nuclear-powered cargo-passenger ship, loads her first cargo as a commercial vessel following 2 years of demonstration visits to leading ports in this country and abroad. Here the *Savannah* is shown at pierside in Baltimore, Md., where she topped off a cargo of tractors, agricultural implements, food, automobiles, household goods and scrap metal by swinging 200 "Jeeps" (*extreme right of photo*) on board for delivery in Europe. After a stop in Philadelphia, the *Savannah* left New York September 3 for Spain, France, Belgium, The Netherlands, and Germany. Constructed as a joint project of the AEC and the Maritime Administration of the U.S. Department of Commerce, the ship is now operated under charter by First Atomic Ship Transport, Inc., a subsidiary of American Export Isbrandtsen Lines.

Reactor Export Licenses

Exports of four reactors to foreign countries were licensed in the 12-month period ending December 31, 1965. Three of these were research reactors and the fourth was a reactor for production of electricity, being installed near Madrid, Spain. Exported by Westinghouse Electric International Co., the 515 thermal megawatt pressurized light water reactor has a design power rating of 160,000 gross ekw. Construction was started in July, and shipments from the United States began in November.

OTHER PRODUCTION AND UTILIZATION FACILITIES

Because of the nature of the processes, the quantities of material and the safety considerations involved, some nuclear material plants are subject to licensing procedures similar to those established for nuclear reactors. This includes the processing of construction permits and operating licenses, and establishment of financial protection levels, indemnity fees, and special operator licensing programs for each new type of facility.

Fission Product Conversion and Encapsulation Plant

During the fall, the Commission determined that the proposed Fission Product Conversion and Encapsulation Plant to be built at Hanford, Wash., by Isochem, Inc., is a utilization facility and therefore, subject to licensing under its facility regulations set out in 10 CFR Part 50. An early-1966 application is anticipated from Isochem requesting appropriate AEC licensing.

The proposed facility, which Isochem has projected for operation in the fall of 1968, is designed for large-scale production and distribution of four radioisotopes: strontium 90, promethium 147, cerium 144, and cesium 137. These isotopes would be recovered from the waste stream generated at the AEC Hanford plants in the course of producing and recovering plutonium. Isochem is jointly owned by Martin-Marietta Corp. and the U.S. Rubber Co.

Irradiated Fuel Chemical Processing Plant

An application from Nuclear Fuel Services, Inc. (NFS), and the New York State Atomic and Space Development Authority to operate the first privately-owned irradiated reactor fuel reprocessing facility continued under review. The State has leased the site to NFS and has assumed responsibility for perpetual care of the radioactive wastes generated by the plant. The facility is at the Western New York

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Nuclear Service Center near West Valley, N.Y., about 32 miles south of Buffalo, and is expected to begin operations early in 1966.

In May, the AEC issued a materials license authorizing receipt by NFS of irradiated fuel from the Hanford "N" Reactor (formerly called NPR), and the Yankee and Dresden reactors for storage prior to completion of construction. The first shipments of spent fuel were received at the NFS plant on June 3.

In 1964, the AEC proposed an interim amount of financial protection and interim indemnity fee for both the preoperational and operational stages of the NFS plant. In the absence of criteria on these matters for chemical processing plants, the AEC in 1965 issued an effective rule establishing the interim levels which it had proposed in 1964, pending the development of general criteria. The levels of financial protection were established at $5 million for the preoperational fuel storage stage, and $20 million for the operational phase of the facility. Indemnity fees for the two phases were set at $500 and $4,000, respectively.

OPERATOR LICENSING

Licensing of individuals to operate reactor and plant controls is required under regulation 10 CFR Part 55, and comprehensive written and on-the-job examinations are administered by the AEC.

In the 12-month period ending November 30, 1965, the AEC staff issued 333 operator licenses and 249 senior operator licenses. These included 267 new licenses, 12 amended licenses, and 303 renewed licenses. During the same period 43 license applications were denied. Including previously-issued licenses, 909 operator licenses and 553 senior operator licenses were in effect on November 30.

The NFS spent-fuel reprocessing plant will be the first nonreactor facility where operators are required to hold Part 55 licenses.

OTHER SAFETY REVIEWS

The AEC's regulatory staff also conducts safety reviews of Government-owned reactor facilities, including AEC-owned reactors at its Hanford, Oak Ridge, Idaho, and Savannah River operations, and, through arrangements with the Department of Defense, at reactor facilities owned and operated by the Armed Forces. This includes advice on siting, design, and operation of reactors, and port operations for nuclear vessels.

During the year, safety reviews were performed on the following facilities: The Molten Salt Reactor Experiment (MSRE), a 10-thermal megawatt, graphite moderated, circulating fuel reactor at the Oak Ridge National Laboratory; a new core for the S3G prototype reactor located at West Milton, N.Y.; a new core and an increase in power level of the Shippingport, Pa., pressurized water reactor; the proposed Phase II (production and electric power generation) operation of the Hanford "N" reactor with a planned power level of 800,000 electrical kilowatts; the S5G prototype reactor plant at the National Reactor Testing Station (NRTS), Idaho; the High Flux Isotope Reactor (HFIR) located at Oak Ridge National Laboratory which has a design power level of 100 thermal megawatts; Power Burst Facility (PBF) located at NRTS, an experimental reactor with a thermal power level of 20 megawatts; Experimental Gas Cooled Reactor (EGCR), a gas cooled, graphite moderated reactor located at Oak Ridge, Tenn., with a thermal power level of 84.3 megawatts; and the Experimental Beryllium Oxide Reactor (EBOR), a gas cooled BeO moderated reactor located at NRTS, with a thermal power level of 10 megawatts.

COMPLIANCE INSPECTIONS OF FACILITIES

Routine inspection of a licensed facility begins shortly after the start of initial construction, and continues throughout the life of the facility. By inspection of the premises, records, and operations of licensees, the status of compliance is determined and any safety problems that need correction can be identified.

In the 12 months ending November 30, 1965, 350 facility inspections were made by AEC compliance personnel. These were distributed among 121 facilities as follows: power reactors, 127; test reactors, 28; research reactors, 130; critical assemblies, 28; NS *Savannah*, 12; and the NFS irradiated fuel reprocessing plant, 25.

Among the factors influencing the frequency of inspection is the status of a facility—whether it is under construction, undergoing initial testing, in startup status, or in routine operation. For those reactors in routine operation in 1965, an average of 6.5 inspections were made of each power reactor and an average of 1.8 inspections at each research reactor.

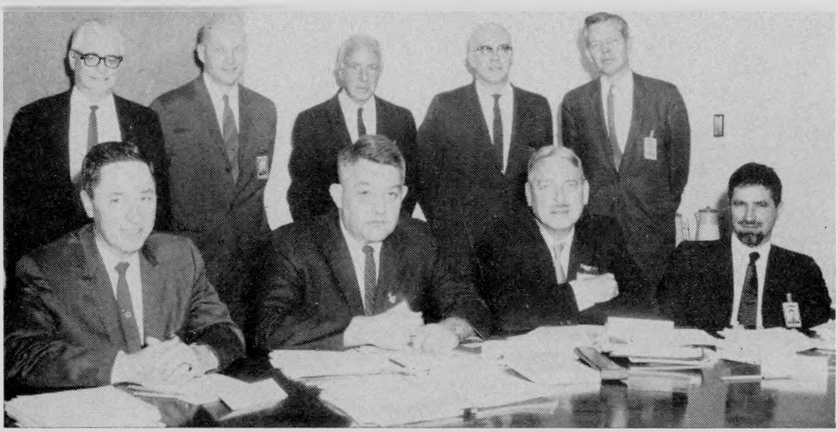
AEC regulation 10 CFR 20 requires licensees to report to the AEC any significant radiation incident.[3] Only one radiation incident was reported involving reactors in the 12-month period ending November 30, 1965. This was a loss of more than 24 hours operating time when a capsule failed while undergoing irradiation in a nuclear reactor. There was no exposure to personnel and no release of airborne concentrations of radioactive materials in excess of limits specified in AEC regulations.

[3] See "Radiation Safety Record of Licensees" item in Chapter 1 of Part Two.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

The Commission's Advisory Committee on Reactor Safeguards is established by statute to review safety studies and various reactor license applications, to advise the Commission with regard to the hazards of proposed or existing reactor facilities and the adequacy of proposed reactor safety standards, and to perform such other duties as the Commission may request. For license applications referred to it, the Committee conducts an independent review, concurrently with the Commission's regulatory staff, and presents its recommendations to the Commission in written reports. These reports are made part of the public record, except for security material.

During 1965, the full committee met 11 times and 55 meetings of ACRS Subcommittees were held. It furnished to the Commission 13 reports on privately- or municipally-owned facilities, 12 reports on Commission facilities, and three reports on reactors owned by other Government agencies. In addition the ACRS submitted several reports on general topics, including: Seismic Considerations in the Design of Nuclear Power Plants, and Reactor Pressure Vessels. The committee also worked with the regulatory staff during the year in the review of proposed criteria and guides.



ACRS Committee. The AEC's Advisory Committee on Reactor Safeguards (ACRS) not only evaluates the safety aspects of proposed new reactors, but also any significant changes to existing reactors or to their mode of operation. Photo, taken in November, shows, *seated left to right:* Nunzio J. Palladino, Pennsylvania State University; William D. Manly, *Chairman*, Union Carbide Corp.; Dr. Henry W. Newson, Duke University; and Dr. David Okrent, *Vice Chairman*, Argonne National Laboratory; *standing:* Dr. Jack E. McKee, California Institute of Technology; Dr. Theos J. Thompson, Massachusetts Institute of Technology; Harold Etherington, Consultant (Florida); Dr. Franklin A. Gifford, U.S. Weather Bureau (Tenn.); and Dr. Carroll W. Zabel, University of Houston. Missing from the photo are Dr. Stephen H. Hanauer, University of Tennessee; Dr. Herbert J. C. Kouts, Brookhaven National Laboratory; and Dr. Leslie Silverman, Harvard University.

Chapter 3

CONTROL OF RADIOACTIVE MATERIALS

Both Federal and State activities in the licensing and regulation of radioactive materials expanded in 1965, and the State share of the regulatory activities continued to increase. Total licenses administered in the Federal-State programs increased about 10 percent during the year, resulting principally from steadily rising uses of radioisotopes. At year's end, the AEC had agreements with 11 States for the transfer of certain of the AEC's regulatory authority over atomic energy materials. Several other States were actively considering agreements.

Steady Increase in Licenses

In March 1962, immediately prior to the effective date of the first agreement with a State for the transfer of specified AEC regulatory control over materials, as authorized under a 1959 amendment to the Atomic Energy Act,[1] 10,338 AEC material licenses were in effect. Since then, the AEC has transferred some 3,700 licenses to 11 agreement States. The aggregate of AEC and agreement State material licenses in effect as of November 30, 1965, totaled approximately 14,000, of which 9,460 were administered by the AEC, and more than 4,500 were encompassed in the regulatory programs of the agreement States.

Three categories of materials are subject to licensing control under AEC regulations: (*a*) byproduct material, generally characterized as reactor-produced radioisotopes; (*b*) source material, consisting of uranium or thorium in any physical or chemical form, and (*c*) special nuclear material, which means plutonium, uranium 233, or uranium enriched in the isotopes U^{233} or U^{235}. Almost 90 percent of all atomic energy material licenses are for byproduct material.

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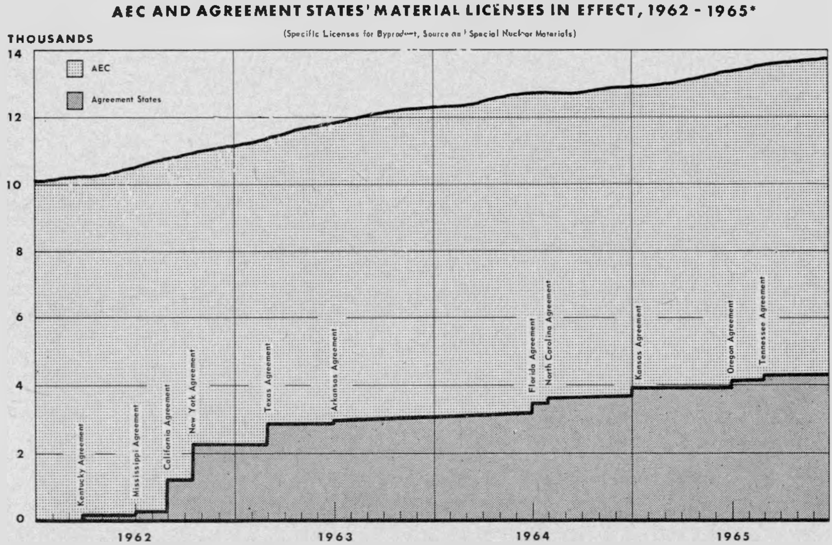
[1] Public Law 86–373, effective September 23, 1959, added section 274 to the Atomic Energy Act of 1954, as amended. See pp. 266–267, "Annual Report to Congress for 1959;" pp. 375–376, "Annual Report to Congress for 1961."

The overall increase in material licensing activities by both the AEC and the agreement States is reflected in the chart—AEC and Agreement States' Material Licenses in Effect, 1962–1965.



*The above chart and other statistics in this report understate to some degree the growth in the licensed use of radioactive materials. Several hundred specific licenses, reflected in the totals for earlier years, have been eliminated by consolidation under single, broad AEC licenses at several institutions which conduct extensive radioisotope programs. Some States also have instituted broad licensing systems.

STATE RELATIONS AND AGREEMENTS

The AEC's Federal-State agreements program offers a demonstration of the transfer to State governments of authority and responsibilities formerly vested solely in the Federal Government.

Under section 274 of the Atomic Energy Act, the Governors of the various States may seek agreements with the AEC to assume responsibilities for the control of byproduct material, source material, and special nuclear material in quantities not sufficient to form a critical mass (*i.e.*, too small to sustain a fissioning reaction). Upon finding that a proposed State program is adequate to protect the public health and safety, and is compatible with the AEC regulatory program, the Commission may transfer certain of its regulatory authority to the State.

Since 1962, when the first agreements became effective, cooperative Federal-State activities in this program have increased markedly.

In addition to assisting the States in developing competent regulatory programs, the AEC in 1965 stepped up its exchange-of-information activities with agreement States in the interest of compatibility, initiated improvements to strengthen health physics training courses offered to State and local personnel, and cooperated in numerous other State and local activities in atomic energy matters.

An important byproduct of the AEC-State agreements program has been a general strengthening of State control of the uses of other sources of radiation (*i.e.*, X-rays, radium and accelerator-produced radioisotopes, which are not regulated by the AEC).

STATE AGREEMENT ACTIVITIES

Agreements were made during 1965 for the transfer of regulatory authority to Oregon and Tennessee, and the Kansas agreement became effective January 1, 1965, bringing to 11 (see Table 1) the number of States formally participating in the program.

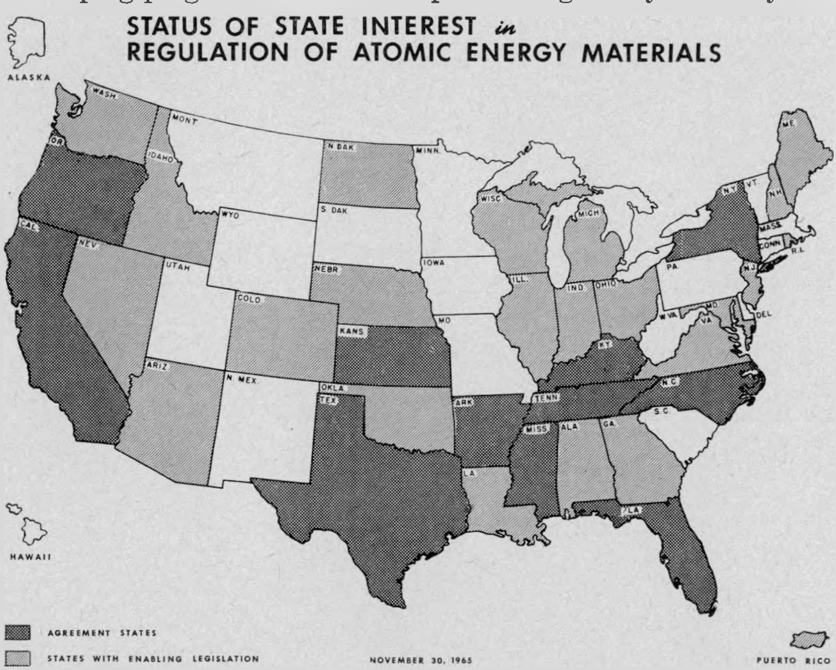
Tennessee Becomes Agreement State. Governor Frank Clement (*right*) of Tennessee signs an agreement with the AEC for assumption of certain regulatory authority over radioactive materials as AEC Commissioner James T. Ramey (*left*) looks on. The ceremony on August 12 at the State capitol in Nashville, consummated the 11th State agreement under section 274 of the Atomic Energy Act of 1954. The agreement became effective on September 1, when 181 material licenses were transferred from the AEC to Tennessee. The State's Department of Public Health administers its radiation control program.

TABLE 1.—AGREEMENTS IN EFFECT

State	Effective date of agreement	Agreement material licenses transferred from AEC	Total State licenses in effect on Sept. 30, 1965
Kentucky	Mar. 26, 1962	104	[1] 115
Mississippi	July 1, 1962	52	[2] 163(62)
California	Sept. 1, 1962	912	[2] 996(142)
New York	Oct. 15, 1962	1,095	[2] 1,489(51)
Texas	Mar. 1, 1963	573	804
Arkansas	July 1, 1963	53	[2] 179(22)
Florida	July 1, 1964	265	[2] 408(62)
North Carolina	Aug. 1, 1964	183	244
Kansas	Jan. 1, 1965	150	[2] 161(20)
Oregon	July 1, 1965	126	[2] 126(2)
Tennessee	Sept. 1, 1965	181	[1] 181

[1] Agreement materials only.
[2] Number in parentheses denotes radium licenses.

During 1965, legislation adopted by Colorado, Michigan, and North Dakota, brought to 23 the number of additional States now authorized to enter into agreements with the Commission. Similar legislation was enacted by Puerto Rico. In two other States—Alaska and New Mexico—their Attorneys General have concluded that legislation is not required for an agreement. Several of these States are actively developing programs for the assumption of regulatory authority.



State Licensing Jurisdiction Increased

State licensing jurisdiction over special nuclear material was changed by an amendment to the AEC's regulation 10 CFR Part 150, "Exemptions and Continued Regulatory Authority in Agreement States Under Section 274," which became effective October 21, 1965. Under the amendment, the determination of the quantity of special nuclear material that a State may authorize for a single licensee is based on the quantity possessed at any particular plant or other authorized location of use rather than on the total amount that the licensee may possess within the State. This has the effect of increasing the amount of special nuclear material subject to State licensing jurisdiction.

COOPERATION WITH AGREEMENT STATES

To assure the continued adequacy of the States' programs to protect the public health and safety, and compatibility with the AEC's regulatory program, postagreement reviews are conducted and a procedure for continuous exchange of information is maintained with agreement States. During 1965, the exchange of data through correspondence continued to increase and 18 review meetings were held with individual States, plus 1 general meeting with representatives of all agreement States.

Exchange-of-Information Program

The stepped-up exchange-of-information program is designed to keep both the States and the AEC currently informed of each other's activities, as well as to keep each State advised of developments in other agreement States. Subjects include licensing and inspection procedures and criteria, new or unusual licensed uses or conditions on licenses, enforcement actions and procedures, and changes or proposed changes in regulations. In addition, the AEC provides, upon request, technical or other advice in the administration of specific State programs.

Training Programs and Assistance

Since an adequately trained staff is essential to the conduct of a State regulatory program, the AEC assists in the development of such competence by sponsoring training courses. These courses are open to local as well as State officials, since some State regulatory programs involve local governments.

The Oak Ridge Institute of Nuclear Studies (ORINS), in cooperation with the Oak Ridge National Laboratory, conducts a 10-week course in health physics each fall. On-the-job type experience is offered to complement academic and laboratory sessions. The 1965 course was attended by 18 participants from 11 States and the Commonwealth of Puerto Rico.

Cooperative Course. As a part of its cooperative arrangements with States assuming nuclear regulatory authority, the AEC arranges special courses of instruction for the State employees who will be responsible for the program. Photo shows a group of State employees who were enrolled in an AEC-sponsored health physics course conducted by the University of Tennessee Extension Service.

Special university courses in health physics have been established to meet a need in States where it has not been practical to send individuals to Oak Ridge for 10 weeks. These courses, conducted by local universities for an academic year or longer, usually one afternoon or evening a week, are similar to the ORINS 10-week course but are generally limited to lecture and laboratory sessions. The one course in 1964–65 at the Medical College of Virginia enrolled 14 students. Three courses are being conducted in 1965–66, at Rutgers University, the University of Tennessee, and the University of Nebraska, with an average enrollment of 15 students.

Two three-week orientation courses in the regulatory policies and practices of the Commission were conducted in 1965 at AEC Headquarters. A total of 39 State and local personnel from 25 States participated. The courses were specifically designed for those personnel who may be engaged in a radiation control program when their States assume regulatory responsibilities from the Commission. Two similar courses are planned for 1966.

THE AEC MATERIALS LICENSING PROGRAM

During the 12-month period ending November 30, 1965, more than 8,800 applications for material licenses were filed with the Commission's regulatory staff. As of that date, 9,460 licenses were in effect, consisting of 8,435 byproduct material licenses, 441 source material licenses, and 584 special nuclear material licenses.

