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UNITED STATES ATOMIC ENERGY COMMISSION

Annual Report to Congress

OF THE

ATOMIC ENERGY COMMISSION

FOR

1967

January 1968

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LETTER OF SUBMITTAL

WASHINGTON, D.C.,
January 31, 1968.

SIRS: We have the honor to submit herewith the Annual Report of the United States Atomic Energy Commission for 1967 as required by the Atomic Energy Act of 1954.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION,
JAMES T. RAMEY.
GERALD F. TAPE.
WILFRID E. JOHNSON.
GLENN T. SEABORG, *Chairman.*

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

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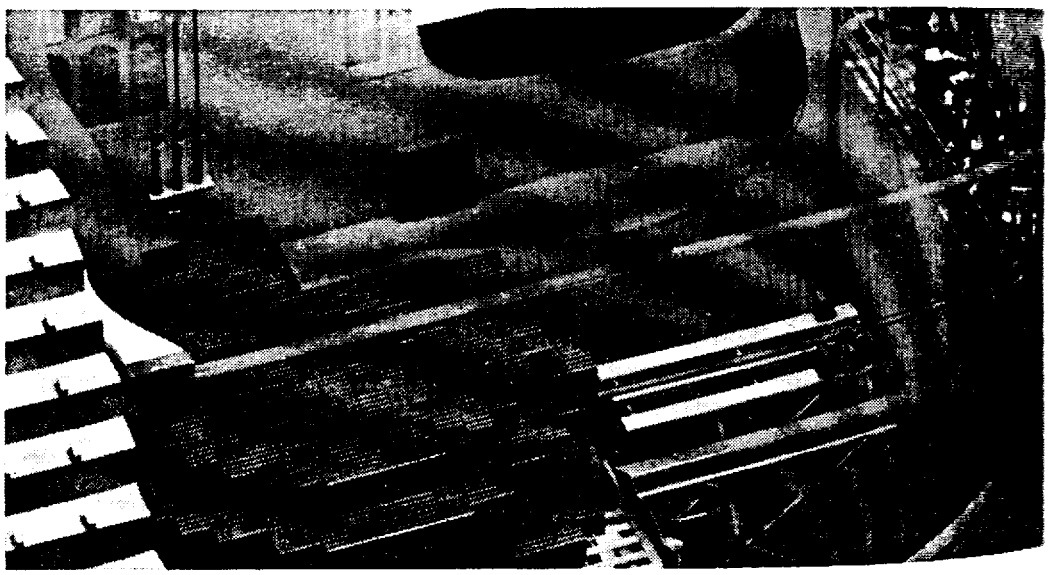
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25th Anniversary of First Nuclear Reactor. At 3:25 p.m. on December 2, 194 a team of scientists led by the late Dr. Enrico Fermi first brought the power of the atom under man's control in the world's first successful nuclear reactor. On December 2, 1967, the 25th anniversary of that event was observed by surviving members of Dr. Fermi's team and others interested in nuclear science at the University of Chicago. As a part of the observance, President Johnson addressed the gathering via television and called upon all nations of the world to put the atom to work for the peace and welfare of mankind. Because of wartime secrecy no photographers were present when the Dr. Fermi's reactor went critical, i.e., achieved a self-sustained chain reaction in 1942. Photo *below* shows a cutaway model of the reactor—a "pile" of 57 alternating layers of uranium-containing graphite and "dead" graphite. The model is based on the memories of the scientists who were in the makeshift laboratory beneath the stands of the University of Chicago's Stagg Field 25 years ago.



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An Introduction To:

THE ATOMIC ENERGY PROGRAM DURING 1967

The surge toward greater use of nuclear power to meet the Nation's electricity needs of the future continued to be the dominating highlight of the Nation's atomic energy program during 1967 as utility planning announcements doubled the previous pace-setting growth of 1966.

During the year, the Atomic Energy Commission received construction permit applications for 29 power reactors having a combined generating capacity of 24,287 megawatts of electricity (Mwe.); four prior-year applications totaling 2,356 Mwe. were also under review. In 1966 there had been 16 reactor applications, totaling 11,626 Mwe. The corresponding figures for 1965 were four and 2,557 Mwe., respectively. In addition, to the plants applied for, there were 11 other units, totaling 8,746 Mwe., actually ordered during the year by utilities. At year's end, another 11 nuclear units with a combined estimated capacity of 9,500 Mwe. had been announced but not ordered by utility managements.