A notable increase occurred in the number of specific licenses issued for the manufacture and distribution of generally-licensed devices containing byproduct material. In effect on November 30, 1965, were 109 such licenses, compared with 47 in effect 12 months earlier.

Much of the AEC's regulatory effort in the materials field during 1965 was centered on simplifying licensing procedures for appropriate uses of radioactive materials. For example, an amendment in June to regulation 10 CFR Part 30, "Licensing of Byproduct Material," facilitates the use of a number of radioisotopes with well-established applications in medical diagnosis. Under this amendment, a general license was issued for specified diagnostic uses of certain byproduct materials in capsules, disposable syringes, or other forms of prepackaged individual doses. The result is that a physician now is required only to file a simple registration form instead of applying for a specific license authorizing the specified use.

Broad Licenses

A growing number of institutions, particularly universities and hospital, are availing themselves of the opportunity provided by AEC rules to consolidate under a single, broad AEC license their numerous radioisotope programs conducted previously under multiple licenses. Such broad licenses are advantageous in that the institution may more effectively exercise centralized control over its radiation protection program and the procurement and use of radioisotopes. A broad license requires that the institution establish an isotopes committee to review and act on all requests for new radioisotope uses. The flexibility afforded by broad licenses reduces significantly the need for submitting requests to the AEC for license amendments.

During the 12-month period ending November 30, 1965, 17 organizations obtained broad licenses. Their various radioisotope programs were previously conducted under a total of 151 separate licenses.

Irradiator Applications

Applications were filed in 1965 requesting licenses for the operation of two large facilities to irradiate products by intense gamma radiation (see Chapter 13—Isotopes and Radiation Development).

American Novawood Corp., Lynchburg, Va., requested a license for a pool-type irradiator containing 400,000 curies of cobalt 60. The facility is intended to serve as a pilot plant operation for irradiating wood, wood products, and related materials. The radiation is used as part of a hardening process.

The U.S. Department of the Interior, Bureau of Commercial Fisheries (Gloucester, Mass.) applied for a license to use a 30,000-curie cobalt 60 irradiator aboard a fishing trawler to be operated out of Gloucester. The irradiator will be used in experiments on preservation of freshly caught fish as an extension of the Bureau's marine food preservation program being carried out in its 275,000-curie cobalt 60 irradiator at the Marine Products Development Irradiator Facility.

Private Commercial Activities in the Hanford Area

Several firms applied for licenses during 1965 as a result of increased commercial interests in nuclear-related industrial development of the Richland-Pasco-Kennewick area of Washington. Licensed were California Nuclear, Inc., for the receipt, packaging and burial of radioactive waste; and United States Testing Laboratories, Inc., for the performance of health physics services in connection with the use of radioactive materials. Under review at year's end was an application from Battelle Memorial Institute for the conduct of varied research and development programs.

Materials Export Licenses

During the year, the AEC issued more than 100 each of source material and byproduct material export licenses. Nearly one-third of the byproduct material export licensing actions were in the form of broad licenses, each providing for multiple shipments of radioisotope products. As foreign markets become more clearly defined, an increase is anticipated in applications for broad licenses to cover multiple export shipments in single licensing actions.

Licensing Guides

Nine licensing guides are currently available [2] as aids in the preparation of applications for materials licenses:

(*1*) Plutonium-Beryllium Neutron Sources for Well Logging;
(*2*) Plutonium-Beryllium Neutron Sources for Uses Other than Well Logging;
(*3*) Fabricated Plutonium Alpha Sources;
(*4*) Industrial Radiography;
(*5*) Teletherapy Programs;
(*6*) Fabrication of Thorium-Magnesium Alloys Containing Not More than 4 Percent Thorium;
(*7*) Embankment Retention Systems;
(*8*) Medical Uses of Byproduct Materials; and
(*9*) Processing 200 Grams or Less of Plutonium or Uranium 233.

Included among those in preparation are guides intended to assist licensees with extensive programs in applying for broad licenses which authorize a large degree of flexibility in adjusting operations to meet changing or new research and development or production objectives.

TYPES OF MATERIAL LICENSEES

The 9,460 AEC material licenses in effect as of November 30, 1965, were held by about 7,000 licensees located in every State, the District of Columbia, and Puerto Rico.

About 37 percent of all AEC material licenses are held by commercial and industrial firms, and approximately one-third have been issued to medical institutions and physicians. About 20 percent have been issued to local, State, and Federal agencies and civil defense organizations and workers, and 10 percent to educational institutions.

[2] Single copies available without charge on request to Director, Division of Materials Licensing, U.S. Atomic Energy Commission, Washington, D.C., 20545.

Byproduct Material Licensees

The largest number of AEC material licenses are for byproduct material (generally reactor-produced isotopes) with 6,142 in effect on November 30, 1965. The term of these licenses may run from one to five years, depending on the nature of the licensed activity. The scope of activities covered ranges from microcurie quantities, such as those used in medical diagnosis or research, to megacurie quantities processed commercially for use in isotopic-powered SNAP generators.

Licensees include more than 2,000 hospitals and physicians who use radioisotopes in medical research, diagnosis and therapy; about 2,000 commercial and industrial firms, of which 400 are engaged in radiography; about 1,000 civil defense workers who use small quantities for radiological defense training; about 350 local, State, and Federal agencies, who employ radioisotopes in various research projects, health programs, and law enforcement investigative procedures; and about 350 educational institutions who use the materials for instructional purposes.

Source Material Licensees

Licenses for source material—uranium (natural or depleted) and thorium—are usually issued for three-year periods. About two-thirds of the 441 licensees are commercial and industrial firms, most of which use the materials for purposes unrelated to their radioactive or nuclear energy characteristics. For instance, a number of licensees fabricate thorium-magnesium alloys for use in aircraft engine components, aircraft fuselages, and missile skins. (Thorium improves the heat resistance of the alloy.) Thorium also is used in the manufacture of incandescent gas mantles, lenses for optical systems, and welding rods. Uranium is used by licensees in reactor fuel research; in subcritical assemblies; in photographic negatives and prints; as counterweights in aircraft, rockets, and projectiles; as a coloring agent in ceramics and glassware; and as radiation shielding in various devices.

Educational institutions comprise the largest part of the remaining source material licensees.

Special Nuclear Material Licensees

There are 584 special nuclear material licenses, not including over 100 reactor licenses incorporating special nuclear material (plutonium, uranium 233, or uranium enriched in the isotopes 233 or 235) authorizations for fuel possession and use. More than half the special nuclear material licenses are issued to educational institutions for instructional and research programs. About 175 are issued to commercial and industrial organizations, principally for nuclear energy applications such as reactor fuel research, development, and fabrication. A number of firms use plutonium-beryllium neutron sources for oil well logging. The remainder of special nuclear material licenses, which have normal terms of three years, are issued to Federal agencies, mostly military and NASA installations.

TRANSPORTATION OF AEC-LICENSED MATERIALS

The AEC published for public comment on December 21, 1965, a proposed revision of 10 CFR 71 containing packaging standards and some shipping requirements for special nuclear (fissile) material, irradiated nuclear fuels, and "large quantities" of licensed material. These are compatible with the International Atomic Energy Agency's revised regulations published in 1965 which are being applied in most of the countries using nuclear energy. Also, with AEC cooperation, the Interstate Commerce Commission (ICC) published for public comment on December 1, 1965, a proposed revision of the ICC regulations for controlling fissile radioactive material, making them consistent with the AEC's revised 10 CFR 71.

Existing and new types of shipping containers have been tested against the proposed standards. Studies continue of the transportation environment, methods of testing containers, and the response of containers to the tests.

COMPLIANCE ACTIVITIES

Compliance personnel performed 2,119 inspections of operations being conducted under specific material licenses during the 12-month period ending November 30, 1965. Selection of operations for inspection is based on consideraton of the degree of potential hazard associated with the amount and kind of licensed material, the type of licensed operation, and the licensee's record of compliance with regulatory requirements.

Radiation Incidents

In response to the AEC requirements in 10 CFR Part 20 for the reporting of all significant radiation incidents, 7 such incidents were reported to the AEC from among the approximately 7,000 materials licensees during the 12-month period that ended November 30, 1965. All of these incidents were investigated.

Five of these incidents involved radiation exposures in excess of limits prescribed in the Commission's regulations to a total of eight persons. Four of the incidents occurred during radiography operations, and the fifth was in a plant engaged in the manufacture of sealed sources. The highest exposure resulting from the radiography incidents was a whole body dose of 12 *rems*. In the other incident, exposures on the order of 2,000 *rems* were experienced to the right hands of two persons while removing curie quantities of iridium 192 from an irradiation capsule.

The two other incidents reported by material licensees did not involve excessive radiation exposures. One, required by regulations to be reported because it involved property damage of more that $1,000, was a fire in an industrial plant which damaged two 100-millicurie strontium 90 gages. The other incident, at an industrial plant, was the accidental release of about 150 curies of krypton 85 gas through a 120-foot exhaust stack. There was no exposure to personnel in excess of AEC prescribed limits.

Lost Radioactive Materials

Losses of radioactive materials also are required to be reported to the AEC. Licensees reported 38 such losses, some of which were temporary, during the 12-month period ending November 30, 1965.

There were five instances in which a radioactive source became detached from logging gear during oil well logging operations. These sources, none of which could be recovered, were cemented in place so that they would not constitute a radiation hazard during subsequent drilling operations.

In 7 of the other 33 cases of reported loss, the missing material was subsequently recovered. In four instances where the material was not recovered, it appeared that the material had been disposed of inadvertently through normal refuse channels, and in a manner that would not result in any significant hazard. In the 22 remaining cases where ultimate disposition could not be ascertained, no significant radiation hazard was apparent, because of the circumstances of the loss or the amount of material involved.

Part Three

Adjudicatory Activities

795-958-- 66----23

ADJUDICATORY ACTIVITIES

Within the Atomic Energy Commission, there are various adjudicatory tribunals: the Commission itself, Atomic Safety and Licensing Boards which are drawn from a panel (see Appendix 2); the hearing examiners, the Board of Contract Appeals, and the Patent Compensation Board. The decisions of Atomic Safety and Licensing Boards, hearing examiners, and the Patent Compensation Board are subject to review by the five-man Commission, while the decisions of the Board of Contract Appeals are final without such review.

COMMISSION ADJUDICATION

The Commission reviews adjudicatory action within the agency in three distinct categories of cases: (*a*) decisions involving the licensing of nuclear power and test reactors and other licensed facilities, as well as contested material licensing cases and other regulatory matters; (*b*) decisions of hearing examiners in contract appeals, and (*c*) decisions of the Patent Compensation Board.

Proceedings for the licensing of nuclear power and test reactors and other licensed facilities are ordinarily heard by atomic safety and licensing boards whose decisions are subject to formal review by the Commission either on a petition for review filed by a party or on the Commission's own motion.

1965 MATTERS CONSIDERED

During the year, the Commission considered 17 adjudicatory matters, 10 regarding facility licensing, 1 concerning materials licensing, 5 contract appeals, and 1 patent compensation case. The Commission did not review any decisions of hearing examiners in cases involving discrimination in Federally assisted programs, there being no decisions in that category.

Facility Licensing

In *Matter of Jersey Central Power and Light Co., Oyster Creek Nuclear Power Plant No. 1*, the Commission granted the petition of the regulatory staff to review a decision of an atomic safety and licensing board. The board had issued a provisional construction permit authorizing the construction of a power reactor in Lacey Township, N.J., but had refused to make a definitive finding as to the power level of the proposed reactor and had required that the applicant submit certain additional technical evidence and other evidence as to the respective responsibilities of the reactor designer and the applicant for safety of the design. The regulatory staff's petition for review asserted that the limitations and additional requirements imposed by the board were beyond its authority, or, alternatively, that they should not have been imposed on the basis of the Commission's regulations and precedents in facility licensing cases. The Commission's order granting review was limited to the question whether the board's imposition of those limitations and additional requirements constituted an abuse of discretion. The Commission denied a motion of the applicant to suspend, pending the determination of the staff's petition, the requirements that additional information be filed. On full consideration of the petition, the Commission held that the requirements imposed by the board did not constitute an abuse of its discretion, and affirmed the board's decision. It observed that there might soon be enough experience to provide more detailed guidance than existing regulations afford in specifying the information required of an applicant at the construction permit stage.

Matter of Department of Water and Power of the City of Los Angeles was a proceeding for the issuance of a construction permit for a power reactor at Corral Canyon, Malibu, Calif. Lester T. (Bob) Hope applied for leave to intervene as a party. The Commission referred the application to an Atomic Safety and Licensing Board to be appointed for the proceeding, as it had done in the case of earlier similar applications of Marblehead Land Co. and Malibu Citizens for Conservation, Inc. The board allowed his intervention.

Matter of National Bureau of Standards was a proceeding in which a construction permit for a test reactor to be built near Gaithersburg, Md., had previously been granted. The National Bureau of Standards, the applicant, filed a petition for review of an initial decision by the Chief Hearing Examiner modifying the construction permit to require the construction of a stack gas continuous monitor in order to ascertain promptly the rate of discharge of radioactive iodine isotopes which might be released in the event of a major accident. The Commission granted the Bureau's petition to review this modification of the construction permit so ordered. It suspended the requirement of the addition of a stack gas monitor, pending the determination of an application for an operating license, and ordered that the application for an operating license be referred to an Atomic Safety and Licensing Board consisting of the Chief Hearing Examiner and two technically qualified members to be designated by further order of the Commission.

Matter of First Atomic Ship Transport, Inc., was a proceeding to issue a license to a private corporation for the operation of the nuclear ship *Savannah.* The applicant's motion requesting that the board be authorized to provide, in its discretion, that any initial decision and order become effective immediately upon issuance, subject to review by the Commission, was certified to the Commission by the board. Finding that the N.S. *Savannah* had had considerable operating experience and that the public interest would be served by granting the motion, the Commission issued an order to that effect. The initial decision of the board, issued on June 16, 1965, granted the operating license sought by the applicant and directed that the decision be effective immediately.

In the Matter of Consolidated Edison Co. of New York, Inc. (Indian Point Proposed License Amendment No. 2), the licensee had filed an application for authority to install a second core in the Indian Point power reactor at Buchanan, N.Y., and to increase the steady state operating power level. The Commission published a notice of the proposed issuance of an amendment which would authorize the action. After the expiration of the time prescribed by the regulations, the Hempstead Town Lands Resources Council filed a petition for leave to intervene. The applicant and the staff took the position that the petition related only to nonradiological aspects of the plant's operation, and that the petition should be denied. The Commission denied the petition by an order dated October 27, 1965. The council later filed an "expanded petition to intervene," which was dismissed at the Commission's own motion by an order of November 24, 1965.

Informal reviews. In accordance with its usual practice of conducting informal reviews of decisions in reactor licensing proceedings even when a petition for review has not been filed, the Commission conducted such reviews without making any order during the year in *Matter of Southern California Edison Co.*, in which a construction permit was issued for a power reactor at Camp Pendleton in California; *Matter of Niagara Mohawk Corp.*, in which a provisional construction permit was granted for a reactor at Nine Mile Point, near Oswego, N.Y.; *Matter of First Atomic Ship Transport, Inc.*, granting authority to a private operator to operate the reactor aboard the NS *Savannah; Matter of General Electric Co. and Southwest Atomic Energy Associates*, in which a construction permit was issued for a test reactor near Fayetteville, Ark. and *Matter of Power Reactor Development Co.*, granting a full-power operating license for the Fermi reactor at Monroe, Mich.

Materials Licensing

Hamlin Testing Laboratories, Inc., v. *United States Atomic Energy Commission* was a proceeding brought in the United States Court of Appeals for the Sixth Circuit to review a decision of the Commission reversing a hearing examiner's decision and denying renewal of a byproduct material license which authorized the use of sealed sources for industrial radiography. The Commission had held that a considerable number of violations of the regulations and the license which had been committed by the licensee warranted denial of renewal of the license, and that there had been no violation of due process of law on the part of the staff in the proceedings leading to the denial of renewal. It also held that denial of renewal is not withdrawal of the license, and that prior written notice of the violations was not required by the Administrative Procedure Act or the Commission's regulations. Finally, the Commission held that even if such written notice were ordinarily required, it was not in this case because the violations were willful. The case had been argued before the Court of Appeals as the year ended, and the Court's decision was pending.

In *Matter of California Nuclear, Inc.*, the Commission had issued a notice that it was considering the issuance of an amendment of an existing byproduct, source and special nuclear material license which authorized California Nuclear, Inc., Pleasanton, Calif., to possess, process, repackage and store such material at a facility in Benton County, Wash. The amendment sought would authorize the burial of solid radioactive waste material at the site. Nuclear Engineering Co., Inc., of Walnut Creek, Calif., requested leave to intervene. The Commission denied the application on the grounds that it specified no interest in the proceeding such as is required by the Commission's regulations as a basis for intervention, and that it had not been served on the applicant or the Commission's regulatory staff.

Contract Appeals

In August of 1964, the Commission created a Board of Contract Appeals to determine appeals from decisions of contracting officers. A few contract appeals in which proceedings had been commenced before hearing examiners prior to that date are still pending and occasionally come before the Commission for review. Decisions of the Board of Contract Appeals (in cases initiated after the board's formation) are final and are not subject to review by the Commission.

During the course of the year, the Commission issued final decisions on the merits in two cases and denied a contracting officer's petition for review in a third case. It also denied a petition for reconsideration of an earlier order denying a contracting officer's petition for review in a fourth case.

In *Matter of Appeal of Fenco-Polytron by and through Walsh Construction Co.*, a decision of a hearing examiner had granted a substantial recovery against the Government as an equitable adjustment in favor of a subcontractor and a sub-subcontractor under a fixed price contract. The Commission reversed the decision and dismissed the claim on the grounds that the appellants had no standing to prosecute it and that the merits of the claim did not warrant an equitable adjustment. In order to designate accurately the identity of the claimants, the Commission ordered that the title of the proceeding be amended to read *Matter of Appeal of Owens-Corning Fiberglas Corp., and Polytron Corp., by and through Walsh Construction Co.*

In a later case, *Matter of Appeal of Rutherford Construction Co.*, the Commission granted the prime contractor's petition for review of an initial decision of a hearing examiner which, on the authority of the Fenco-Polytron case, dismissed the claim. Exceptions having been filed by the prime contractor, the Commission had the case under advisement as the year ended.

Matter of Appeal of The Beryllium Corp. was a proceeding in which the Beryllium Corp. appealed from a decision of a contracting officer which rejected a tender of beryllium metal on the ground that deliveries under the contract had already been completed. A hearing examiner held that the tender was properly made to the extent of a specified quantity. The Commission granted the contracting officer's petition for review as to certain specific questions, and reversed the hearing examiner's decision with respect to those issues. It dismissed the claim on the ground that deliveries had been completed under the contract without including the tendered material.

In *Matter of Wm. E. Goetz & Sons*, the Commission denied a contracting officer's petition for review of a hearing examiner's decision directing payment to a contractor of an amount which had been withheld as expenses of the Government incurred by reason of the alleged late completion of work by the contractor. The Commission had previously denied a petition of the contracting officer to review the decision, without prejudice to a motion for reconsideration to be submitted to the Chief Hearing Examiner, and the new petition had been filed to review his decision denying reconsideration.

In *Matter of Timmons, Butt and Head, Inc.*, the Commission denied a petition for reconsideration of an earlier order, which had denied a contracting officer's petition for review of a hearing examiner's decision granting an equitable adjustment to a contractor.

Patent Compensation

In *Application of Richard M. Stephenson*, the Commission denied review of a decision of the Patent Compensation Board dismissing a claim for an award under the Atomic Energy Act of 1954, as amended, for the alleged invention of a type of flux trap reactor.

OFFICE OF HEARING EXAMINERS

The Office of Hearing Examiners is responsible to the Commission for the conduct of hearings and the issuance of orders and decisions in licensing cases and in certain patent licensing matters. A newly assigned area for hearing examiner adjudication involves possible controversies concerning availability of Federal funds under Title VI (see "Civil Rights Act" item, Chapter 1, Part One) of the Civil Rights Act of 1964. Two AEC hearing examiners attended a Civil Service Commission seminar to prepare a pool of 25 hearing examiners for Governmentwide duties in such civil rights matters. No patent licensing or civil rights proceedings arose during 1965.

A principal function of the hearing examiners during 1965 was to serve as the chairman of the Atomic Safety and Licensing Boards (ASLB) in reactor licensing hearings. Also before them were 10 contract disputes appeals which were filed before the establishment of the Board of Contract Appeals (BCA). One of the three hearing examiners serves as a member of the BCA panel.

During the year, ASLB proceedings involved construction permits for four large power reactors, in New Jersey, New York, southern California, and Illinois. Also considered in ASLB hearings were an operating license for NS *Savannah* and a provisional construction permit for a plutonium-fueled sodium-cooled fast-oxide experimental reactor in Arkansas. A reactor power increase proposal was considered by an ASLB for the Fermi breeder reactor facility in Michigan; the National Bureau of Standards reactor proposal has been assigned by the Commission to an ASLB for consideration of its application for an operating license. Construction permits have been provisionally granted for each of the above facilities except for the California (Malibu) reactor concerning which licensing proceedings were pending at year's end.

BOARD OF CONTRACT APPEALS

The rules of procedure in contract appeals of the Board of Contract Appeals (BCA) became operative during November 1964. Since that time, the board has received 21 appeals. This number exceeds the average number of appeals (11) received annually over the past 5 years and also exceeds the highest number that was received in any 1 year (19) during the same period.

The board, under this new system for resolving, with finality for the Commission, appeals from decisions by contracting officers under "disputes" clauses in AEC contracts and certain AEC subcontracts, has been successful in bringing the parties together informally for the purpose of considering the disposition of appeals by agreement. A great measure of this success can be attributed to the proper utilization by the BCA of the conference (10 CFR 3.12) which was devised, in part, for just such a purpose. Of the 15 appeals which have been finally disposed of by the board, 8 were settled or withdrawn during or subsequent to the conference.

One of the innovations of this new appeals system was the addition of technical members to the board. This innovation has proved successful. Technical members have been used in five appeals. Great care has been taken by the board to insure that the judgment of the technical members is not substituted for that of the expert witness. Rather, the technical members are able to provide astute and precise questioning which aids the BCA in the establishment of a complete and intelligent appeal record.

The accelerated procedure (10 CFR 3.13) provides for the treatment of appeals without regard to their normal position on the docket and permits the expeditious handling of appeals not exceeding a certain dollar limit ($10,000) or for other good causes. This procedure has proved invaluable to the board and to appellants as a tool in avoiding long pendency of appeals before the board. This procedure has been employed in seven appeals. Of the 10 small business appellants, 6 have requested and been granted the application of the accelerated procedure. The average pendency of appeals subject to this procedure was 65 days.

Twelve appeals received by the Board of Contract Appeals have involved subcontractors. This number is due in part to the AEC's procedure for permitting direct appeals of subcontractors if the subcontract contains a "dispute" provision requiring the AEC contracting officer's decision and providing for an appeal therefrom to the Commission, and the AEC has approved the insertion of the disputes provision in the subcontract. Of the subcontractor appeals, 10 have been direct appeals and 2 have been appeals by prime contractors on behalf of subcontractors. The status of the board in such appeals is in the nature of arbitration. Although the contracting officer is a party to these proceedings, the claim of the subcontractor does not necessarily become a claim against the AEC.

Only one appeal docketed with the board involved classified information. All proceedings were conducted in compliance with the security regulations of the Commission. No difficult problems were encountered.

The board has been conscious of the costs associated with an appeal proceeding and has made an effort to reduce these costs for both the Government and the parties wherever possible. For example, the number of copies of documents required by the BCA has been reduced as has the number of transcripts ordered by the board.

The average pendency of an appeal before the Board of Contract Appeals from the time of docketing to its final disposition amounted to 74 days. The shortest period amounted to nine days.

At the year's end, there were six appeals pending before the board. All of these have been docketed since July 15, 1965, and have been fully scheduled for conference or hearings with anticipated disposition in early 1966.

APPENDIX 1

ORGANIZATION AND PRINCIPAL STAFF OF U.S. ATOMIC ENERGY COMMISSION

COMMISSIONERS

Atomic Energy Commission	GLENN T. SEABORG, *Chairman*
	ARNOLD R. FRITSCH, *Special Assistant*
	JAMES T. RAMEY
	JAMES R. YORE, *Special Assistant*
	JOHN G. PALFREY
	HARRIET S. SHAPIRO, *Special Assistant*
	GERALD F. TAPE
	WILLIAM C. BARTELS, *Technical Assistant*
	(One Commissioner position vacant)
Secretary to the Commission	W. B. MCCOOL
Controller	JOHN P. ABBADESSA
General Counsel	JOSEPH F. HENNESSEY
Chairman, AEC Board of Contract Appeals	PAUL H. GANTT
Chief Hearing Examiner	SAMUEL W. JENSCH

OPERATING AND PROMOTIONAL FUNCTIONS

General Manager	ROBERT E. HOLLINGSWORTH
Executive Assistant to General Manager	JOHN V. VINCIGUERRA
Assistant to the General Manager	HARRY S. TRAYNOR
Deputy General Manager	EDWARD J. BLOCH
Assistant General Manager	DWIGHT A. INK
Director, Office of Congressional Relations	JOHN J. BURKE
Assistant General Manager for Operations	JOHN A. ERLEWINE
Director, Office of Economic Impact and Conversion	CLARENCE C. OHLKE
Director, Division of Construction	JOHN A. DERRY
Director, Division of Contracts	JOSEPH L. SMITH
Director, Division of Labor Relations	H. T. HERRICK *
Director, Division of Operational Safety	PETER A. MORRIS
Assistant General Manager for Research and Development	SPOFFORD G. ENGLISH
Director, Division of Biology and Medicine	CHARLES L. DUNHAM, M.D.
Director, Division of Isotopes Development	E. E. FOWLER

*Effective Jan. 3, 1966.

Assistant General Manager for Research and Development—Continued	
Director, Division of Nuclear Education and Training	RUSSELL S. POOR
Director, Division of Peaceful Nuclear Explosives	JOHN S. KELLY
Director, Division of Research	PAUL W. MCDANIEL
Assistant General Manager for Plans and Production	GEORGE F. QUINN
Director, Division of Operations Analysis and Forecasting	PAUL C. FINE
Director, Division of Plans and Reports	WILLIAM H. SLATON
Director, Division of Production	F. P. BARANOWSKI
Director, Division of Raw Materials	RAFFORD L. FAULKNER
Assistant General Manager for Reactors	GEORGE M. KAVANAGH*
Director, Division of Naval Reactors	VADM H. G. RICKOVER
Director, Division of Reactor Development and Technology	MILTON SHAW
Director, Division of Space Nuclear Systems	HAROLD B. FINGER
Assistant General Manager for International Activities	JOHN A. HALL
Director, Division of International Affairs	MYRON B. KRATZER
Assistant General Manager for Administration	HOWARD C. BROWN, JR.
Director, Division of Classification	C. L. MARSHALL
Director, Division of Headquarters Services	EDWARD H. GLADE
Director, Division of Intelligence	C. H. REICHARDT
Director, Division of Nuclear Materials Management	DOUGLAS E. GEORGE
Director, Division of Personnel	ARTHUR L. TACKMAN
Director, Division of Public Information	DUNCAN C. CLARK
Director, Division of Security	JOHN A. WATERS, JR.
Director, Division of Technical Information	EDWARD J. BRUNENKANT, JR.
Director, Division of Military Application	BRIG. GEN. DELMAR L. CROWSON, USAF
Controller, Office of the Controller	JOHN P. ABBADESSA
General Counsel, Office of the General Counsel	JOSEPH F. HENNESSEY
Director, Division of Industrial Participation	ERNEST B. TREMMEL
Director, Division of Inspection	CURTIS A. NELSON

Managers of Field Offices

Albuquerque (N. Mex.) Operations Office	LAWRENCE P. GISE
Amarillo (Tex.) Area	H. JACK BLACKWELL
Burlington (Iowa) Area	E. W. GILES
Dayton (Miamisburg, Ohio) Area	WILLIS B. CREAMER
Kansas City (Mo.) Area	HENRY A. NOWAK
Los Alamos (N. Mex.) Area	CHARLES C. CAMPBELL
Pinellas (Fla.) Area	WALTER C. YOUNGS, JR.
Rocky Flats (Colo.) Area	SETH R. WOODRUFF, JR.
Sandia (N. Mex.) Area	LADDIE W. OTOSKI
South Albuquerque (N. Mex.) Area	WALTER W. STAGG

Brookhaven (Upton, N.Y.) Office	E. L. Van Horn
Chicago (Ill.) Operations Office	Kenneth A. Dunbar
Canoga Park (Calif.) Area	Joel V. Levy
Grand Junction (Colo.) Office	Allan E. Jones
Idaho (Idaho Falls) Operations Office	William L. Ginkel
Nevada (Las Vegas) Operations Office	James E. Reeves
Honolulu (Hawaii) Area	William A. Bonnet
New York (N.Y.) Operations Office	Wesley M. Johnson
Health and Safety Laboratory (New York City)	John Harley, M.D.
Oak Ridge (Tenn.) Operations Office	S. R. Sapirie
Cincinnati (Ohio) Area	Clarence L. Karl
New Brunswick (N.J.) Area	C. J. Rodden
Paducah (Ky.) Area	Bernard N. Stiller
Portsmouth (Ohio) Area	Roy V. Anderson
Puerto Rico (San Juan) Area	Floyd P. Trent
St. Louis (Mo.) Area	Fred H. Belcher
Pittsburgh (Pa.) Naval Reactors Office	Lawton D. Geiger
Richland (Wash.) Operations Office	Donald G. Williams
San Francisco (Calif.) Operations Office	Ellison C. Shute
Palo Alto (Calif.) Area	Lawrence G. Mohr
Savannah River (Aiken, S.C.) Operations Office	Nathaniel Stetson
Schenectady (N.Y.) Naval Reactors Office	Stanley W. Nitzman

AEC Representatives in Foreign Offices

Brussels, Belgium	Charles F. Schank, *Senior Representative*
Buenos Aires, Argentina	Lester R. Rogers
Chalk River, Ontario, Canada	Miller N. Hudson, Jr.
London, England	Samuel G. Nordlinger
Paris, France	Martin B. Biles
Tokyo, Japan	(Vacant)

LICENSING AND REGULATORY FUNCTIONS

Director of Regulation	Harold L. Price
Deputy Director	Clifford K. Beck
Assistant Director	(Vacant)
Assistant Director for Nuclear Safety	M. M. Mann
Assistant Director for Administration	C. L. Henderson
Director, Division of Compliance	Lawrence D. Low
Director, Division of Reactor Licensing	Richard L. Doan
Director, Division of Safety Standards	Forrest Western
Director, Division of Materials Licensing	John A. McBride
Director, Division of State and Licensee Relations	Eber R. Price

Directors of Compliance Field Organizations

Region I (New York)	Robert W. Kirkman
Region II (Atlanta)	John G. Davis
Region III (Chicago)	Roy C. Hageman
Region IV (Denver)	Donald I. Walker
Region V (San Francisco)	Richard W. Smith

APPENDIX 2

MEMBERSHIP OF COMMITTEES DURING 1965

STATUTORY COMMITTEES AND BOARDS

Joint Committee on Atomic Energy—89th Congress (First Session)

The Committee was established by the Atomic Energy Act of 1946, and continued under the Atomic Energy Act of 1954, to make "continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy." The Committee is kept fully and currently informed with respect to the Commission's activities. Legislation relating primarily to the Commission or to atomic energy matters is referred to the Committee. The Committee's membership is composed of nine Members of the Senate and nine Members of the House of Representatives. During 1965, the Committee was composed of:

Representative CHET HOLIFIELD (California), *Chairman.*
Senator JOHN O. PASTORE (Rhode Island), *Vice Chairman.*
Senator RICHARD B. RUSSELL (Georgia).
Senator CLINTON P. ANDERSON (New Mexico).
Senator ALBERT GORE (Tennessee).
Senator HENRY M. JACKSON (Washington).
Senator BOURKE B. HICKENLOOPER (Iowa).
Senator GEORGE D. AIKEN (Vermont).
Senator WALLACE F. BENNETT (Utah).
Senator CARL T. CURTIS (Nebraska).
Representative MELVIN PRICE (Illinois).
Representative WAYNE N. ASPINALL (Colorado).
Representative ALBERT THOMAS (Texas).
Representative THOMAS G. MORRIS (New Mexico).
Representative CRAIG HOSMER (California).
Representative WILLIAM H. BATES (Massachusetts).
Representative JOHN B. ANDERSON (Illinois).
Representative WILLIAM M. MCCULLOCH (Ohio).
JOHN T. CONWAY, *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. W. J. HOWARD, *Chairman.*

Maj. Gen. ARTHUR C. AGAN, Jr., United States Air Force.

Maj. Gen. AUSTIN W. BETTS, United States Army.

Maj. Gen. OTTO J. GLASSER, United States Air Force.

Brig. Gen. DONALD G. GROTHAUS, United States Army.

RAdm. FRANCIS D. FOLEY, United States Navy.

Capt. HARRY B. HAHN, United States Navy.

General Advisory Committee

This Committee was established by the Atomic Energy Act of 1946, and is continued by 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. L. R. HAFSTAD, *Chairman;* Vice President, Research Laboratories, General Motors Corp., Warren, Mich.

Dr. MANSON BENEDICT, Professor of Nuclear Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. JOHN C. BUGHER, Director, Puerto Rico Nuclear Center, San Juan, P.R.

Dr. DAROL FROMAN, Retired, Espanola, N. Mex.

Dr. STEPHEN LAWROSKI, Associate Director, Argonne National Laboratory, Argonne, Ill.

Dr. NORMAN F. RAMSEY, Professor of Physics, Harvard University, Cambridge, Mass.

HOWARD G. VESPER, Vice President, Standard Oil Co. of California, San Francisco, Calif.

WILLIAM WEBSTER, Chairman, New England Electric System, Boston, Mass.

Dr. JOHN H. WILLIAMS, Professor of Physics, University of Minnesota, Minneapolis, Minn.

DUANE C. SEWELL, *Scientific Officer;* Lawrence Radiation Laboratory, University of California, Livermore, Calif.

ANTHONY A. TOMEI, *Secretary;* U.S. Atomic Energy Commission, Washington, D.C.

The Committee held four meetings in 1965, on January 11–13, March 29–31, July 12–14, and November 1–3.

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.

ROBERT C. WATSON, Chairman; firm of Watson, Cole, Grindle & Watson, Washington, D.C.

DOUGLAS MCLEOD COOMBS, Simmonds Precision Products, Inc., Tarrytown, N.Y.

MALCOLM W. FRASER, law firm of Fraser and Fraser, Toledo, Ohio.

HERMAN I. HERSH, firm of McDougall, Hersh & Scott, Chicago, Ill.

LAWRENCE C. KINGSLAND, firm of Kingsland, Rogers, Ezell, Eilers & Robbins, St. Louis, Mo.

The Board met once during 1965, on April 30.

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 regrad 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 four 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.

WILLIAM D. MANLY, *Chairman;* Director of Technology, Stellite Division, Union Carbide Corp., Kokomo, Ind.

Dr. DAVID OKRENT, *Vice Chairman;* Physicist, Argonne National Laboratory, Argonne, Ill.

HAROLD ETHERINGTON; Consultant, Jupiter, Fla.

Dr. FRANKLIN A. GIFFORD, Jr., Director, Atmospheric Turbulence & Diffusion Laboratory, U.S. Weather Bureau, Oak Ridge, Tenn.

Dr. STEPHEN H. HANAUER, Professor of Nuclear Engineering, University of Tennessee, Knoxville, Tenn.

Dr. HERBERT J. C. KOUTS, Reactor Physics Division, Brookhaven National Laboratory, Upton, Long Island, N.Y.

Dr. JACK E. MCKEE, Professor of Environmental Health Engineering, California Institute of Technology, Pasadena, Calif.

Dr. HENRY W. NEWSON, Professor of Physics, Duke University, Durham, N.C.

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NUNZIO J. PALLADINO, Professor and Head, Department of Nuclear Engineering, The Pennsylvania State University, University Park, Pa.

Dr. LESLIE SILVERMAN, Professor of Engineering in Environmental Hygiene and Head of Department of Industrial Hygiene, Harvard University, Boston, Mass.

Dr. THEOS J. THOMPSON, Professor of Nuclear Engineering and Director, MIT Nuclear Reactor, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. CARROLL W. ZABEL, Associate Dean of Arts and Sciences, University of Houston, Houston, Tex.

R. F. FRALEY, *Executive Secretary;* U.S. Atomic Energy Commission, Washington, D.C.

Dr. DICK DUFFEY, *Technical Secretary;* University of Maryland, College Park, Md.

During 1965, the Committee met 11 times, on January 14–16, February 6, March 11–13 and 26–27, May 13–15, June 18, July 8–11, August 5–7, September 9–11, October 7–9, November 10–12 and 22.

Atomic Safety and Licensing Boards

Public Law 87–615 of the 87th Congress, which became law on August 29, 1962, adopted certain amendments to the Atomic Energy Act of 1954 authorizing, in addition to other matters, the Commission to establish one or more atomic safety and licensing boards. Each board would be composed of three members, two of whom are to be technically qualified and one of whom is to be qualified in the conduct of administrative proceedings. The boards conduct such hearings as the Commission may direct and make such intermediate or final decisions as it may authorize in proceedings with respect to granting, suspending, revoking, or amending licenses or authorizations. The Commission has appointed the following panel to serve on atomic safety and licensing boards as assigned.

J. D. BOND, Hearing Examiner, U.S. Atomic Energy Commission, Washington, D.C.

Dr. A. DIXON CALLIHAN, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. EUGENE GREULING, Professor of Physics, Duke University, Durham, N.C.

PATRICK W. HOWE, Head, Health Chemical Department, University of California, Lawrence Radiation Laboratory, Berkeley, Calif.

SAMUEL W. JENSCH, Chief Hearing Examiner, U.S. Atomic Energy Commission, Washington, D.C.

Dr. ALBERT J. KIRSCHBAUM, Lawrence Radiation Laboratory, Livermore, Calif.

ARTHUR W. MURPHY, Columbia University of Law, New York, N.Y.

WARREN E. NYER, Manager, Reactor Projects, Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. HUGH PAXTON, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. THOMAS H. PIGFORD, Professor of Nuclear Engineering, University of California, Berkeley, Calif.

Dr. LAWRENCE R. QUARLES, Dean, School of Engineering and Applied Science, University of Virginia, Charlottesville, Va.

REUEL C. STRATTON, Consulting Engineer, Hartford, Conn.

Dr. CHARLES E. WINTERS, Union Carbide, Parma Research Center, Cleveland, Ohio.

Dr. ABEL WOLMAN, The Johns Hopkins University, Baltimore, Md.

HOOD WORTHINGTON, retired, Wilmington, Del.

Seven boards drawn from the panel were active in regulatory proceedings during 1965.

APPEALS BOARDS

Board of Contract Appeals

On August 25, 1964, the Commission established the AEC Board of Contract Appeals under the supervision of a chairman, who reports directly to the Commission. The Board of Contract Appeals considers and finally decides appeals from findings of fact or decisions of contracting officers in disputes arising under AEC prime contracts containing a disputes provision and certain subcontracts containing such a provision. The rules of practice of the Board were published in the *Federal Register* on September 11, 1964, and codified as Part 3 of Title 10, Code of Federal Regulations. The new rules became effective 60 days after publication in the *Federal Register*. Appeals filed prior to that date are being handled under the procedures and delegations of authority in effect on the date the appeal is filed, unless the appellant requests the application of Part 3.

PAUL H. GANTT, *Chairman*, Board of Contract Appeals, U.S. Atomic Energy Commission, Washington, D.C.

JAMES P. MURRAY, Jr., *Vice Chairman;* U.S. Atomic Energy Commission, Washington, D.C.

WILLIAM T. BARNES, Lybrand, Ross Bros. & Montgomery, Washington, D.C.

CARMINE S. BELLINO, Wright, Long & Co., Washington, D.C.

LAWRENCE R. CARUSO, Legal Counsel, Office of Research Administration, Princeton University, Princeton, N.J.

VALENTINE B. DEALE, Attorney at Law, Washington, D.C.

Dr. C. KENNETH GREEN, Chairman, Accelerator Department, Brookhaven National Laboratory, Associated Universities, Inc., Upton, Long Island, N.Y.

HENRY B. KEISER, Attorney at Law and President, Federal Publications, Inc., Washington, D.C.

LEONARD J. KOCH, Director, Reactor Engineering Division, Argonne National Laboratory, Argonne, Ill.

JOHN T. KOEHLER, Attorney at Law, Butler, Koehler & Tausig, Washington, D.C.

E. RIGGS MCCONNELL, retired Hearing Examiner, U.S. Atomic Energy Commission, Washington, D.C.

JOHN A. MCINTIRE, Consulting Attorney, Office of Judge Advocate General, U.S. Navy, Washington, D.C.

CHARLES G. SONNEN, Assistant to the Director, Division of Construction, U.S. Atomic Energy Commission, Washington, D.C.

JOHN M. STOY, Stoy, Malone & Co., Washington, D.C.

ROBERT M. UNDERHILL, Vice President and Treasurer Emeritus, University of California, Berkeley, Calif.

Capt. DANIEL B. VENTRES, Consultant and Director, Vogt, Ivers & Associates, Washington, D.C.

JOHN W. WHELAN, Professor of Law, Georgetown University Law Center, Washington, D.C.

During 1965, the full Board met once, on June 15; numerous panel meetings were also held.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Atomic Energy Labor-Management Advisory Committee

This Committee was established in March 1962 for the purpose of bringing together representatives of organized labor with representatives of management and the AEC to discuss general problems, procedures, and requirements in connection with the radiological aspects of industrial safety. Its charter was expanded in 1963 to permit consideration of questions other than those concerned with the radiological aspects of industrial safety.

H. T. Herrick, *Chairman;* Director, Division of Labor Relations, U.S. Atomic Energy Commission, Washington, D.C.

C. L. Henderson, *Vice Chairman;* Assistant Director of Regulation for Administration, U.S. Atomic Energy Commission, Washington, D.C.

Andrew J. Biemiller, Director, Department of Legislation, AFL–CIO, Washington, D.C.

Henry R. Chope, Executive Vice President for Development and Engineering, Industrial Nucleonics Corp., Columbus, Ohio

Roger J. Coe, Vice President, Yankee Atomic Electric Co., Boston, Mass.

Harold A. Fidler, Associate Director, Lawrence Radiation Laboratory, University of California, Berkeley, Calif.

Gordon M. Freeman, President, International Brotherhood of Electrical Workers, Washington, D.C.

Charles D. Harrington, General Manager, Douglas United Nuclear Corp., Richland, Wash.

Albert J. Hayes, Retired as President, International Association of Machinists, Washington, D.C.

Howard K. Nason, President, Monsanto Research Corp., St. Louis, Mo.