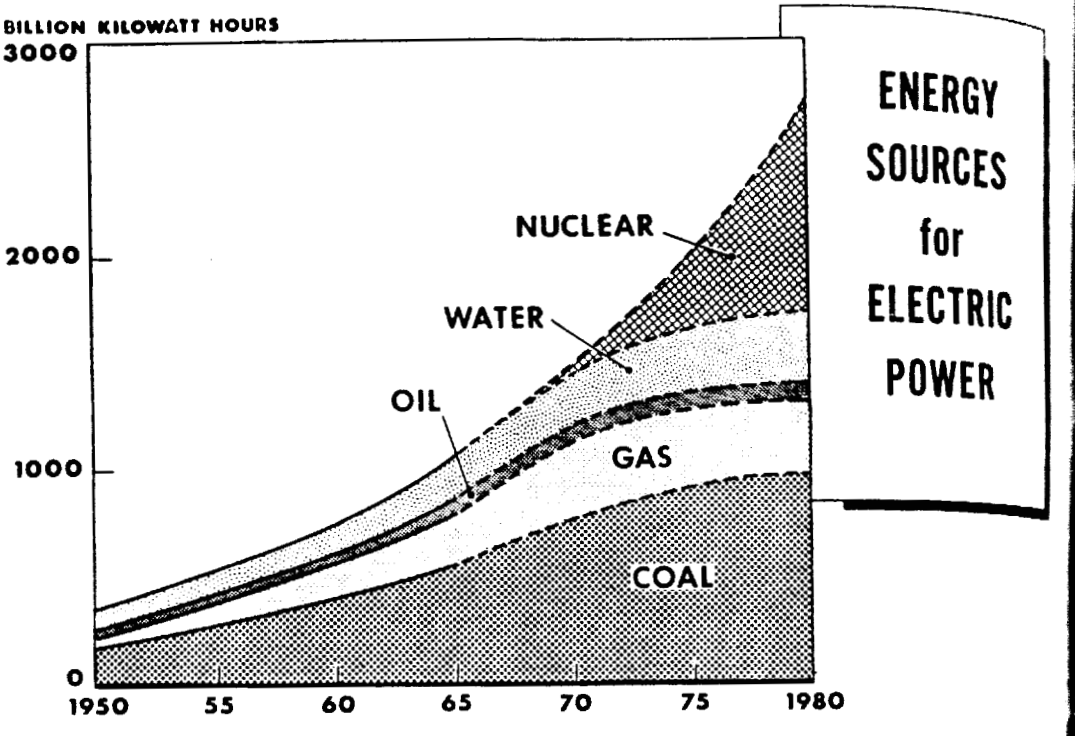
As of December 31, 1967, there were more than 42,750 Mwe. of civilian nuclear generating capacity either in operation, under construction, or on order—a capacity comparable to that of the national total distribution immediately before World War II. (Appendix 5 lists the nuclear central stations in operation, being built, for which applications have been received, and on order.)

In recognition of the continuing high rate of commitments to build new nuclear powerplants, the AEC revised upward its forecast made in 1966, that there would be 80,000 to 110,000 megawatts of nuclear capacity by the end of 1980. The new projection is for a range of 120,000 to 170,000 Mwe., with the most likely figure near the middle of the range. The implications of this level are significant, both for the commercial and Government sectors of the economy. In addition to the multibillion dollar annual level of reactor plant sales expected by

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1980, sales of uranium concentrates will probably exceed $600 million, and uranium enrichment charges will be about the same amount, with a significant fraction consisting of foreign exchange.

The effects of the continuing surge toward reliance upon the atom to help meet the power needs of the future were widespread. As evidenced throughout this report, there has been a general strengthening of the cooperative effort between the AEC and industrial groups to further enhance the viable and competitive state of the nuclear industry.



CONTENTS SUMMARY

The next 20 pages of this "Annual Report to Congress for 1967"[1] briefly summarize the contents on a chapter-by-chapter basis. Achievements being made under AEC-sponsored basic research and development (highlighted in Chapters 5 and 15) are described in greater detail in the supplemental report, "Fundamental Nuclear Energy Research—1967."[2]

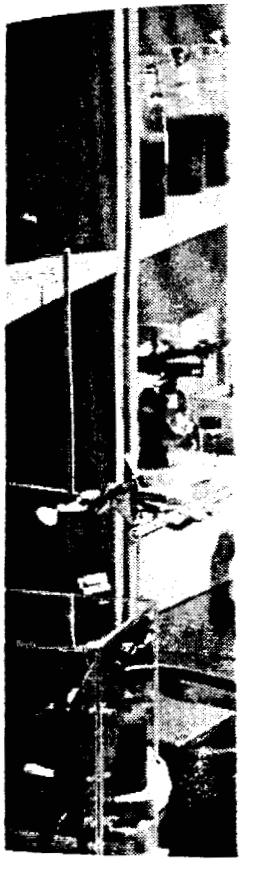
[1] This "Annual Report to Congress for 1967" is available to the public under an alternate title, "Major Activities in the Atomic Energy Programs—January-December 1967," available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $1.50.