Peter T. Schoemann, President, United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry, Washington, D.C.

Elwood D. Swisher, Vice President, Oil, Chemical and Atomic Workers International Union, Denver, Colo.

The Committee met three times in 1965—January 28, May 4, and September 7.

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. Fred J. Hodges, *Chairman;* Retired Professor and Chairman of Radiology, University of Michigan Medical Center, Ann Arbor, Mich.

Dr. James H. Sterner, *Vice Chairman;* Medical Director, Eastman Kodak Co., Rochester, N.Y.

Dr. William F. Bale, Professor, Radiation Biology, Department of Radiation Biology and Atomic Energy Project, University of Rochester School of Medicine and Dentistry, Rochester, N.Y.

Dr. Mary I. Bunting, President, Radcliffe College, Cambridge, Mass.

Dr. Philip P. Cohen, Professor and Chairman, Department of Physiological Chemistry, University of Wisconsin School of Medicine, Madison, Wis.

Dr. Earl L. Green, Director, The Jackson Laboratory, Bar Harbor, Maine

Dr. Carl V. Moore, Professor of Medicine, Department of Internal Medicine Washington University, School of Medicine, Barnes and Wohl Hospital, St. Louis, Mo.

Dr. Morell B. Russell, Director, Agricultural Experiment Station, University of Illinois, Urbana, Ill.

Dr. Harvey M. Patt, *Scientific Secretary;* Director, Laboratory of Radiobiology, San Francisco Medical Center, University of California, San Francisco, Calif.

Rosemary Elmo, *Executive Secretary;* U.S. Atomic Energy Commission, Washington, D.C.

The Committee held four meetings during 1965, on January 8–9, March 26–27, May 14–15, and October 25–26.

Historical Advisory Committee

The Historical Advisory Committee was established by the Commission in February 1958 to advise the Commission and its historical staff on matters relating to the preparation of the history of the Atomic Energy Commission.

Dr. James P. Baxter, III, *Chairman;* Senior Fellow, Council on Foreign Relations, Inc., New York, N.Y.

Dr. James L. Cate, Professor of History, University of Chicago, Chicago, Ill.

Dr. Constance McL. Green, Washington, D.C.

Dr. Ralph W. Hidy, Professor of Business History, Graduate School of Business Administration, Harvard University, Cambridge, Mass.

Dr. George E. Mowry, Professor of History and Dean, Department of Social Sciences, University of California, Los Angeles, Calif.

Dr. Isadore Perlman, Associate Director, Lawrence Radiation Laboratory, University of California, Berkeley, Calif.

Dr. Don K. Price, Jr., Dean, Graduate School of Public Administration, Harvard University, Cambridge, Mass.

Dr. Robert R. Wilson, Director, Laboratory of Nuclear Studies, Cornell University, Ithaca, N.Y.

Dr. Richard G. Hewlett, AEC representative, Chief Historian, U.S. Atomic Energy Commission, Washington, D.C.

The Committee met twice during 1965, on April 26–27 and October 25–26.

Advisory Committee on Isotopes and Radiation Development

This committee was established by the Commission in July 1958 to advise on means of encouraging wide-scale industrial use of radioisotopes and nuclear radiation.

John L. Kuranz, *Chairman;* Vice President, Nuclear-Chicago Corp., Des Plaines, Ill.

John W. Landis, *Vice Chairman;* General Manager, Washington Operations, The Babcock & Wilcox Co., Washington, D.C.

Dr. John C. Brantley, Union Carbide Nuclear Corporation, New York, N.Y.

E. Alfred Burrill, Vice President, High Voltage Engineering Corp., Burlington, Mass.

Dr. Willard P. Conner, Technical Assistant to the Director, Hercules Research Center, Hercules Powder Co., Wilmington, Del.

Joseph J. Fitzgerald, President and Director, Iso/Serve, Inc., Cambridge, Mass.

BEARDSLEY GRAHAM, President, Spindletop Research Center, Lexington, Ky.

Dr. GEORGE M. KAVANAGH, Assistant General Manager for Reactors, U.S. Atomic Energy Commission, Washington, D.C.

E. ROBERT KINNEY, President, Gorton Corp., Gloucester, Mass.

Dr. WILLIAM KOCH, Chief, Radiation Physics Division, National Bureau of Standards, Washington, D.C.

Dr. JAMES R. MAXFIELD, Jr., Maxfield Clinic-Hospital, Dallas, Tex.

Dr. EUNICE M. MOORE, Director for Research & Development, Electric Utilities Co., La Salle, Ill.

HOWARD K. NASON, President, Monsanto Research Corp., St. Louis, Mo.

Dr. LEONARD REIFFEL, Apollo Program, National Aeronautics and Space Administration, Washington, D.C.

Dr. MARVIN G. SCHORR, President, Technical Operations, Inc., Burlington, Mass.

JOSEPH W. SELDEN, Division Vice President, New Products Commercial Development, Minnesota Mining and Manufacturing Co., St. Paul, Minn.

Dr. RODMAN A. SHARP, President, Sharp Laboratories Division, Beckman Instruments, Inc., La Jolla, Calif.

Prof. JOSEPH SILVERMAN, College of Engineering, Glenn L. Martin Institute of Technology, University of Maryland, College Park, Md.

Dr. CHAUNCEY STARR, President, Atomics International, A Division of North American Aviation, Inc., Canoga Park, Calif.

Dr. ERNST STUHLINGER, Army Ballistic Missile Agency, Marshall Space Flight Center, Huntsville, Ala.

DAVID E. TRUMBULL, Manager-Planning Projects, Atomic Products Division, General Electric Co., San Jose, Calif.

Dr. WALTER M. URBAIN, Food Science Department, Michigan State University, East Lansing, Mich.

The Committee met October 14 and 15, 1965.

Advisory Committee on Medical Uses of Isotopes

The Committee was established in 1958 and replaced 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. JOHN A. MCBRIDE, *Chairman;* Director, Division of Materials Licensing, U.S. Atomic Energy Commission, Washington, D.C.

Dr. WALLACE D. ARMSTRONG, Professor, Department of Biochemistry, University of Minnesota Medical School, Minneapolis, Minn.

Dr. REYNOLD 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, Dean of Sciences, Northwestern University Medical School, Chicago, Ill.

Dr. ROBERT H. GREENLAW, Associate Professor of Radiology, University of Kentucky, Lexington, Ky.

Dr. E. RICHARD KING, Professor of Radiology, Medical College of Virginia, Richmond, Va.

Dr. GEORGE V. LEROY, Medical Director, Metropolitan Hospital, Detroit, Mich.

Dr. EDITH H. QUIMBY, Professor Emeritus, Department of Radiology, College of Physicians and Surgeons, Columbia University, New York, N.Y.

Dr. Rulon W. Rawson, Attending Physician and Chairman, Memorial Hospital, New York, N.Y.

Dr. Harald Rossi, Professor of Radiology, College of Physicians and Surgeons, Columbia University, New York, N.Y.

The Committee met February 13, 1965, in Washington, D.C.

Technical Advisory Panel on Peaceful Use Safeguards

This Panel was established by the Commission during 1965 to advise the AEC on technical matters relating to safeguards for providing assurance of the peaceful uses of nuclear materials and equipment including: development of safeguard procedures, implementation of safeguard procedures, and research and development in safeguards.

Myron B. Kratzer, *Chairman;* Director, Division of International Affairs, U.S. Atomic Energy Commission, Washington, D.C.

Floyd L. Culler, Jr., Assistant Director, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Jane H. Hall, Assistant Director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Wendall P. Johnson, Plant Superintendent, Yankee Atomic Electric Co., Rowe, Mass.

John W. Landis, General Manager, Washington Operations, The Babcock & Wilcox Co., Washington, D.C.

Horace W. Norton, III, Professor of Statistical Design and Analysis, University of Illinois, Urbana, Ill.

Bernard I. Spinrad, Director, Reactor Engineering Division, Argonne National Laboratory, Argonne, Ill.

Everett B. Sheldon, Superintendent, Separations Tachnology Section, Savannah River Plant, E. I. du Pont de Nemours and Co., Aiken, S.C.

The Panel did not meet during 1965.

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;* Assistant General Manager for Research and Development, U.S. Atomic Energy Commission, Washington, D.C.

Willard Bascom, President, Ocean Science & Engineering, Inc., Washington, D.C.

Lt. Gen. James H. Doolittle, Consultant, TRW Systems, Redondo Beach, Calif.

Dr. Louis H. Hempelmann, Professor, Experimental Radiology, Strong Memorial Hospital, University of Rochester, Rochester, N.Y.

Dr. Richard Latter, Research Council, The RAND Corp., Santa Monica, Calif.

Dr. Willard F. Libby, Director, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, Calif.

Dr. Donald H. McLaughlin, Chairman of the Board, Homestake Mining Co., San Francisco, Calif.

Dr. PHILIP C. RUTLEDGE, Partner, Mueser, Rutledge, Wentworth & Johnston, New York, N.Y.

Dr. PAUL B. SEARS, Professor Emeritus and former Chairman, Conservation Program, Yale University, New Haven, Conn.

The Committee met twice in 1965, on April 12–13, and November 9–10.

Advisory Committee on Reactor Physics

This Committee was established in 1951 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 research and development work in the field of reactor physics.

Dr. IRA F. ZARTMAN, *Chairman;* Division of Reactor Development and Technology, U.S. Atomic Energy Commission, Washington, D.C.

Dr. ROBERT AVERY, Director, Reactor Physics Division, Argonne National Laboratory, Argonne, Ill.

JACK CHERNICK, Associate Head, Reactor Physics Division, Brookhaven National Laboratory, Upton, Long Island, N.Y.

Dr. E. RICHARD COHEN, Associate Director, North American Aviation Science Center, Canoga Park, Calif.

Dr. FRANK G. DAWSON, Jr., Manager, Reactor Physics, Pacific Northwest Laboratory, Battelle Memorial Institute, Richland, Wash.

Dr. GERHARD DESSAUER, Director, Physics Section, Savannah River Laboratory, 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. RICHARD EHRLICH, Manager, Advanced Development Activity, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N.Y.

Dr. REX FLUHARTY, Manager, Nuclear Physics Branch, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. E. R. GAERTTNER, Rensselaer Polytechnic Institute, Troy, N.Y.

Dr. GORDON HANSEN, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

PHILIP B. HEMMIG, Division of Reactor Development and Technology, U.S. Atomic Energy Commission, Washington, D.C.

Dr. IRVING KAPLAN, Professor, Department of Nuclear Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. F. C. MAIENSCHEIN, Associate Director, Neutron Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. MARK NELKIN, Professor, Nuclear Reactor Laboratory, Cornell University, Ithaca, N.Y.

Dr. LORTHAR W. NORDHEIM, Chairman, Theoretical Physics Department, General Atomic, San Diego, Calif.

Dr. THOMA M. SNYDER, Consultant, Research and Engineering Program, General Electric Atomic Power Equipment Dept., San Jose, Calif.

JOHN J. TAYLOR, Manager, Reactor Development and Analysis Department, Bettis Atomic Power Division, Westinghouse Electric Corp., Pittsburgh, Pa.

Dr. ALVIN RADKOWSKY, *Secretary;* Division of Naval Reactors, U.S. Atomic Energy Commission, Washington, D.C.

The Committee met once during 1965, on March 29–30.

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.

- Dr. SAMUEL C. T. MCDOWELL, *Chairman;* Assistant Director for Control, Division of Nuclear Materials Management, U.S. Atomic Energy Commission, Washington, D.C.
- JOHN L. HAGUE, Chief, Inorganic Standards, Office of Standard Reference Materials, National Bureau of Standards, Department of Commerce, Washington, D.C.
- RALPH J. JONES, Chief, Survey and Appraisal Branch, Division of Nuclear Materials Management, U.S. Atomic Energy Commission, Washington, D.C.
- Dr. CHARLES F. METZ, Group Leader, Chemical and Instrumental Analysis, 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. LEONARD P. PEPKOWITZ, Vice President, Nuclear Materials & Equipment Corp., Apollo, Pa.
- C. J. RODDEN, Area Manager, New Brunswick Area Office, U.S. Atomic Energy Commission, New Brunswick, N.J.
- CHARLES M. STEVENS, Associate Physicist, Chemistry Division, Argonne National Laboratory, Argonne, Ill.
- C. D. W. THORNTON, Technical Director—North America, International Telephone & Telegraph Corp., New York, N.Y.
- Dr. EDWARD WICHERS, Consultant to the National Academy of Sciences, Washington, D.C.
- Dr. J. ERNEST WILKINS, Assistant Chairman, Theoretical Physics Department, General Atomic, San Diego, Calif.

The Committee did not meet during 1965.

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. In 1960, its function was enlarged to furnish guidance in the implementation of the Commission's program of cooperation with States. At the same time, its membership was broadened to provide a larger cross section of views consistent with its additional functions.

- H. L. PRICE, *Chairman*, Director of Regulation, U.S. Atomic Energy Commission, Washington, D.C.
- Dr. BERNARD BUCOVE, Director of Health, State Department of Public Health, Olympia, Wash.
- Dr. R. L. CLEERE, Director of Public Health, State Department of Public Health, Denver, Colo.
- CARL FRASURE, Committee of State Officials on Suggested State Legislation, West Virginia University, Morgantown, W. Va.

ROBERT H. GIFFORD, Executive Director, Southern Interstate Nuclear Board, Atlanta, Ga.

Dr. ALBERT E. HEUSTIS, State Health Commissioner, Michigan Department of Health, Lansing, Mich.

C. W. KLASSEN, Chief Sanitary Engineer, Department of Public Health, Springfield, Ill.

Dr. MORRIS KLEINFELD, Director, Division of Industrial Hygiene, Department of Labor, New York, N.Y.

W. T. LINTON, Executive Director, Water Pollution Control Authority, South Carolina State Board of Health, Columbia, S.C.

HENRY M. MARX, Coordinator, Atomic Development Activities, Westport, Conn.

KARL M. MASON, Director, Bureau of Environmental Health, Pennsylvania Department of Health, Harrisburg, Pa.

Dr. JAMES E. PEAVY, Commissioner of Health, State Department of Health, Austin, Tex.

WILLIAM J. PIERCE, National Conference of Commissioners on Uniform Laws, University of Michigan Law School, Ann Arbor, Mich.

B. A. POOLE, Director, Bureau of Environmental Sanitation, Indiana State Board of Health, Indianapolis, Ind.

D. P. ROBERTS, Chief, Industrial Hygiene Section, Tennessee Department of Health, Nashville, Tenn.

OLIVER H. TOWNSEND, Director, Office of Atomic and Space Development, New York, N.Y.

The Committee did not meet in 1965.

Advisory Committee on Technical Information

This committee was established during 1961, replacing the Advisory Committee on Industrial Information, formed in 1949. The committee advises and assists in the planning and execution of the AEC's technical information program.

EDWARD J. BRUNENKANT, Jr., *Chairman;* Director, Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C.

JOHN E. DOBBIN, Project Director, Educational Testing Service, Princeton, N.J.

Dr. HOYLANDE YOUNG FAILEY, Chicago, Ill.

JAMES L. GAYLORD, Senior Partner of James L. Gaylord Associates, Santa Monica, Calif.

Dr. ALLEN G. GRAY, Editor, "Metal Progress," American Society for Metals, Metals Park, Ohio.

NORMAN H. JACOBSON, Technical Publishing Co., Barrington, Ill.

JOHN W. LANDIS, General Manager, Washington Operations, the Babcock & Wilcox Co., Washington, D.C., representing American Nuclear Society, Chicago, Ill.

Dr. FRED P. PETERS, Vice President, Reinhold Publishing Co., New York, N.Y.

KARL T. SCHWARTZWALDER, Director of Research, A–C Spark Plug Division, General Motors Corp., Flint, Mich., representing the American Ceramic Society, Inc., Columbus, Ohio.

OLIVER H. TOWNSEND, Director, Office of Atomic and Space Development, New York, N.Y.

JOHN W. WIGHT, Vice President, McGraw-Hill Book Co., Inc., New York, N.Y.

The Committee met once, on November 19, during 1965.

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 eight members each of whom is appointed for a 1-year term.

Dr. WARREN C. JOHNSON, *Chairman;* Vice President, Special Scientific Programs, University of Chicago, Chicago, Ill.

Dr. EUGENE EYSTER, Alternate GMX Division Leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. A. C. HAUSSMANN, A Division Leader, Lawrence Radiation Laboratory, University of California, Livermore, Calif.

Dr. JOHN P. HOWE, Professor of Engineering, Cornell University, Ithaca, N.Y.

Dr. FRANK C. HOYT, Missiles Systems Division, Lockheed Aircraft, Corp., Palo Alto, Calif.

Dr. J. REGINALD RICHARDSON, Professor of Physics, University of California at Los Angeles, Calif.

Dr. JESSE W. BEAMS, Professor of Physics, University of Virginia, Charlottesville, Va.

The Committee met twice in 1965, on June 7–9 and December 8–10.

Mathematics and Computer Sciences Research Advisory Committee

The Mathematics and Computer Sciences Research Advisory Committee was established in 1960 as an advisory board to the Division of Research of the AEC to make recommendations on computer research and development programs and provide advice and guidance on problems in this field.

Dr. JOHN R. PASTA, *Chairman;* Digital Computer Laboratory, University of Illinois, Urbana, Ill.

SAMUEL N. ALEXANDER, Information Technology Division, National Bureau of Standards, Washington, D.C.

Prof. FREDERICK P. BROOKS, Department of Computer Science, University of North Carolina, Chapel Hill, N.C.

Dr. SIDNEY FERNBACH, Computation Division, Lawrence Radiation Laboratory, University of California, Livermore, Calif.

Dr. ALSTON S. HOUSEHOLDER, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. MARIO L. JUNCOSA, The RAND Corp., Santa Monica, Calif.

Dr. YOSHIO SHIMAMOTO, Brookhaven National Laboratory, Upton, Long Island, N.Y.

Dr. JAMES J. STOKER, Courant Institute of Mathematical Sciences, New York University, New York, N.Y.

Dr. CHARLES V. L. SMITH, Mathematics & Computers Branch, Physics & Mathematics Programs, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.

Dr. WILLIAM F. MILLER, *Secretary;* Stanford Linear Accelerator Center, Stanford University, Stanford, Calif.

The Committee met twice in 1965, on April 6 and November 18.

Nuclear Cross Sections Advisory Group

This Group, appointed on a yearly basis, provides consultation and guidance for the Commission's program of nuclear cross-section measurements. Information from this program is of fundamental importance to many activities of the Commission.

Dr. ALAN B. SMITH, *Chairman;* Argonne National Laboratory, Argonne, Ill.
Dr. HERMAN J. DONNERT, U.S. Army Nuclear Defense Laboratory, Edgewood Arsenal, Md.
Prof. HERBERT GOLDSTEIN, Columbia University, New York, N.Y.
DON R. HARRIS, Westinghouse Corp., Bettis Laboratories, Pittsburgh, Pa.
Dr. WILLIAM H. KOCH, U.S. National Bureau of Standards, Washington, D.C.
Dr. MICHAEL S. MOORE, Phillips Petroleum Co., Idaho Falls, Idaho
Prof. HENRY W. NEWSON, Department of Physics, Duke University, Durham, N.C.
HARRY PALEVSKY, Brookhaven National Laboratory, Upton, Long Island, N.Y.
Prof. GERALD C. PHILLIPS, Department of Physics, Rice University, Houston, Tex.
Dr. GEORGE L. ROGOSA, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.
Prof. EDWIN F. SHRADER, Case Institute of Technology, Cleveland, Ohio
Dr. PAUL H. STELSON, Oak Ridge National Laboratory, Oak Ridge, Tenn.
Dr. IRA F. ZARTMAN, Division of Reactor Development and Technology, U.S. Atomic Energy Commission, Washington, D.C.
Dr. HENRY MOTZ, *Secretary;* Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Ex-Officio Members

Dr. RICHARD F. TASCHEK, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. GEORGE A. KOLSTAD, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.
Prof. WILLIAM W. HAVENS, Jr., Department of Physics, Columbia University, New York, N.Y.

Official Observers

CHARLES M. GOTTSCHALK, Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C.
MURREY D. GOLDBERG, Brookhaven National Laboratory, Upton, Long Island, N.Y.

The Group met twice in 1965; on March 8–9, and October 13–14.

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.
JOHN J. WILSON, firm of Whiteford, Hart, Carmody & Wilson, Washington, D.C.
LOUIS A. TURNER, Princeton University, Princeton, N.J.

The Board met twice during 1965 on January 11 and May 10.

Technical Information Panel

The panel was established in 1948 to advise and assist the AEC in the planning, testing, development, and execution of the Commission's technical information program, primarily on matters of interest to the National Laboratories and major operating contractors.

EDWARD J. BRUNENKANT, Jr., *Chairman;* Director, Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C.

H. S. ALLEN, Chief, Information Services, Atomic Energy Division, Babcock & Wilcox Co., Lynchburg, Va.

BREWER F. BOARDMAN, Director, Technical Information, Phillips Petroleum Co., Idaho Falls, Idaho

Dr. THOMAS S. CHAPMAN, Manager Technical Information Operations, Dow Rocky Flats, Golden, Colo.

C. L. CHASE, Manager, Technical Information, General Electric Co., Nuclear Materials and Propulsion Operation, Cincinnati, Ohio

W. E. DREESZEN, Administrative Aide to Director, Ames Laboratory, Ames, Iowa

DOUGLAS DUPEN, Technical Information Department, Stanford Linear Accelerator Center, Stanford University, Stanford, Calif.

W. L. HARWELL, Head, Legal and Information Control Department, Union Carbide Corp., Oak Ridge, Tenn.

Dr. C. P. KEIM, Director, Technical Information Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

MAX K. LINN, Director, Technical Information and Publications, Sandia Corp., Sandia Base, Albuquerque, N. Mex.

FRANK R. LONG, General Supervisor, Information Services, Atomics International, Canoga Park, Calif.

JOHN H. MARTENS, Director, Technical Publications Department, Argonne National Laboratory, Argonne, Ill.

W. A. MINKLER, Supervisor, Bettis Technical Information, Westinghouse Electric Corp., Pittsburgh, Pa.

Dr. JUDD C. NEVENZEL, University of California, Laboratory of Nuclear Medicine, Los Angeles, Calif.

STEWARD W. O'REAR, Supervisor, Technical Information Service, Savannah River Laboratory, Aiken, S.C.

DENNIS PULESTON, Head, Information Division, Brookhaven National Laboratory, Upton, Long Island, N.Y.

HELEN REDMAN, Librarian, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. ARCHIE E. RUEHLE, Assistant Technical Director, Uranium Division, Mallinckrodt Chemical Works, St. Charles, Mo.

FRANK D. SHEARIN, Technical Editor, Monsanto Research Corp., Mound Laboratory, Miamisburg, Ohio

C. G. STEVENSON, Manager, Technical Information, Pacific Northwest Laboratory, Battelle-Northwest, Richland, Wash.

Dr. STUART STURGES, Knolls Atomic Power Laboratory, Schenectady, N.Y.

CHARLES D. TABOR, Superintendent, Works Laboratory, Goodyear Atomic Corp., Piketon, Ohio

JOSEPH W. VOTAW, Assistant to Technical Director, National Lead Co. of Ohio, Cincinnati, Ohio

Dr. RAYMOND K. WAKERLING, Head, Technical Information Division, Lawrence Radiation Laboratory, Berkeley, Calif.

ROBERT L. SHANNON, *Secretary;* Ext. Manager, Division of Technical Information Extension, U.S. Atomic Energy Commission, Oak Ridge, Tenn.

The Panel met once in 1965 on January 12–13.

Accelerator Safety Panel

The Advisory Panel on Accelerator Safety was established in July 1965 to review unique safety problems which may arise in AEC operations. Such characteristics as the high energy, the pulse nature, and the complex spectrum of the stray radiations around the accelerators have made the measurement of radiation and the estimation of radiation dose to personnel difficult. The specialized skills of the Advisory Panel will be available to each AEC field office to assist in carrying out surveillance and provide advice on these scientific tools. The panel consists of the following consultants specifically oriented in the radiation protection aspects of accelerator operations.

Dr. MIGUEL AWSCHALOM, *Chairman;* Princeton-Pennsylvania Accelerator, Princeton, N.J.

Dr. FRED COWAN, Brookhaven National Laboratory, Upton, Long Island N.Y.

KERAN O'BRIEN, AEC Health and Safety Laboratory, New York, N.Y.

Dr. ROGER WALLACE, Lawrence Radiation Laboratory, Berkeley, Calif.

ROBERT WHEELER, Argonne National Laboratory, Argonne, Ill.

The Panel met once in 1965, on November 4.

APPENDIX 3

MAJOR AEC-OWNED, CONTRACTOR-OPERATED INSTALLATIONS*

Ames Laboratory (Iowa State University of Science and Technology, contractor) Ames, Iowa

Argonne National Laboratory (University of Chicago, contractor), Argonne, Ill.

Director	Dr. Albert V. Crewe
Associate Director	Dr. Stephen Lawroski
Associate Director	Dr. Winston M. Manning
Associate Director for High Energy Physics	Dr. Robert G. Sachs
Associate Director for Education	Dr. Frank E. Myers
Assistant Director	Dr. Richard M. Adams

Bettis Atomic Power Laboratory (Westinghouse Electric Corp., contractor), Pittsburgh, Pa.

General Manager	N. A. Beldecos
Executive Assistant to the General Manager	W. A. Brecht
Manager, Operations	A. P. Zechella
Manager, Naval Reactor Facility (NRTS), Idaho	R. C. Mairson

Brookhaven National Laboratory (Associated Universities, Inc., contractor), Upton, Long Island, N.Y.

Chairman, Board of Trustees	Dr. Ernest F. Johnson
President, AUI	Dr. T. Keith Glennon
Laboratory Director	Dr. Maurice Goldhaber
Deputy Director	Dr. Clarke Williams
Associate Director	Dr. Charles Falk

The participating institutions are:

- Columbia University
- Cornell University
- Harvard University
- The Johns Hopkins University
- Massachusetts Institute of Technology
- Princeton University
- University of Pennsylvania
- University of Rochester
- Yale University

Burlington AEC Plant (Mason & Hanger-Silas Mason Co., Inc., contractor) Burlington, Iowa

Contract Manager (Vice President)	R. B. Jewell
Plant Manager	D. E. Heffelbower
Program Planning Manager	A. S. Peter, Jr.
Administrative Assistant	B. W. Calvit

*Only installations where the AEC's investment in plant and equipment exceeds $25 million are listed. Other research and development installations are listed in the Appendix to the supplementary report, "Fundamental Nuclear Energy Research—1965."

Feed Materials Production Center (National Lead Co. of Ohio, contractor), Fernald, Ohio

Vice President ---------- GEORGE WUNDER
Manager ---------- JAMES H. NOYES
Assistant Manager ---------- M. S. NELSON

Hanford Facilities (five contractors), Richland, Wash.

Douglas-United Nuclear, Inc., Richland, Wash.

General Manager ---------- C. D. HARRINGTON
Deputy General Manager ---------- S. P. SMITH
Assistant General Manager for Operations ---------- O. C. SCHROEDER
Assistant General Manager for Finance and Administration ---------- S. KOEPCKE

General Electric Co., Hanford Atomic Products Operation, Richland, Wash.

General Manager ---------- W. E. JOHNSON
General Manager, Irradiation Processing Dept ---------- A. B. GRENINGER
Acting Manager, Hanford Utilities and Purchasing Operation ---------- A. B. GRENINGER
General Manager, Chemical Processing Dept ---------- J. H. WARREN
General Manager, N-Reactor Dept ---------- R. L. DICKEMAN

Isochem, Inc., Richland, Wash.

President ---------- J. N. JUDY
Vice President, Chemical Processing ---------- P. E. REED
Vice President, FPCE Facility ---------- T. S. WEISSMANN
Vice President, Business Management ---------- H. D. GILBERT
Vice President, Marketing ---------- E. T. O'SULLIVAN

Pacific Northwest Laboratory (Battelle Memorial Institute, Columbus, Ohio, Contractor), Richland, Wash.

Director ---------- S. L. FAWCETT
Manager, Physics and Instruments Dept ---------- R. S. PAUL
Manager, Chemistry Dept ---------- M. T. WALLING
Manager, Reactor & Materials Technology Dept ---------- F. W. ALBAUGH
Manager, Biology Dept ---------- H. A. KORNBERG

United States Testing Co., Inc., Richland, Wash.

General Manager (Pacific Northwest Laboratory) ---------- D. B. WILCOX
Manager, Dosimetry Services ---------- R. L. PIERCE
Manager, Radiochemistry ---------- D. P. ARGYLE
Manager, Engineering Services ---------- N. W. HAAGENSON

Kansas City Plant (The Bendix Corp., Kansas City Division, contractor), Kansas City, Mo.

General Manager ---------- E. E. EVANS
Assistant General Manager ---------- R. J. QUIRK
Director, Manufacturing ---------- V. L. RITTER
Director, Engineering ---------- R. M. SOMERS

Knolls Atomic Power Laboratory (General Electric Co., contractor), Schenectady, N.Y.

General Manager	K. A. KESSELRING
Manager, West Milton Site	W. H. BRUGGEMAN
Manager, S5G Project	H. E. STONE
Manager, SAR Project	C. S. HOFMANN
Manager, D1G Project	E. C. RUMBAUGH

Los Alamos Scientific Laboratory (University of California, contractor), Los Alamos, N. Mex.

Director	Dr. NORRIS E. BRADBURY
Technical Associate Director	Dr. RAEMER E. SCHREIBER
Assistant Director	Dr. JANE H. HALL
Assistant Director, Production	Dr. MAX F. ROY

Mound Laboratory (Monsanto Research Corp., contractor), Miamisburg, Ohio

Project Director (president, Mansanto Research Corp.)	H. K. NASON
Plant Manager (vice president, Monsanto Research Corp.)	DAVID L. SCOTT
Technical Coordinator	Dr. JOHN F. EICHELBERGER
Director, Production	J. E. BRADLEY

National Reactor Testing Station (NRTS), (seven contractors), Idaho Falls, Idaho

Phillips Petroleum Co., Atomic Energy Division, Idaho Falls

Project Manager	J. P. LYON
Assistant Manager, Operations	M. H. BARTZ
Assistant Manager, Nuclear and Chemical Technology	D. R. DEBOISBLANC
Assistant Manager, Nuclear Safety Technology	W. E. NYER
Assistant Manager, Engineering	L. J. WEBER
Assistant Manager, Administration	L. L. LEEDY

Aerojet-General Corp., San Ramon, Calif.

Program Manager, Army Gas Cooled Reactor Systems	R. H. CHESWORTH
Manager, NRTS Operations	W. D. WAYNE
Assistant Manager, NRTS Operations	N. K. SOWARDS
Administrative Supervisor, NRTS Operations	N. D. ZIPKIN

Argonne National Laboratory, the Idaho Division, Idaho Falls

Director	M. NOVICK
Associate Director	F. W. THALGOTT
AFSR Project Manager	R. N. CURRAN
EBR-II Project Manager	G. K. WHITHAM
EBR-II Fuel Cycle Facility Project Manager	C. E. STEVENSON
TREAT Project Manager	J. F. BOLAND
ZPR-II Project Manager	J. K. LONG

General Atomic (Division of General Dynamics), Idaho Falls

EBOR Site Manager	A. C. JONES, Jr.

General Electric Co., Knolls Atomic Power Laboratory, S5G Field Office, Idaho Falls

Manager ---------- R. S. Zeno
Manager, Administrative Services ---------- D. R. Seymour

General Electric Co. (Idaho Test Station, Nuclear Materials and Propulsion Operation, Atomic Products Division), Idaho Falls

Manager ---------- Dr. J. W. Morfitt
Manager, Administrative ---------- E. G. Blake
Manager, Engineering Projects ---------- Dr. R. E. Wood
Manager, Materials Projects ---------- F. O. Urban

Westinghouse Electric Corp., Idaho Falls

Manager, Naval Reactors Facility ---------- R. C. Mairson
Manager, S1W Operations ---------- H. D. Ruppel
Manager, Expended Core Facility ---------- A. A. Simmons
Manager, A1W Operations ---------- B. G. Hooten

Nevada Test Site (Reynolds Electrical & Engineering Co., Inc., contractor), Mercury, Nev.

General Manager ---------- J. R. Crockett
Deputy General Manager ---------- R. W. Kiehn
Assistant Project Manager, Construction ---------- W. A. Stevens
Assistant Project Manager, Engineering ---------- R. D. Cunningham
Assistant Project Manager, Logistics ---------- R. R. Saunders

Nuclear Rocket Development Station (Pan American World Airways, Guided Missile Range Division, contractor), Jackass Flats, Nev.

Project Manager ---------- R. L. Yordy
Manager, Operations ---------- D. I. Wallace

Oak Ridge Research and Development and Production Facilities (Union Carbide Corp., contractor), Oak Ridge, Tenn., and Paducah, Ky.

General Manager (President, Union Carbide Nuclear Division) ---------- Dr. C. E. Larson

Oak Ridge Production Facilities

Manager of Production (Vice President, Union Carbide Nuclear Division) ---------- Clarke E. Center
Superintendent, Y-12 Plant ---------- R. F. Hibbs
Superintendent, Oak Ridge Gaseous Diffusion Plant ---------- Robert G. Jordan
Superintendent, Paducah Gaseous Diffusion Plant ---------- Robert A. Winkel

Oak Ridge National Laboratory

Director (Vice President, Union Carbide Nuclear Division) ---------- Dr. Alvin M. Weinberg
Deputy Director ---------- Dr. H. G. MacPherson

Pantex Plant (Mason & Hanger-Silas Mason Co., Inc., contractor), Amarillo, Tex.

Contract Manager (Vice President) ---------- R. B. Jewell
Plant Manager ---------- John C. Drummond
Chief Engineer ---------- Marion L. Ott
Production Manager ---------- Robert B. Carroll

Portsmouth Gaseous Diffusion Plant (Goodyear Atomic Corp., contractor), Piketon, Ohio

General Manager	C. H. REYNOLDS
Deputy General Manager	C. R. MILONE

Rocky Flats Plant (Dow Chemical Co., contractor), Rocky Flats, Colo.

General Manager	DR. LLOYD M. JOSHEL
General Services Manager	ROBERT R. HARRISON
Director of Research and Development	LORNE A. MATHESON
Director of Technical Services	EDWARD J. WALKO

Sandia Laboratory (Sandia Corp., contractor), Sandia Base, Albuquerque, N. Mex.

President	S. P. SCHWARTZ
Vice President	R. W. HENDERSON
Vice President	E. H. DRAPER
Vice President	R. B. POWELL
Vice President	C. W. CAMPBELL
Vice President	R. C. FLETCHER
Vice President	F. C. CHESTON, Jr.
Vice President	R. A. BICE
Vice President	B. S. BIGGS
Vice President	G. A. FOWLER

Savannah River Laboratory (E. I. du Pont de Nemours & Co., contractor), Aiken, S.C.

Director	W. P. OVERBECK
Assistant Director	A. A. JOHNSON
Section Director—Physics Section	G. DESSAUER
Section Director—Nuclear Engineering and Materials Section	J. W. MORRIS
Section Director—Separations Chemistry and Engineering Section	C. H. ICE

Savannah River Plant (E. I. du Pont de Nemours & Co., contractor), Aiken, S.C.

Plant Manager	JULIAN D. ELLETT
Assistant Plant Manager	J. A. MONIER, Jr.
General Superintendent, Works Technical Department	W. P. BEBBINGTON
General Superintendent, Production	FREDERICK H. ENDORF

South Albuquerque Works (ACF Industries, Inc., contractor), Albuquerque, N. Mex.

Vice President and General Manager	W. J. JACKEL
Assistant General Manager	J. C. O'HARA
Director, Engineering	W. T. GEYER
Director, Applied Research and Development	C. R. GARR

E. O. Lawrence Radiation Laboratory (University of California, contractor), Berkeley and Livermore, Calif.

Director	Dr. EDWIN M. MCMILLAN
Associate Director and Director, Livermore Laboratory	Dr. MICHAEL M. MAY
Associate Director and Director, Donner Laboratory	Dr. JOHN H. LAWRENCE
Business Manager	RICHARD P. CONNELL

Weldon Spring Feed Materials Plant (Mallinckrodt Chemical Works, contractor), Weldon Spring, Mo.

Vice President and General Manager of Operations Division	S. H. ANONSEN
Manager, Uranium Division	WILLIAM J. SHELLEY

APPENDIX 4

MANPOWER IN THE ATOMIC ENERGY FIELD

TABLE 1.—EMPLOYEES IN INDUSTRIAL ESTABLISHMENTS IN THE ATOMIC ENERGY FIELD BY ECONOMIC SEGMENT AND TYPE OF ESTABLISHMENT OWNERSHIP, JANUARY 1964 AND 1965 [1]

[Preliminary Data

Economic segment	Number of establishments		Total employment in atomic energy field			
			1964		1965	
	Government	Private	Government	Private	Government	Private
Commission laboratories and research facilities	21	------	49,039	--------	49,176	--------
Atomic energy defense production facilities	19	7	47,040	902	45,987	464
Production of feed materials	6	6	7,978	524	6,964	352
Reactor and reactor component design and manufacturing	4	61	3,935	14,769	3,454	14,094
Design and engineering of nuclear facilities	[2] 2	36	[2] 194	1,542	[2] 285	1,593
Power reactor operation and maintenance	4	12	383	596	401	617
Production of special reactor materials	------	31	--------	1,895	--------	1,228
Uranium milling	------	24	--------	2,220	--------	2,079
Fuel element fabrication and recovery activities	------	13	--------	1,773	--------	1,658
Radioactive waste disposal	------	9	--------	91	--------	67
Nuclear instrument manufacturing	------	106	--------	5,358	--------	4,979
Industrial radiography services	------	62	--------	805	--------	640
Processing and packaging radioisotopes	------	22	--------	407	--------	407
Private research laboratories [3]	------	48	--------	1,198	--------	1,129
Particle accelerator manufacturing	------	8	--------	1,099	--------	933
Miscellaneous	3	67	172	3,114	150	2,547
Total	59	512	108,741	36,293	106,417	32,787

[1] Data for both years from 1965 survey.
[2] Data published with consent of employers.
[3] Excludes nonprofit establishments.

TABLE 2.—EMPLOYMENT BY OCCUPATIONAL CATEGORIES IN GOVERNMENT-OWNED AND PRIVATELY-OWNED INDUSTRIAL ESTABLISHMENTS BY ECONOMIC SEGMENT, JANUARY 1965 [Preliminary data]

	Total employees		Scientists		Engineers		Technicians		All other employees		Percent S&E in R&D	
	Government	Private	Government	Private	Government	Private	Government	Private	Government	Private	Government	Private
Commission laboratories and research facilities	49, 176	-------	7, 289	------	7, 893	------	9, 710	------	24, 284	-------	88. 2	------
Atomic energy defense production facilities	45, 987	464	1, 403	2	3, 503	84	4, 397	100	36, 684	278	29. 6	53. 5
Production of feed materials	6, 964	352	408	15	497	26	475	28	5, 584	283	40. 1	34. 1
Reactor and reactor component design and manufacture	3, 454	14, 094	242	935	1, 172	3, 759	664	2, 705	1, 376	6, 695	87. 1	65. 9
Design and engineering of nuclear facilities [1]	285	1, 593	------	38	142	655	90	420	53	480	3. 5	10. 2
Power reactor operation and maintenance	401	617	18	10	91	152	80	142	212	313	------	3. 1
Production of special materials for reactor use	--------	1, 228	------	54	-------	119	-------	228	-------	827	------	33. 5
Uranium milling	--------	2, 079	------	30	-------	128	-------	120	-------	1, 801	------	9. 5
Fuel element fabrication and recovery activities	--------	1, 658	------	42	-------	184	-------	401	-------	1, 031	------	38. 1
Radioactive waste disposal	--------	67	------	7	-------	5	-------	24	-------	31	------	8. 3
Nuclear instrument manufacturing	--------	4, 979	------	230	-------	763	-------	964	-------	3, 022	------	54. 0
Industrial radiography services	--------	640	------	8	-------	48	-------	479	-------	105	------	7. 4
Processing and packaging radioisotopes	--------	407	------	116	-------	27	-------	142	-------	122	------	25. 9

Private research laboratories [2]	--------	1, 129	------	347	-------	193	-------	363	-------	226	------	79. 4
Particle accelerator manufacturing	--------	933	------	63	-------	143	-------	226	-------	501	------	37. 9
Miscellaneous	150	2, 547	3	102	2	440	13	250	132	1, 755	------	------
Total	106, 417	32, 787	9, 363	1, 999	13, 300	6, 726	15, 429	6, 592	68, 325	17, 470	72. 5	53. 4

[1] Data published with consent of employers.
[2] Excludes nonprofit establishments.

APPENDIX 5

INTERNATIONAL COOPERATION

Table 1.—AGREEMENTS FOR COOPERATION

Bilateral Agreements for Cooperation in the Civil Uses of Atomic Energy

Country	Scope	Effective date	Termination date
Argentina	Research and power	July 29, 1955	July 27, 1969
Australia	do	May 28, 1957	May 27, 1967
Austria	Research	Jan. 25, 1960	Jan. 24, 1970
Brazil [1]	do	Aug. 3, 1955	Aug. 2, 1965
Canada	Research and power	July 21, 1955	July 13, 1980
China, Republic of	Research	July 18, 1955	July 17, 1974
Colombia	do	Mar. 29, 1963	Mar. 28, 1967
Costa Rica	do	Feb. 8, 1961	Feb. 7, 1966
Denmark	do	July 25, 1955	Sept. 7, 1968
France	Research and power	Nov. 20, 1956	Nov 19, 1966
Germany:			
Federal Republic of	do	Aug. 7, 1957	Aug. 6, 1967
City of West Berlin	Research	Aug. 1, 1957	July 31, 1967
Greece [2]	do	Aug. 4, 1955	Aug. 3, 1974
India	Research and power	Oct. 25, 1963	Oct. 24, 1993
Indonesia [3]	Research	Sept. 21, 1960	Sept. 20, 1965
Iran [1]	do	Apr. 27, 1959	Apr. 26, 1964
Ireland	do	July 9, 1958	July 8, 1968
Israel	do	July 12, 1955	Apr. 11, 1975
Italy	Research and power	Apr. 15, 1958	Apr. 14, 1978
Japan	do	Dec. 5, 1958	Dec. 4, 1968
Korea [1]	Research	Feb. 3, 1956	Feb. 2, 1966
Netherlands	Research and power	Aug. 8, 1957	Aug. 7, 1967
Norway	do	June 10, 1957	June 9, 1967
Panama	Research	June 27, 1963	June 26, 1968
Philippines	do	July 27, 1955	July 26, 1968
Portugal	do	July 21, 1955	July 20, 1969
South Africa	Research and power	Aug. 22, 1957	Aug. 21, 1967
Spain [1]	do	Feb. 12, 1958	Feb. 11, 1968
Sweden	Research	Jan. 18, 1956	June 1, 1968
Switzerland [4]	Research and power	Jan. 29, 1957	Jan. 28, 1967
Thailand	Research	Mar. 13, 1956	Mar. 12, 1975
Turkey	do	June 10, 1955	June 9, 1966
United Kingdom	Research and power	July 21, 1955	July 20, 1966
Venezuela	do	Feb. 9, 1960	Feb. 8, 1970
Vietnam	do	July 1, 1959	June 20, 1974

See footnotes at end of tables.

Special Agreements

Organization	Scope	Effective date
European Atomic Energy Community (Euratom).	Joint Nuclear Power Program	2–18–59
Euratom	Additional agreement to Joint Nuclear Power Program.	7–25–60
International Atomic Energy Agency (IAEA).	Supply of materials, etc	8– 7–59
U.S./IAEA/Austria	Trilateral for application of IAEA safeguards to U.S.-supplied materials.	12–13–65
U.S./IAEA/Republic of China	do	10–29–65
U.S./IAEA/Japan	do	11– 1–63
U.S./IAEA/Philippines	do	9–24–65
U.S./IAEA/Portugal	do	12–15–65
U.S./IAEA/South Africa	do	10– 8–65
U.S./IAEA/Thailand	do	9–16–65
U.S./IAEA/Vietnam	do	10–21–65
U.S./IAEA/Argentina	do	[5]
U.S./IAEA/Greece	do	[5]
U.S./IAEA/Iran	do	[5]
U.S./IAEA/Israel	do	[5]
U.S./IAEA/Norway	do	[5]
U.S.-U.S.S.R.[6]	Memorandum on cooperation in peaceful uses (information and personnel exchange).	5–21–63
U.S.-U.S.S.R.[6]	Agreement on cooperation in desalination.	11–18–64

Effective Agreement for Mutual Defense Purposes

	Effective date
NATO [7] [8]	Mar. 12, 1965
Australia [7]	Aug. 14, 1957
Belgium [7]	Sept. 5, 1962
Canada [7]	July 27, 1959
France	July 20, 1959
France [7]	Oct. 9, 1961
Germany, Federal Republic of [7]	July 27, 1959
Greece [7]	Aug. 11, 1959
Italy [7]	May 24, 1961
Netherlands [7]	July 27, 1959
Turkey [7]	July 27, 1959
United Kingdom (subsequently amended) [7]	July 20, 1959

[1] Extending amendment signed but not yet in force.
[2] Provisionally in force.
[3] Extending amendment not yet signed.
[4] Superseding agreement signed but not yet in force.
[5] Effective date to be established.
[6] Under the current U.S.-U.S.S.R. agreement in "Cultural Relations: Exchanges in the Scientific, Technical, Educational, Cultural and Other Fields in 1964-1965."
[7] Provides for various exchanges of classified information.
[8] Superseding agreement in force.

TABLE 2.—DISTRIBUTION ABROAD OF AEC-PRODUCED NUCLEAR MATERIAL

	Enriched uranium (kilograms U-235)				U-233 (grams)		Plutonium (grams)		Heavy water (tons)	
	Less than 20 percent U-235 [1]		Greater than 20 percent U-235 [2]							
	Through calendar year 1964	Calendar year 1965 through Nov. 30	Through calendar year 1964	Calendar year 1965 through Nov. 30	Through calendar year 1964	Calendar year 1965 through Nov. 30	Through calendar year 1964	Calendar year 1965 through Nov. 30	Through calendar year 1964	Calendar year 1965 through Nov. 30
Argentina			9.1	7.2						
Australia	(*)		9.1		1,009		1,920	4,084	13	1
Austria			12.9	.1	1		161	1		
Belgium [3]	103.2		41.3		10	1	306	5	(*)	
Brazil			19.8				80			
Canada	126.7		192.6	89.4			195		165	183
China, Republic of			4.7				95		(*)	
Colombia			2.2				80			
Denmark			15.3		1		81		18	
Euratom	(*)		.2				2		(*)	
Belgium	(*)	2.9	110.7	57.9	18		1,309	91		
Eurochemic					1	2	(*)	14		
France	0.2	123.5	146.1	367.9			7,261			
Germany	1.8	130.9	43.3	623.9			74	189,650		
Italy	2,332.7		94.4	48.7					35	1
Netherlands	(*)	.1	61.8							
France	570.4	97.8	419.5	46.1	18	67	2,127	3,892	30	24
Germany	307.9	35.2	320.4	12.4	2	11	2,478	7	173	
Greece			6.0				112			

IAEA							(*)			
Argentina			2.9							
Austria	(*)	(*)	.2			1	96			
Congo			2.0							
Finland			2.5							
Greece							80			
Norway	59.7									
Pakistan				5.2				112		
Yugoslavia			(*)				(*)			
India									10	
Indonesia			2.4							
Ireland			(*)				16			
Israel	(*)		7.2	1.9	5		526		4	
Italy	2.8	1.8	42.9	23.2	5		138		2	3
Japan	334.3	43.3	63.1	17.0	4		180		51	
Korea			2.4				8			
Netherlands	73.8		18.6	.4	(*)		281	100	2	
New Zealand							30			
Norway	37.0	1.7	(*)				5	1	25	3
Philippines	4.3		(*)				32			
Portugal			6.0							
South Africa			(*)	7.0				159	5	1
Spain	(*)		18.0				5		5	
Sweden	42.7	2.6	178.6	32.1	2		721	402	29	
Switzerland	18.6	.2	19.1		10	20	890		23	1
Thailand			4.8				80			
Turkey		1.2	4.8				288			
United Kingdom	2.6		206.9	253.4	512		578	123	70	
Venezuela			4.9				10			
Vietnam			2.4				80			
Total	4,018.7	441.1	2,099.1	1,593.8	1,598	102	20,375	198,641	660	217

[1] Primarily for fueling power reactors.
[2] Primarily for fueling research and test reactors and other research applications.
[3] As of July 30, 1965.
*Minute quantities.

APPENDIX 6

TECHNICAL INFORMATION

TABLE 1.—AEC-SPONSORED BOOKS, MONOGRAPHS, AND PROCEEDINGS PUBLISHED IN 1965

Title	Authors or editors	Publisher and price
BOOKS		
Thermal Stress Techniques in the Nuclear Industry.	Z. Zudans T. C. Yen. W. H. Steigelmann.	American Elsevier, New York City, $20.
Practical Vacuum Techniques	W. F. Brunner T. H. Batzer.	Reinhold, New York City, $8.25.
The Technology of Nuclear Reactor Safety, vol. 1, Reactor Physics and Control.	T. J. Thompson J. G. Beckerley.	M.I.T. Press, Cambridge, Mass., $25.
Remote Handling of Mobile Nuclear System.	D. C. Layman G. Thornton.	U.S. Atomic Energy Commission [1] $4.50.
MONOGRAPHS (Cooperating society)		
Light: Physical and Biological Action (American Institute of Biological Sciences).	H. H. Seliver W. D. McElroy.	Academic Press, New York City, $12.
Ionizing Radiation—Neural Function and Behavior (American Institute of Biological Sciences).	D. J. Kimeldorf E. L. Hunt.	Academic Press, N York City, $10.
Mammalian Radiation Lethality: A Disturbance in Cellular Kinetics (American Institute of Biological Sciences).	V. P. Bond T. M. Fliedner. J. O. Archambeau.	Academic Press, New York City, $9.50.
Irradiation Effects in Cladding and Structural Materials (American Society for Metals).	S. H. Bush	Rowman & Littlefield, New York City, $4.45 (paperback), $6.95 (hardback).
AEC SYMPOSIUM SERIES		
Radioactive Fallout from Nuclear Weapons Tests (Proceedings).	A. W. Klement, Jr.	U.S. Atomic Energy Commission [1] $6.50.

[1] Available at indicated prices from Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., 22151.

TABLE 2.—SPECIALIZED INFORMATION AND DATA CENTERS SUPPORTED BY AEC

[These centers provide the nuclear science and engineering community with critically evaluated condensations of the vast amount of technical literature existing in the specific fields of interest]

Title	Location	Address
Atomic and Molecular Processes Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn., 37831.
Argonne Code Center	Argonne National Laboratory.	Argonne, Ill., 60440.
Charged Particle Cross Section Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn., 37831.
Information Center for Internal Exposure.	do	Do.
Isotopes Information Center	do	Do.
Man-Made Radiation in the Biosphere.	Lawrence Radiation Laboratory—Livermore.	Livermore, Calif., 94551.
National Oceanographic Data Center.	U.S. Naval Oceanographic Office.	Washington, D.C., 20309.
Neutron Cross Sections Center.	Lawrence Radiation Laboratory—Livermore.	Livermore, Calif., 94551.
Nuclear Data Project	Oak Ridge National Laboratory.	Oak Ridge, Tenn., 37831.
Nuclear Safety Information Center.	do	Do.
Radiation Chemistry Data Center.	University of Notre Dame.	Notre Dame, Ind. 46556.
Radiation Effects Information Center.	Battelle Memorial Institute.	Columbus, Ohio, 43201.
Radiation Shielding Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn., 37831.
Rare-Earth Information Center.	Ames Laboratory	Iowa State University, Ames, Iowa, 50012.
Reactor Physics Constants Center.	Argonne National Laboratory.	Argonne, Ill., 60440.
Research Materials Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn., 37831.
Selected Values of Chemical Thermodynamic Properties.	National Bureau of Standards.	Washington, D.C., 20234.
Sigma Center	Brookhaven National Laboratory.	Upton, Long Island, N.Y., 11973.
Thermodynamic Properties of Metals and Alloys.	Lawrence Radiation Laboratory—Berkeley.	Berkeley, Calif., 94720.

TABLE 3.—TITLES OF BOOKLETS IN THE AEC'S "UNDERSTANDING THE ATOM SERIES"[1]

Accelerators[2]
Atomic Fuel[3]
Atomic Power Safety
Atoms at the Science Fair
Atoms in Agriculture[3]
Atoms, Nature and Man
Careers in Atomic Energy
Controlled Nuclear Fusion
Direct Conversion of Energy[3]
Fallout from Nuclear Tests
Food Preservation by Irradiation
Microstructure of Matter
Neutron Activation Analysis[3]
Nondestructive Testing
Nuclear Power and Merchant Shipping
Nuclear Reactors[3]
Nuclear Terms, A Brief Glossary
Our Atomic World[3]
Plutonium
Popular Books on Nuclear Science
Power From Radioisotopes
Power Reactors in Small Packages
Radioactive Wastes
Radioisotopes in Industry
Rare Earths
Research Reactors
Synthetic Transuranium Elements
Whole Body Counters

[1] Single copies available free from USAEC, Post Office Box 62, Oak Ridge, Tenn., 37831.
[2] Spanish translations also available.
[3] French and Spanish translations also available.

APPENDIX 7

FILM LIBRARIES

As part of its information and education program, the Commission maintains motion picture libraries from which qualified borrowers throughout the United States and Canada may obtain 16 mm. sound films which explain various aspects of atomic energy. All films are loaned free, and only for educational, nonprofit, noncommercial, screenings. Also, many are available for use in unsponsored "public service" telecasts. The Commission's domestic film libraries are located at the following AEC offices and service requests from the following States:

Washington, D.C.	Delaware, District of Columbia, Maryland, Virginia, West Virginia, and Canada.
New York, N.Y.	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.
Aiken, S.C.	Alabama, Florida, Georgia, North Carolina, and South Carolina.
Idaho Falls, Idaho	Idaho, Montana, and Utah.
Berkeley, Calif.	California, Hawaii, and Nevada.
Grand Junction, Colo.	Colorado, Kansas, Nebraska, and Wyoming.
Argonne, Ill.	Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, North Dakota, Ohio, South Dakota, and Wisconsin.
Oak Ridge, Tenn.	Arkansas, Kentucky, Louisiana, Mississippi, and Tennessee.
Albuquerque, N. Mex.	Arizona, New Mexico, Oklahoma, and Texas.
Richland, Wash.	Alaska, Oregon, and Washington.

NEW AEC FILMS MADE AVAILABLE TO PUBLIC DURING 1965

Professional Level

ACCEL: AUTOMATED CIRCUIT CARD ETCHING LAYOUT: 20 minutes, color, produced for the AEC by the Sandia Corp. Describes the computer program which designs printed circuit boards and produces the drawings for their construction with the unusual algorithms used to accomplish the design feat.

ACROMEGALY: DIAGNOSIS-ETIOLOGY-THERAPY: 23 minutes, color, produced by Donner Laboratory and Lawrence Radiation Laboratory. Describes the successful application of heavy particle radiation, obtained from high energy cyclotrons, for treatment of the rare disease, acromegaly.

CURRENT METHODS IN PLUTONIUM FUEL FABRICATION: 30 minutes, color, produced by the Hanford Atomic Products Operation, General Electric Co. Depicts the steps employed in the fabrication of plutonium-uranium ceramic fuel elements for the PRTR and EBWR at Hanford's Plutonium Fabrication Pilot Plant.

FABRICATION OF THE ACCELERATOR STRUCTURE: 40 minutes, color, produced by the Stanford Linear Accelerator Center. Describes the methods used in the fabrication of the accelerating structure and associated components for the AEC's 2-mile linear electron accelerator being built at Stanford University.

NEUTRON IMAGE DETECTOR: 5⅔ minutes, color, produced by Argonne National Laboratory. Describes a new vacuum tube which contains a neutron-sensitive screen 1 foot in diameter.

RFD-2: 14 minutes, color, produced by Sandia Corp. Investigates experimentally the disassembly design of an inert SNAP isotopic generator to determine the history of fuel capsule exposure to reentry heating; measures heat rates and correlates analytical predictions with flight test data.

SNAPTRAN 2/10A WATER IMMERSION TEST: 20 minutes, color, produced by Phillips Petroleum Co. as contractor for the AEC at the National Reactor Testing Station, Idaho. Portrays a test which investigated the effects of water immersion on a SNAP-10A aerospace reactor.

SPERT DESTRUCTIVE TEST, Part I, On Aluminum, Highly Enriched Plate Type Core: 15 minutes, color, produced by Phillips Petroleum Co. as contractor for the AEC at the National Reactor Testing Station, Idaho. Documents the destructive test program of a highly-enriched, aluminum plate-type core in the SPERT-I reactor.

A STUDY OF GRAIN GROWTH IN BeO USING A NEW TRANSMITTED LIGHT HOT STAGE: 16½ minutes, color, produced for the AEC by Atomics International. Depicts the design and operation of a new hot stage used with a polarizing microscope and transmitted light.

TERNARY PHASE DIAGRAM: 7 minutes, color, produced by Lawrence Radiation Laboratory. Depicts the development of a new and rapid technique for preparation of ternary phase diagrams required in the search for useful alloys.

TRANSCURIUM ELEMENTS: SYNTHESIS, SEPARATION, AND RESEARCH: 31 minutes, color, produced by the AEC's Lawrence Radiation Laboratory. Describes three basic transcurium research experiments to further the knowledge of the chemical nature and nuclear structure of the recently discovered heavy elements, berkelium, californium, einsteinium, and fermium.

TRANSPORTATION OF RADIOACTIVE MATERIALS, PART II, ACCIDENTS: 34½ minutes, black and white, produced under the technical direction of the AEC's Division of Operational Safety. A Commission safety engineer discusses the control of transportation accidents involving radioactive materials.

TRANSPORTATION OF RADIOACTIVE MATERIALS, PART III, PRINCIPLES OF REGULATION: 15½ minutes, black and white. Lecture film by two AEC safety engineers who discuss the basic principles underlying two sets of regulations for the transportation of radioactive materials—those of the U.S. Interstate Commerce Commission and those of the International Atomic Energy Agency.

THE WOODEN OVERCOAT: 14 minutes, color, produced for the AEC by the Sandia Corp. Shows the development and testing of the wooden jackets for the safe transportation of radioactive materials.

Professional and Popular Level

CLEAN AIR IS A BREEZE (Airborne Contamination Control Through Laminar Air Flow): 16 minutes, color, produced by the Sandia Corp. for the AEC. The theory and basic operating principles of laminar airflow systems (various clean rooms and clean benches), application of such devices to industrial processes, research and development problems, and to the field of medical care and medical research are illustrated.

EXPERIMENTS IN CONTROLLING BRUSH FIRES WITH DETERGENT FOAM: 6½ minutes, color, produced by AEC's Argonne National Laboratory. Describes a series of tests to explore the use of detergent foam as a fire break.

THE NUCLEAR WITNESS—ACTIVATION ANALYSIS IN CRIME INVESTIGATION: 28 minutes, color, produced by General Atomic Division of General Dynamics Corp. for the AEC. With three examples of police investigation, illustrates the powerful analytical technique of making samples of various elements radioactive, then identifying and measuring the induced radioactivities to complete the quantitative analysis.

PAX ATOMIS: SNAP-7 TERRESTRIAL ISOTOPIC POWER SYSTEMS: 25 minutes, color, produced for the AEC by the Martin Co. Summarizes the parallel development of a family of fully shielded thermoelectric power converters and chemical processing of the radioisotope strontium 90 fuel.

PLOWSHARE: 28 minutes, color, produced by AEC's San Francisco Operations Office. Describes the Commission's program for the safe use of nuclear explosives for civilian applications for mining and petroleum applications, for performing massive earthmoving and excavation projects for all nations.

PROJECT DUGOUT: 8½ minutes, color, produced by AEC's Lawrence Radiation Laboratory. Reports on a chemical high explosive experiment conducted June 24, 1964, at the Nevada Test Site in the Commission's Plowshare program.

SNAPSHOT: 29 minutes, color, produced for the AEC by Atomics International. Describes the scheduled flight test in space of the 500-watt SNAP-10A nuclear reactor which was placed in orbit by an Atlas-Agena booster system launched from Vandenberg Air Force Base.

FIRST REACTOR IN SPACE: SNAP-10A; 15 minutes. Produced for the AEC by Atomics International. Story of the preparation for and launching of the first nuclear reactor into space—the Snapshot test flight to obtain technical data for the application of nuclear reactor direct-conversion electrical power systems in satellites and spacecraft.

Popular Level

ATOMS ON THE MOVE: THE TRANSPORTATION OF RADIOACTIVE MATERIALS: 28 minutes. Produced by AEC's New York Operations Office. Tells how radioactive materials are packed and shipped safely by plane, train, automobile, and ship. Details given on packaging and labeling, safety testing of containers, and the handling of accidents.

THE NEW POWER—STORY OF THE NATIONAL REACTOR TESTING STATION: (Revised version, 1965) 45 minutes, color, produced by the AEC's Idaho Operations Office. Tells how some 25 reactors being operated and built at the NRTS in Idaho are furthering development of economic nuclear power, naval propulsion reactors, fast breeder reactors, and reactor safety.

POWER FOR PROPULSION: 15 minutes, color, produced by the Aerojet-General Corp. Traces the history of power sources for propulsion, illustrates principles of rocketry, operation of nuclear rocket engines, development of NERVA, including its first test firing at the AEC–NASA Nuclear Rocket Development Station.

RADIOISOTOPE SCANNING IN MEDICINE: 16 minutes, produced by Handel Film Corp. Radioactive drugs give off signals that can be converted into black and white or color pictures, to reveal valuable medical diagnosis information about the size, shape, position, and functioning of organs.

THE RIDDLE OF PHOTOSYNTHESIS: 14½ minutes, color and/or black and white, produced by Handel Film Corp. Shows the role of photosynthesis in growth of food, and use of radiocarbon to explore the process; describes, with animation, key steps in one of the experiments designed to help solve the riddle.

TOMORROW'S SCIENTISTS AT ARGONNE: 13½ minutes, black and white, produced by Argonne National Laboratory. Shows the AEC special award winners, selected at the 16th National Science Fair-International, experiencing "Nuclear Research Orientation Week."

APPENDIX 8

SUMMARY OF LICENSING ACTIONS

Facilities [1]	Sept. 1, 1954, to Nov. 30, 1965	Nov. 30, 1964 to Nov. 30, 1965	Permits and licenses in effect as of Nov. 30, 1965
Power reactors (part 50):			
Construction permits	17	3	6
Construction permit amendments and orders	31	4	----------
Licenses to operate	12	1	12
License amendments, authorizations and orders	310	93	----------
Power reactors (part 115):			
Construction authorizations	5	0	1
Construction authorization amendments	1	0	----------
Operating authorizations	7	1	4
Operating authorization amendments	53	17	----------
Test reactors:			
Construction permits	5	0	1
Construction permit amendments and orders	5	0	----------
Licenses to operate	4	0	4
License amendments and authorizations	52	5	----------
Research reactors:			
Construction permits	89	8	[2] 8
Construction permit amendments and orders	80	4	----------
Licenses to operate (including acquire and operate)	93	3	68
License amendments	455	95	----------
Terminations	25	3	----------
Reactor exports:			
Research reactor licenses	47	3	(3)
Test reactor licenses	3	0	(3)
Power reactor licenses	[4] 8	1	(3)
Critical experiment facilities	[5] 1	0	(3)
License amendments	79	4	----------
Critical experiment facilities:			
Construction permits	24	1	0
Construction permit amendments and orders	14	0	----------
Licenses to operate	23	1	17
License amendments	112	16	----------

See footnotes at end of table.

Facilities	Sept. 1, 1954, to Nov. 30, 1965	Nov. 30, 1964 to Nov. 30, 1965	Permits and licenses in effect as of Nov. 30, 1965
Production facilities:			
Construction permits	2	0	1
Construction permit amendments and orders	5	0	0
Licenses to operate	0	0	0
Operator licenses (including senior)	2, 507	272	1, 662
Operator license amendments and renewals	1, 420	319	----------
Operator license denials	289	44	----------
Special nuclear material licenses	918	88	584
SNM license amendments and renewals	2, 513	619	----------
SNM license denials	7	0	----------
Source material licenses issued or renewed	9, 412	168	441
Source material export licenses	5, 136	116	[3]
Source material license denials	12	0	----------
Byproduct material licenses (domestic use)	[6] 20, 319	1, 635	8, 435
Byproduct material license amendments	[7] 44, 407	6, 143	----------

[1] Applications to construct and operate are filed simultaneously; conversions from construction permits to licenses to operate are made upon satisfactory completion of construction.

[2] Permits authorize construction of 11 reactors.

[3] Export licenses terminate upon completion of shipment.

[4] Two power reactors exported under a single license, July 17, 1964.

[5] A power reactor and a critical facility exported under a single license Mar. 16, 1962.

[6] Prior to Feb. 10, 1956, procurement authorizations were issued.

[7] From July 1956 through Nov. 30, 1965.

APPENDIX 9

RULES AND REGULATIONS

The Commission's regulations are contained in Title 10, Chapter I of the Code of Federal Regulations. Effective and proposed regulations concerning licensed activities, and published in the *Federal Register* during 1965, are set forth below.

REGULATIONS AND AMENDMENTS PUT INTO EFFECT

Part 20—"Standards for Protection Against Radiation"

On November 23, 1965, Part 20 was amended to extend the retention period for records of individual radiation exposure to December 31, 1970, or until a date five years after the individual's employment, whichever is later. The rule became effective December 23, 1965.

On December 22, 1965, an amendment to Part 20 was published to revise Appendix B, Concentrations in Air and Water Above Natural Background, as follows: concentration values are added for certain individual radionuclides not presently listed, and generally applicable values are provided for any radionuclide not individually listed. Existing values for occupational exposure to soluble strontium 90 also are revised. The effective date of the amendment is January 21, 1966.

Parts 30–36—"Licensing of Byproduct Material"

On January 7, 1965, an amendment to Part 30 was issued which permits, under certain conditions, intervals longer than six months for leak testing and testing of the on-off mechanism of certain devices possessed under general license. The amendment also includes requirements for reporting of transfers of devices and results of leak tests showing 0.005 microcurie or more of removable radioactive material. The amendment became effective February 6, 1965.

On March 13, 1965, Part 30 was amended to extend the exemption for tritium activated automobile lock illuminators and the general license for tritium activated luminous aircraft safety devices to include units activated by promethium 147. The amendment also sets out specific licensing criteria for the manufacture or import of such items. The rule became effective April 12, 1965.

On March 16, 1965, the Commission published a policy statement in the *Federal Register* setting forth criteria which the Commission will use for approval of products containing byproduct or source material and intended for use by the general public.

On April 3, 1965, Parts 30 and 150 were amended to make it clear that persons holding an agreement State specific license are authorized under the conditions of the general license provided in § 150.20 of Part 150 to introduce byproduct material in exempt concentrations into products or materials for persons in nonagreement States who are not licensed by the Commission. The rule became effective May 3, 1965.

On May 13, 1965, a general license was issued authorizing the use by physicians of the following well-established and useful medical diagnostic applications of radioisotopes: Iodine 125 (or iodine 131) as iodinated human serum albumin for determinations of blood and blood plasma volume; iodine 131 as sodium iodide for measurement of thyroid uptake; cobalt 58 (or cobalt 60) for the measurement of intestinal absorption of cyanocobalamin; and chromium 51 as sodium radiochromate for determination of red blood cell volumes and studies of red blood cell survival time. The general license became effective June 12, 1965.

On June 26, 1965, Parts 30 and 31 were recodified to provide an expanded format and more suitable organization of the byproduct material licensing regulations. Common requirements applicable to all byproduct material licensing were retained in Part 30 and the remainder of the sections were relocated in new Parts 31, 32, 33, 34, 35, and 36. The recodification became effective August 25, 1965.

On August 10, 1965, Part 31 was amended to provide a general license for 50 microcuries of strontium 90 when contained in an ice detection device. Part 32 was amended to set out criteria for Commission issuance of specific licenses for manufacture or import of the ice detection devices. The amendments became effective September 9, 1965.

On August 24, 1965, Part 31 was amended to modify the labeling requirements for certain generally licensed gaging devices so that the specified label may be used on devices within either agreement States or nonagreement States. The amendments also make it clear that devices which do not require "installation" in the usual sense may be possessed under the general license. The rule became effective September 23, 1965.

On December 10, 1965, Parts 36 and 40 were amended to clarify the Commission's licensing requirements with respect to export of byproduct material and import of byproduct and source material by licensees of agreement States. The rule became effective January 9, 1966.

Part 40—"Licensing of Source Material"

On December 22, 1965, an amendment was published to exempt from the licensing requirements of Part 40 small quantities of thorium contained in certain electric lamps used for illuminating purposes. The effective date of the amendment is January 21, 1966.

Part 140—"Financial Protection Requirements and Indemnity Agreements"

On November 30, 1965, Part 140 was amended with respect to levels of financial protection required of licensees of facilities having a rated capacity of 100 Mw(e) or more to reflect changes in the Act made in P.L. 89–210 and the increase in the maximum amount of privately-available insurance. The amount of financial protection for such facilities set out in Part 140 is increased to $74 million. The corresponding reduction in the amount of indemnity the Commission is authorized to extend to licensees also is incorporated in the amendments. The effective date of the amendments is January 1, 1966.

Part 150—"Exemptions and Continued Regulatory Authority in Agreement States Under Section 274"

On September 22, 1965, § 150.11(b) of Part 150 was amended to provide that in determining whether the exemption of special nuclear material in quantities insufficient to form a critical mass, contained in § 150.10, applies at any particular authorized location of use, only the special nuclear material which the person is authorized to receive, possess or use at that location at any one time need be included in the computation. The amendment became effective October 22, 1965.

Utilization Facility Ruling

On August 5, 1965, the Commission determined by rule that the Fission Product Conversion and Encapsulation Facility to be built by Isochem, Inc., at Hanford, Washington, is a utilization facility as defined in the Atomic Energy Act.

PROPOSED REGULATIONS AND AMENDMENTS

Part 2—"Rules of Practice"

Part 50—"Licensing of Production and Utilization Facilities"

Part 115—"Procedures for Review of Certain Nuclear Reactors Exempted From Licensing Requirements"

On November 5, 1965, proposed amendments to Parts 2, 50 and 115 were published, which would eliminate review of initial decisions by the petition for review procedure and substitute therefor appeals as of right by the filing of exceptions.

Part 30—"Licensing of Byproduct Material"

On September 17, 1965, proposed amendments of Parts 30 and 32 were published which would exempt from licensing certain quantities of tritium contained in luminous thermostat dials and pointers, radio dials and pointers, automobile shift quadrants, and marine compasses, provide criteria for issuance of specific licenses for manufacture of those items and consolidate certain sections of Parts 30 and 32.

Part 50—"Licensing of Production and Utilization Facilities"

Part 70—"Special Nuclear Material"

Part 115—"Procedures for Review of Certain Nuclear Reactors Exempted From Licensing Requirements"

Part 140—"Financial Protection Requirements and Indemnity Agreements"

On September 21, 1965, proposed amendments to Parts 50, 70, 115 and 140 were published, which would reflect the authority granted the Commission by Public Law 88–489 (Private Ownership of Special Nuclear Materials Act of 1964) to issue licenses to receive title to, own, acquire, deliver, import or export special nuclear material (*i.e.*, the private ownership amendments).

Part 140—"Financial Protection Requirements and Indemnity Agreements"

On September 16, 1965, a proposed amendment to an endorsement to the form of nuclear energy liability policy set forth in Appendix A of Part 140 was published for public comment. The amendment proposes an alternative paragraph which would provide, in cases where reduction of limit of liability results from a clearly identifiable nuclear event, for restoration of the limit of liability coverage retroactive to the effective date of the policy for claims other than those resulting from the identified event.

On November 30, 1965, public comments were solicited on the question of whether the Commission should effect a proportional increase in the financial protection requirements for licensees of power or testing reactors having an authorized thermal power level in excess of one megawatt but having a rated electrical capacity less than 100,000 kilowatts.

Part 30—"Licensing of Byproduct Material"

Part 70—"Special Nuclear Material"

Part 71—"Transport of Licensed Radioactive Material"

On December 21, 1965, a proposed amendment of 10 CFR 71 was published for 60 day comment. The proposed amendment would extend the scope of the regulation to include the radiation aspects of shipments of "large quantities" of licensed radioactive materials as well as both the radiation and criticality aspects of shipments of special nuclear (fissile) material.

On December 21, 1965, proposed amendments to Parts 30 and 70 were published for a 60 day comment period which would provide that general authority to transfer byproduct and special nuclear material may be exercised only on condition that material is transported in accordance with 10 CFR 71.

APPENDIX 10

AEC FINANCIAL SUMMARY FOR FISCAL YEAR 1965*

The Atomic Energy Commission is an independent agency responsible to the President and Congress. Established by the Atomic Energy Act of 1946, its functions and responsibilities were expanded by the Atomic Energy Act of 1954 to put greater emphasis on the peaceful uses of atomic energy.

Funds are provided to the AEC in two congressional appropriations—one for construction and one for operations. The AEC accounting system, therefore, must comply with the requirements of Federal Government fund accounting. In addition, since the AEC is engaged in large industrial and research activities, those responsible for its management require knowledge of the cost of each step in its operations. The AEC accounting system, approved by the U.S. General Accounting Office, provides the essential cost information through the application of commercial accrual and cost accounting principles, including the recording of depreciation. For the AEC, both governmental and commercial accounting have been combined into a single system. Consequently, the principles of both underlie the preparation of this report.

Most of the work involved in actually achieving the AEC goals is performed by commercial firms and educational or other non-profit organizations under contract to the AEC. Government-owned facilities are operated by these contractors who maintain complete accounting records on their AEC contract activities that are an integral part of the Commission's accounting system. The summary contained in the following pages is a consolidation of unclassified information obtained from financial reports made to the AEC by its contractors as well as information obtained from the AEC records.

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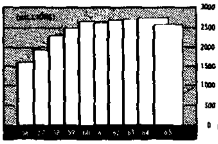
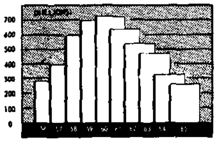
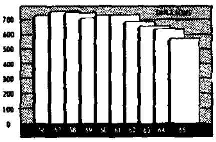
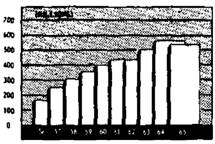
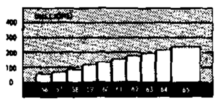
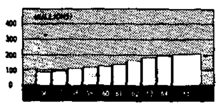
*Material in this appendix is extracted from the "U.S. Atomic Energy Commission 1965 Financial Report," available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, price 35 cents.

SUMMARY OF NET OPERATING COSTS

	1965 (Millions)	
 TOTAL OPERATING COSTS	$2,570	100%
 PROCUREMENT OF RAW MATERIALS	$ 261	10%
 PRODUCTION OF NUCLEAR MATERIALS	$ 571	22%
 WEAPONS DEVELOPMENT AND FABRICATION	$ 763	30%
 REACTOR DEVELOPMENT	$ 536	21%
 PHYSICAL RESEARCH	$ 237	9%
 OTHER PROGRAMS	$ 202	8%

STATEMENT OF OPERATIONS

	Fiscal Year 1965 [In thousands]	Fiscal Year 1964 [In thousands]
Production:		
Procurement of raw materials	$261,082	$326,338
Production of nuclear materials	571,301	636,366
Weapons development and fabrication	763,128	804,598
Total	1,595,511	1,767,302
Research and development:		
Development of nuclear reactors	535,875	561,191
Physical research	236,980	215,682
Biology and medicine research	84,417	77,352
Peaceful application for nuclear explosives	12,316	13,921
Isotopes development	9,853	8,521
Total	879,441	876,667
Community operations:		
Expenses	8,903	10,591
Revenues	(5,341)	(5,706)
Total	3,562	4,885
Sales of materials and services:		
Cost	28,615	14,251
Revenue	(34,168)	(15,400)
Total	(5,553)	(1,149)
Education and training	9,536	9,221
AEC administrative expenses	80,258	72,866
Security investigations	5,286	6,282
Other expenses	9,271	9,954
Other income	(7,514)	(6,970)
Net cost of operations*	2,569,798	2,739,058
Special items:		
Adjustments to costs of prior years—net	91,814	(3,575)
Transfers to inventories—net	(120,363)	(24,011)
Net cost of operations—after special items*	$2,541,249	$2,711,472

*Includes depreciation of $324 million in 1965 and $302 million in 1964.

BALANCE SHEET

[In thousands]

ASSETS*	June 30, 1965	June 30, 1964
Cash:		
Funds in U.S. Treasury	$1,559,105	$1,559,546
Cash on hand and with contractors	21,398	22,492
Transfers from other agencies	7,777	19,868
Total	1,588,280	1,601,906
Accounts receivable:		
Federal agencies	36,143	25,501
Other	27,342	17,589
Total	63,485	43,090
Inventories:		
Source and nuclear materials leased and at research installations	789,523	707,503
Special reactor materials	102,505	101,486
Stores	84,896	102,844
Isotopes	33,662	27,795
Other special materials	14,385	15,374
Total	1,024,971	955,002
Plant:		
Completed plant and equipment	8,470,362	8,169,613
Less—Accumulated depreciation	2,914,493	2,592,221
Subtotal	5,555,869	5,577,392
Construction work in progress	400,677	408,556
Total	5,956,546	5,985,948
Other	56,618	56,428
TOTAL ASSETS	$8,689,900	$8,642,374

LIABILITIES AND AEC EQUITY*	June 30, 1965	June 30, 1964
Liabilities:		
Accounts payable and accrued expenses	$300,759	$324,910
Advances from other agencies	18,585	33,275
Funds held for others	14,979	12,501
Accrued annual leave of AEC employees	9,290	8,629
Deferred credits	11,709	5,468
Total liabilities	355,322	384,783
AEC equity, July 1	8,257,591	8,192,933
Additions:		
Funds appropriated—net	2,624,555	2,742,661
Nonreimbursable transfers from other agencies	13,535	55,147
Total	2,638,090	2,797,808
Deductions:		
Net cost of operations—after special items	2,541,249	2,711,472
Nonreimbursable transfers to other agencies	19,838	21,633
Funds returned to U.S. Treasury	16	45
Total	2,561,103	2,733,150
AEC equity, June 30	8,334,578	8,257,591
TOTAL LIABILITIES AND AEC EQUITY	$8,689,900	$8,642,374

*The notes on the following page are an integral part of this statement.

NOTES TO THE BALANCE SHEET

1. *The Balance Sheet does not include in assets:*
   a. Certain inventories for security reasons.
   b. 64,751,316 troy ounces of silver loaned to AEC by the Treasurer of the United States for use as electrical conductors in plants. Of this amount, 280,500 troy ounces have been lost in usage and are, therefore, not returnable. Based on market quotations at June 30, 1965, the value of the silver on loan was $83,723,000. The value of silver lost and the cost of recovering and processing that on hand and returning it to the Treasury is estimated at $678,000.
   c. Plant and equipment on loan from other Federal Agencies at June 30, 1965, amounting to $32,804,000.
   d. Contested claims against others of $3,150,000.
2. *The Balance Sheet does not include in liabilities:*
   a. Contingent liabilities related to contracts for the supply of electric power and natural gas for the Oak Ridge, Paducah, and Portsmouth production facilities. If cancellation notice had been given at June 30, 1965, the estimated liabilities would have amounted to $219,871,000.
   b. Contingent liabilities as guarantor of loans to the extent of $6,057,491.
   c. Contingent liabilities for claims against AEC of approximately $57,204,000.
   d. Commitments for an estimated 52,700 tons of U_3O_8 at an estimated cost of $790,000,000.
   e. Commitments under section 56 of the Atomic Energy Act of 1954, as amended, for the acquisition of plutonium and uranium enriched in the isotope 233. Estimated commitments of $2,216,000 for fiscal year 1966 are based upon projected quantities of plutonium and uranium enriched in the isotope 233 to be produced by domestic licensees and delivered to AEC during this period. There is also additional liability, difficult to estimate accurately at this time, for purchase under section 56 of additional quantities of reactor-produced plutonium and uranium enriched in the isotope 233 which may be delivered to the AEC in future years but prior to January 1,1971.
   f. Outstanding contracts, purchase orders, and other commitments of $1,079,000,000.

COSTS INCURRED BY RESEARCH LABORATORIES

A major portion of AEC research and development is conducted in Government-owned laboratories. On June 30, 1965, the investment in major laboratories was $1.6 billion. The AEC's investment in research facilities totaled $2.4 billion. These facilities include research reactors, particle accelerators, general laboratory buildings, equipment and research devices. The research and development work conducted in AEC-owned laboratories includes civilian reactor design and development, research in the physical and life sciences, nuclear weapons development, peaceful applications for nuclear explosives, and research to improve nuclear materials, processes, and techniques.

The 10 laboratories listed below are the principal AEC-owned research centers. The operating costs of these laboratories together with the costs incurred at other AEC-owned installations and the cost of the work performed in facilities owned by universities, industrial, and other privately-owned organizations are included in the costs of the various research areas shown in this summary.

Laboratories	Cost of completed plant June 30, 1965	Operating costs fiscal year [in thousands]	
		1965	1964
Ames Research Laboratory	$13,282	$7,364	$6,777
Argonne National Laboratory [1]	272,311	77,942	70,868
Bettis Atomic Power Laboratory [1]	128,575	62,599	72,124
Brookhaven National Laboratory	188,252	52,703	47,689
Knolls Atomic Power Laboratory [1]	137,191	51,781	54,224
Lawrence Radiation Laboratory [2]	253,143	151,684	154,997
Los Alamos Scientific Laboratory [2]	211,584	97,533	96,838
Oak Ridge National Laboratory	237,541	78,668	74,819
Pacific Northwest Laboratory [3]	82,458	28,038	26,261
Savannah River Laboratory	61,240	15,246	16,893

[1] Includes facilities at NRTS, Idaho.
[2] Includes facilities at Mercury, Nev.
[3] Prior to Jan. 1, 1965 this facility was known as Hanford Laboratories.

COSTS INCURRED BY GEOGRAPHICAL LOCATIONS

The following table shows the costs incurred by the AEC in fiscal year 1965. Allocations of costs are made in accordance with the physical location of contractors and AEC offices but do not necessarily represent funds spent in those locations.

[In thousands]

Location	Operations [1]	Plant and capital equipment	Total
Alabama	$128	$1	$129
Alaska	45		45
Arizona	8,666		8,666
Arkansas	1,290		1,290
California	275,551	74,723	350,274
Colorado	62,836	8,692	71,528
Connecticut	26,520	3,743	30,263
Delaware	63	3	66
District of Columbia	11,263	1,174	12,437
Florida	16,903	1,787	18,690
Georgia	962		962
Hawaii (Including Pacific Test Area)	21,679		21,679
Idaho	61,821	27,621	89,442
Illinois	75,096	19,506	94,602
Indiana	6,785	75	6,860
Iowa	15,819	3,774	19,593
Kansas	468		468
Kentucky	66,069	1,259	67,328
Louisiana	360		360
Maine	271		271
Maryland	39,243	216	39,459
Massachusetts	25,108	6,013	31,121
Michigan	3,993	807	4,800
Minnesota	3,772	30	3,802
Mississippi	149		149
Missouri	103,137	6,977	110,114
Montana	28		28
Nebraska	1,456	411	1,867
Nevada	146,096	28,455	174,551
New Hampshire	108		108
New Jersey	15,351	3,596	18,947
New Mexico	379,043	50,979	430,022
New York	102,492	22,893	125,385
North Carolina	1,302	155	1,457
North Dakota	19		19
Ohio	121,890	8,834	130,724
Oklahoma	185		185
Oregon	681		681
Pennsylvania	89,227	8,714	97,941
Puerto Rico	2,673	1,760	4,433
Rhode Island	670		670
South Carolina	81,448	10,846	92,294
South Dakota	4,817		4,817
Tennessee	214,715	40,497	255,212
Texas	12,921	4,321	17,242
Utah	26,537	70	26,607
Vermont	27	18	45
Virginia	2,639		2,639
Washington	135,278	21,020	156,298
West Virginia	175		175
Wisconsin	3,809	4,606	8,415
Wyoming	34,957		34,957
Foreign Countries	88,396	339	88,735
Totals	$2,294,937	$363,915	$2,658,852

[1] Excludes depreciation.

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COSTS INCURRED BY COLLEGES AND UNIVERSITIES

In addition to the activities of the AEC laboratories, some of which are operated for AEC by universities or associations of universities, the AEC had other contracts with 304 colleges or universities for atomic energy work. The table below shows that the cost of this work totaled about $108 million in fiscal year 1965 and identifies each university where costs in excess of $500,000 were incurred.

Colleges and universities	Fiscal year 1965	
	Rank by dollar volume of costs incurred	Total costs* (in thousands)
Brown University	39	$545
California Institute of Technology	11	2,480
California, University of	4	5,485
California, University of, at Los Angeles	10	2,704
Carnegie Institute of Technology	17	1,762
Case Institute of Technology	25	1,039
Chicago, University of	18	1,459
Colorado, University of	31	772
Columbia University	5	4,541
Cornell University	22	1,332
Duke University	30	780
Florida State University	27	880
Harvard University	3	6,236
Illinois Institute of Technology	36	620
Illinois, University of	7	4,318
Johns Hopkins University	28	876
Maryland, University of	26	1,001
Massachusetts Institute of Technology	2	7,295
Michigan State University	33	713
Michigan, University of	12	2,185
Minnesota, University of	19	1,427
New York University	15	2,166
Notre Dame, University of	23	1,201
Ohio State University	41	514
Pennsylvania State University	34	638
Pennsylvania, University of	13	2,181
Princeton University	1	15,765
Puerto Rico, University of	14	2,167
Purdue University	21	1,359
Rensselaer Polytechnic Institute	24	1,162
Rice University	35	637
Rochester, University of	6	4,501
Southern California, University of	40	522
Stanford University	37	617
Tennessee, University of	20	1,365
Texas, University of	32	752
Utah, University of	29	848
Virginia, University of	38	559
Washington, University of	16	1,969
Wisconsin, University of	9	2,820
Yale University	8	3,230
Other (263 colleges or universities)		14,207
Total		$107,630

*These costs exclude depreciation and include construction and capita lequipment.

COSTS INCURRED BY PRINCIPAL PRIME INDUSTRIAL CONTRACTORS

Private industrial organizations working under contract with the AEC perform most of the production and much of the research and development work accomplished by the AEC. In fiscal year 1965, the AEC's principal prime industrial contractors accomplished work amounting to some $1,766 million. The following table lists the industrial, supply, production, and research and development contractors who incurred costs exceeding $5 million.

Industrial organizations	Fiscal year 1965	
	Rank by dollar volume of costs incurred	Total costs* (in thousands)
ACF Industries, Inc.	14	$27, 047
Aerojet-General Corp.	10	44, 398
American Metal Climax, Inc.	34	6, 555
Anaconda Co.	25	12, 034
Atlas Corp.	13	29, 677
Atomics International Div., N. American Aviation, Inc.	8	61, 775
Bendix Corp.	4	100, 083
Catalytic Construction Co.	31	8, 321
Combustion Engineering Corp.	35	6, 457
Dow Chemical Co.	12	38, 073
Edgerton, Germeshausen & Grier, Inc.	15	26, 280
E. I. duPont de Nemours & Co.	6	89, 141
Federal-Radorock-Gas Hills Partners	37	5, 650
Fluor Corporation, Ltd.	27	9, 850
General Atomic Division, General Dynamics Corp.	26	10, 009
General Electric Co.	3	196, 453
Goodyear Atomic Corp.	7	63, 393
H. K. Ferguson Co.	32	8, 056
Homes & Narver, Inc.	17	24, 150
Homestake-Sapin Partners	22	18, 136
Kermac Nuclear Fuels Corp.—Kerr-McGee Oil Industries, Inc.	16	25, 068
Mallinckrodt Chemical Works	30	8, 986
Mason & Hanger—Silas Mason Co.	20	19, 582
Mines Development, Inc.—Susquehanna Corp.	33	7, 639
Monsanto Research Corp.—Monsanto Co.	19	22, 195
National Lead Co.	18	23, 287
Pan American World Airways, Inc.	24	13, 367
Petrotomics Co.	36	5, 739
Phillips Petroleum Co.	11	40, 267
Pratt & Whitney Aircraft Division of United Aircraft Corp.	21	19, 028
Reynolds Electrical and Engineering Co., Inc.	5	96, 829
Sandia Corp.—Western Electric Co., Inc.	2	217, 919
Union Carbide Corp.	1	218, 100
United Nuclear Corp.	23	15, 952
Utah Construction & Mining Co.	29	9, 421
Western Nuclear, Inc.	28	9, 749
Westinghouse Electric Corp.	9	61, 089
Other		166, 502
Total		$1, 766, 257

*These costs exclude depreciation and include construction and capital equipment.

AEC PLANT AND EQUIPMENT BY LOCATION

(At cost) June 30, 1965

LOCATION AND CONTRACTOR	AUTHORIZED PLANT AND EQUIPMENT (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
California				
Lawrence Radiation Laboratory, University of California:				
Berkeley	$93.4	$3.0	$11.6	$108.0
Livermore	151.7	8.1	49.3	209.1
Total	245.1	11.1	60.9	317.1
Stanford University, Palo Alto:				
Linear electron accelerator	26.8	39.2	48.0	114.0
Other research facilities	3.9	.9	8.0	12.8
Total	30.7	40.1	56.0	126.8
Research facilities, Sandia Corp., Livermore	19.9	.6	2.1	22.6
Medical research facilities, University of California, Los Angeles	1.6		.1	1.7
Research facilities, California Institute of Technology, Pasadena	2.2		2.0	4.2
Reactor and research facilities, Atomic International Division, North American Aviation, Inc., Canoga Park—Santa Susana	43.7	7.4	7.3	58.4
Bio-Med research facilities, University of California—Davis	3.1	.1	.9	4.1
Reactor Facilities, Aerojet-General, San Ramon	.9		.3	1.2
Reactor Facilities, Aerojet-General, Sacramento	.8			.8
Total	72.2	8.1	12.7	93.0
Total California	348.0	59.3	129.6	536.9
Colorado				
Uranium handling, sampling and general facilities, Lucius Pitkin, Inc., Grand Junction	4.1		.1	4.2
Rocky Flats Plant, Dow Chemical Co., Boulder	103.4	8.5	21.4	133.3
University of Colorado, Boulder	1.4		.1	1.5
Total Colorado	108.9	8.5	21.6	139.0
Connecticut				
Pratt and Whitney, Middletown	67.7	1.0	2.3	71.0
Linear accelerator, Yale University, New Haven	4.6	2.3	2.2	9.1
Submarine reactor facilities, Combustion Engineering, Inc., Windsor	15.1			15.1
Total Connecticut	87.4	3.3	4.5	95.2

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

LOCATION AND CONTRACTOR	AUTHORIZED PLANT AND EQUIPMENT (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
FLORIDA				
Pinellas Plant, General Electric Co., Clearwater	$16.1	$0.5	$3.3	$19.9
IDAHO				
Idaho Falls:				
National Reactor Testing Station, Phillips Petroleum Co.:				
Chemical processing plant	55.6	.1	.9	56.6
Waste storage facility	7.8	.7	.9	9.4
Advanced test reactor	.2	41.9	9.9	52.0
Materials test reactor	15.0	.2	.2	15.4
Engineering test reactor	15.8			15.8
MTR-ETR facilities	20.4	.1	.6	21.1
Nuclear safety engineering test facilities	5.0	2.4	17.0	24.4
Reactor facilities	37.5	1.1	10.5	49.1
General facilities	51.0	.2	3.8	55.0
Total	208.3	46.7	43.8	298.8
Westinghouse Electric Corp:				
Large ship reactor	35.7	.3		36.0
Submarine thermal reactor	16.1	1.4		17.5
Other research facilities	15.9	1.7	4.3	21.9
Total	67.7	3.4	4.3	75.4
Reactor facilities, Argonne National Laboratory	23.6	17.8	22.6	64.0
Knolls Atomic Power Laboratory, General Electric Co	19.8		.5	20.3
Experimental Beryllium Oxide Reactor, General Atomic	2.0	8.8	.5	11.3
Total	45.4	26.6	23.6	95.6
Total Idaho	321.4	76.7	71.7	469.8
ILLINOIS				
Argonne National Laboratory, University of Chicago, Argonne	248.7	19.5	76.1	344.3
Argonne Cancer Research Hospital, University of Chicago, Chicago	5.3	.1	1.0	6.4
University of Illinois, Urbana	2.3	.1	1.2	3.6
Total Illinois	256.3	19.7	78.3	354.3
INDIANA				
Radiation Laboratory, University of Notre Dame, Notre Dame	2.4		.4	2.8
IOWA				
Research facilities, Ames Research Laboratory, Ames	13.3	5.8	2.9	22.0
Iowa Ordnance Plant, Mason and Hanger, Burlington	37.3	.3	3.3	40.9
Total Iowa	50.6	6.1	6.2	62.9
KENTUCKY				
Paducah:				
Gaseous diffusion plant, Union Carbide Nuclear Co	756.0	.5	1.2	757.7
Feed materials plant, Union Carbide Nuclear Co	31.2			31.2
Total Kentucky	787.2	.5	1.2	788.9
MARYLAND				
AEC Headquarters, Germantown	21.3		.4	21.7

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

LOCATION AND CONTRACTOR	AUTHORIZED PLANT AND EQUIPMENT (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
MASSACHUSETTS				
Cambridge electron accelerator, Harvard University, Cambridge	$18.2	$0.2	$4.0	$22.4
Research facilities, Edgerton, Germeshausen & Grier, Inc., Boston	17.2	.8	3.7	21.7
Research facilities, Massachusetts Institute of Technology, Cambridge	4.4		5.7	10.1
Total Massachusetts	39.8	1.0	13.4	54.2
MINNESOTA				
Linear accelerator, University of Minnesota, Minneapolis	1.9	2.3	1.3	5.5
Elk River Reactor, Rural Cooperative Power Association, Elk River	9.2		2.0	11.2
Total Minnesota	11.1	2.3	3.3	16.7
MICHIGAN				
Research facilities, University of Michigan, Ann Arbor	.6	1.1	.4	2.1
Research facilities, Michigan State University, East Lansing			.6	.6
Total Michigan	.6	1.1	1.0	2.7
MISSOURI				
Kansas City Plant, The Bendix Corp., Kansas City	61.8	4.2	14.5	80.5
Feed materials plant, Mallinckrodt Chemical Works, Weldon Spring	62.3	.2	1.1	63.6
Total Missouri	124.1	4.4	15.6	144.1
NEBRASKA				
Hallam Nuclear Power Facility, Consumers Public Power District, Hallam	33.4		.6	34.0
NEVADA				
Mercury:				
Nevada Test Site, Reynolds Electrical and Engineering Co., Inc	111.3	2.2	19.1	132.6
Laboratory facilities, Lawrence Radiation Laboratory	8.0			8.0
Total	119.3	2.2	19.1	140.6
Jackass Flats:				
Nuclear Rocket Development Station, Project Rover:				
Los Alamos Scientific Lab	11.9	.8	4.3	17.0
Pan American World Airways, Inc	30.6	19.5	7.7	57.8
Other research facilities	1.6	1.4	1.8	4.8
Total	44.1	21.7	13.8	79.6
Las Vegas: Improvement of U.S. Highway 95	4.0		.5	4.5
Tonopah: Research facilities, Sandia Corp	9.0	.6	1.4	11.0
Total	13.0	.6	1.9	15.5
Total Nevada	176.4	24.5	34.8	235.7

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

LOCATION AND CONTRACTOR	AUTHORIZED PLANT AND EQUIPMENT (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
NEW JERSEY				
Princeton:				
Princeton-Pennsylvania proton accelerator, Princeton University	$27.8	$1.9	$5.3	$35.0
Model C stellarator facilities, Princeton University	24.2		1.7	25.9
Total	52.0	1.9	7.0	60.9
New Brunswick Laboratory, Atomic Energy Commission, New Brunswick	3.0			3.0
Total New Jersey	55.0	1.9	7.0	63.9
NEW MEXICO				
Albuquerque:				
Lovelace Foundation Laboratory	3.8		.6	4.4
Sandia Laboratory, Sandia Corp	144.6	4.7	34.5	183.8
South Albuquerque Works, ACF Industries, Inc	33.5	1.1	3.0	37.6
Diagnostic aircraft support facilities, Kirtland AFB	.9			.9
Total	182.8	5.8	38.1	226.7
Los Alamos:				
Los Alamos Scientific Laboratory, University of California	199.7	15.7	39.1	254.5
Community and general maintenance facilities, The Zia Co	143.8	2.4	10.4	156.6
Total	343.5	18.1	49.5	411.1
Total New Mexico	526.3	23.9	87.6	637.8
NEW YORK				
New York City:				
Computing and other research facilities, New York University	1.0		.1	1.1
Accelerator and research facilities, Columbia University	3.9		.2	4.1
Health and Safety Laboratory, Atomic Energy Commission	1.8		.3	2.1
Total	6.7		.6	7.3
Brookhaven National Laboratory, Associated Universities, Inc., Upton	188.2	17.1	46.8	252.1
Boron plant, Page Airways, Inc., Niagara Falls	7.1		.1	7.2
Research Laboratory, University of Rochester, Rochester	6.3	.1	.2	6.6
Knolls Atomic Power Laboratory, General Electric Co., Schenectady and West Milton	117.4	1.2	10.3	128.9
Fuel and canning preparation areas, Sylvania Electric Products, Inc., Hicksville	2.8			2.8

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

LOCATION AND CONTRACTOR	AUTHORIZED PLANT AND EQUIPMENT (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
NEW YORK—Continued				
Accelerator facility, Rensselaer Polytechnic Institute, Troy	$2.4		$0.3	$2.7
Total	324.2	$18.4	57.7	400.3
Total New York	330.9	18.4	58.3	407.6
OHIO				
Research facilities, General Electric Co., Cincinnati	8.8	.1	.9	9.8
Gaseous diffusion plant, Goodyear Atomic Corp., Portsmouth	763.3	.9	2.4	766.6
Feed materials plant, National Lead Co., Fernald	118.4	.8	1.8	121.0
Mound Laboratory, Monsanto Chemical Co., Miamisburg	45.8	4.1	13.2	63.1
Piqua nuclear power facility, city of Piqua	8.9		1.2	10.1
Feed materials facility, Reactive Metals, Inc., Ashtabula	1.6	.1	.1	1.8
Total Ohio	946.8	6.0	19.6	972.4
PENNSYLVANIA				
Bettis Atomic Power Laboratory, Westinghouse Electric Corp., Pittsburgh	60.8	9.3	10.3	80.4
Accelerator and research facilities, Carnegie Institute of Technology, Pittsburgh	1.5			1.5
Shippingport Atomic Power Station, Duquesne Light Co., Shippingport	47.3	6.1	1.8	55.2
Astro Nuclear Laboratory, Westinghouse Electric Corp., Large	3.0	.6	3.1	6.7
Total Pennsylvania	112.6	16.0	15.2	143.8
SOUTH CAROLINA				
Savannah River Plant, E. I. duPont de Nemours and Co., Inc., Aiken				
Production reactor and separation facilities	899.6	5.0	16.8	921.4
Feed materials production facilities	29.7	.6	.3	30.6
Heavy water production facilities	163.4	.3		163.7
Works laboratory	61.2	1.3	1.1	63.6
General facilities	166.3	2.5	7.6	176.4
Total South Carolina	1,320.2	9.7	25.8	1,355.7

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

LOCATION AND CONTRACTOR	AUTHORIZED PLANT AND EQUIPMENT (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
TENNESSEE				
Oak Ridge:				
Research Laboratory, Oak Ridge Institute of Nuclear Studies	$4.8	$0.1	$0.4	$5.3
Agriculture Research Laboratory and Farm, University of Tennessee	2.3	.1	.6	3.0
Experimental Gas Cooled Reactor, TVA	2.6	54.5	2.8	59.9
Oak Ridge gaseous diffusion plant, Union Carbide Nuclear Co	830.4	1.9	4.8	837.1
Y-12 Plant, Union Carbide Nuclear Co	388.2	6.8	12.2	407.2
Oak Ridge National Laboratory, Union Carbide Nuclear Co	237.5	17.3	39.1	293.9
Service facilities	10.5		.6	11.1
Total	1,476.3	80.7	60.5	1,617.5
Clarksville facility, Mason and Hanger, Clarksville	2.3			2.3
Total Tennessee	1,478.6	80.7	60.5	1,619.8
TEXAS				
Pantex Plant, Mason and Hanger, Amarillo	49.2	1.3	3.6	54.1
Medina facility, Mason and Hanger, San Antonio	16.0			16.0
Research facility, Rice University, Houston	1.5			1.5
Total Texas	66.7	1.3	3.6	71.6
UTAH				
Monticello				
Uranium ore processing plant, Lucius Pitkin, Inc	.5			.5
WASHINGTON				
Richland:				
Hanford Works, General Electric Co.				
Production reactor facilities	715.7	5.1	11.8	732.6
Separation facilities	200.2	4.0	12.6	216.8
Feed materials production facilities	21.5	1.2	.6	23.3
General facilities	118.4	1.8	3.1	123.3
Total	1,055.8	12.1	28.1	1,096.0
Pacific Northwest Laboratory, Battelle Memorial Institute	82.5	9.9	8.6	101.0
Total Washington	1,138.3	22.0	36.7	1,197.0
WEST VIRGINIA				
Huntington pilot plant, International Nickel Co., Huntington	4.9			4.9

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

LOCATION AND CONTRACTOR	AUTHORIZED PLANT AND EQUIPMENT (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
WISCONSIN				
Research facilities, University of Wisconsin, Madison	$1.2		$0.1	$1.3
LaCrosse boiling water reactor, Genoa		$7.8	3.7	11.5
Total Wisconsin	1.2	7.8	3.8	12.8
PUERTO RICO				
Puerto Rico Nuclear Center, University of Puerto Rico, Mayaguez	5.3		.5	5.8
Boiling nuclear super heat reactor, Punta Higuera	10.1	2.7	.8	13.6
Total Puerto Rico	15.4	2.7	1.3	19.4
JAPAN				
Research facilities, National Academy of Science, Hiroshima	2.6	.1	.3	3.0
ALL OTHER				
NS *Savannah*	26.2		1.4	27.6
Weapons storage facilities	23.7			23.7
Other	35.5	2.3	73.0	110.8
Total All Other	85.4	2.3	74.4	162.1
TOTAL	8,470.4	400.7	780.0	9,651.1

[1] Includes capital equipment.
[2] Includes "plant and capital equipment" authorized in Public Law 89-32, approved June 2, 1965.

U.S. ATOMIC ENERGY COMMISSION TEN-YEAR SUMMARY OF FINANCIAL DATA

[Dollars in thousands]

	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956
Cost of operations	$2,569,798	$2,739,058	$2,713,207	$2,695,936	$2,612,909	$2,619,143	$2,496,648	$2,298,589	$1,918,258	$1,607,973
Procurement of raw materials	261,082	326,338	477,873	537,363	636,832	716,507	699,996	596,391	397,813	278,946
Production of nuclear materials	571,301	636,366	652,426	688,533	732,524	731,348	713,247	750,178	762,815	730,972
Weapons development and fabrication	763,128	804,598	696,866	705,893	512,317	505,448	491,981	443,536	337,183	280,765
Development of nuclear reactors	535,875	561,191	507,343	433,150	437,274	399,252	355,600	306,225	255,667	168,853
Physical research	236,980	215,682	198,526	171,782	154,105	132,845	112,318	87,719	69,657	56,547
Biology and medicine research	84,417	77,352	70,523	62,782	53,866	48,878	42,781	35,958	33,148	29,849
Community operations—net	3,562	4,885	4,958	4,432	4,463	7,090	9,892	11,162	8,897	8,954
Administrative expenses	80,258	72,866	67,068	60,592	57,709	51,197	50,135	46,435	38,499	38,195
Miscellaneous expenses and income—net	33,195	39,780	37,624	31,409	23,819	26,578	20,698	20,985	14,579	14,892
Plant construction and equipment costs incurred during the year	$371,513	$376,898	$409,114	$423,765	$432,688	$331,516	$298,979	$289,744	$317,022	$301,682
Total AEC assets excluding inventories of certain products at June 30	$8,689,900	$8,642,374	$8,589,665	$7,803,222	$7,802,395	$7,689,385	$7,764,770	$7,652,784	$7,397,911	$7,368,272
Plant investment at June 30 (gross)	$8,871,039	$8,578,169	$8,233,451	$7,869,250	$7,664,736	$7,344,751	$7,292,784	$7,110,797	$6,907,896	$6,713,061
Production plants	5,464,042	5,497,362	5,447,496	5,344,523	5,453,568	5,458,201	5,552,646	5,494,440	5,392,464	5,212,776
Research and development facilities	2,370,203	2,147,574	1,885,929	1,713,986	1,434,967	1,271,253	1,124,543	937,682	792,633	753,468
Other	636,117	524,677	318,208	306,162	313,403	288,608	365,838	407,529	411,582	499,793
Plant construction in progress at June 30	400,677	408,556	581,818	504,579	462.798	326,689	249,757	271,146	311,217	247,024
Funds appropriated—net	$2,624,555	$2,742,661	$3,134,776	$2,547,338	$2,666,760	$2,649,614	$2,635,335	$2,333,974	$1,898,700	$834,227
Operations	2,261,555	2,342,661	2,872,031	2,351,978	2,456,210	2,387,114	2,385,406	2,225,470	1,740,400	*1,146,400
Plant and capital equipment	363,000	400,000	262,745	195,360	210.550	262,500	249,929	108,504	158,300	*(312,173)
Appropriation expenditures	$2,624,996	$2,764,565	$2,757,876	$2,805,700	$2,713,465	$2,622,838	$2,541,181	$2,267,960	$1,931,485	$1,633,549
Employment at June 30	133,912	136,620	135,278	126,623	122,989	122,718	121,928	121,059	119,455	110,197
AEC employees	7,329	7,268	7,120	6,863	6,846	6,907	6,855	7,107	6,910	6,637
Operating contractor employees	114,783	117,257	115,012	106,394	103,313	104,612	105,195	103,290	98,176	90,238
Construction contractor employees	11,800	12,095	13,146	13,366	12,830	11,199	9,878	10,662	14,369	13,322

*Includes transfer to operations of $571,400,000 appropriated in prior years as plant and equipment.

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795–958—66——28

U.S. GOVERNMENT PRINTING OFFICE: 1966