[2] "Fundamental Nuclear Energy Research—1967" is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $2.50.

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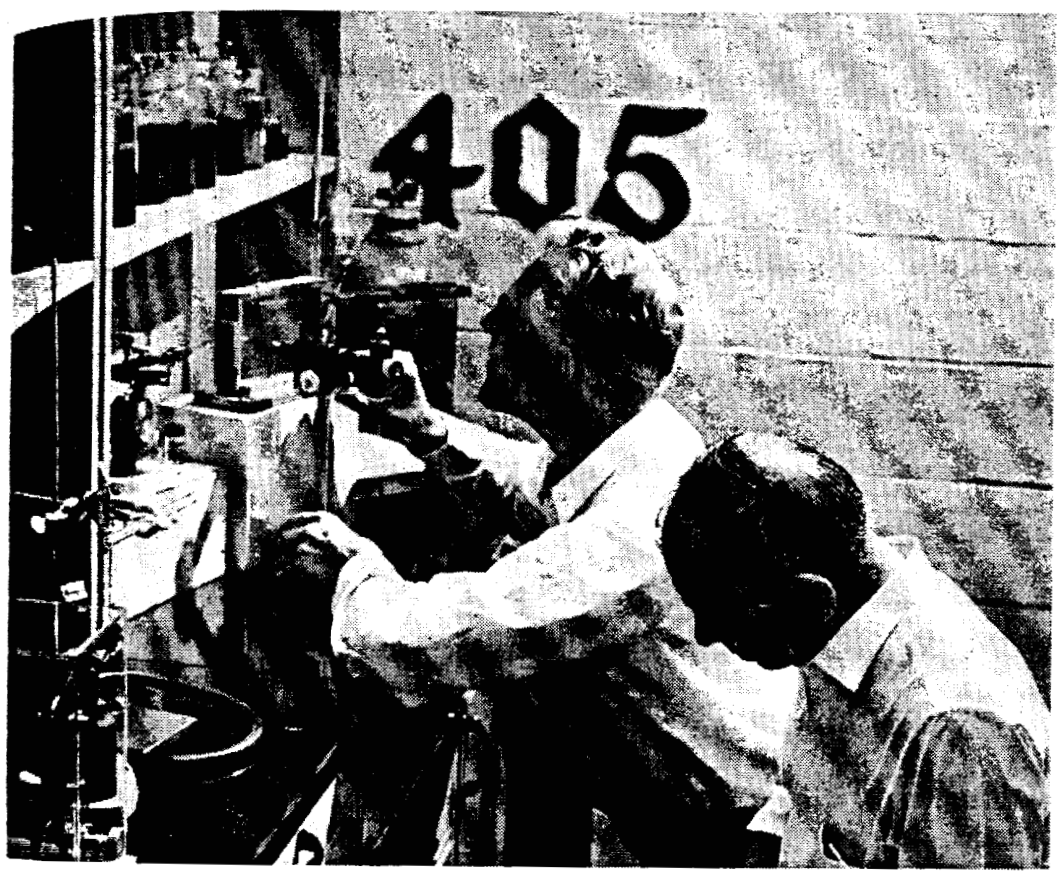
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Source and Special Nuclear Materials

- During 1967, industry contracted for substantial quantities of uranium concentrate (U_3O_8) for future delivery.
- For the first time in 8 years, development of new ore reserves exceeded the quantity mined. Reserves as of December 31, 1967, which could be produced and sold at a price of $8 per pound of uranium concentrate (U_3O_8), were estimated to be 148,000 tons of U_3O_8.
- During 1967, the AEC took steps to provide industry with information needed to plan for "toll enrichment" of uranium which begins in 1969. Studies continued on the feasibility of future transfer of one or more gaseous diffusion plants for private operation.
- The Atlantic Richfield Hanford Co., a newcomer to the nuclear industry, was selected to perform the chemical processing work previously done by Isochem Inc. at the Hanford Works in Washington.

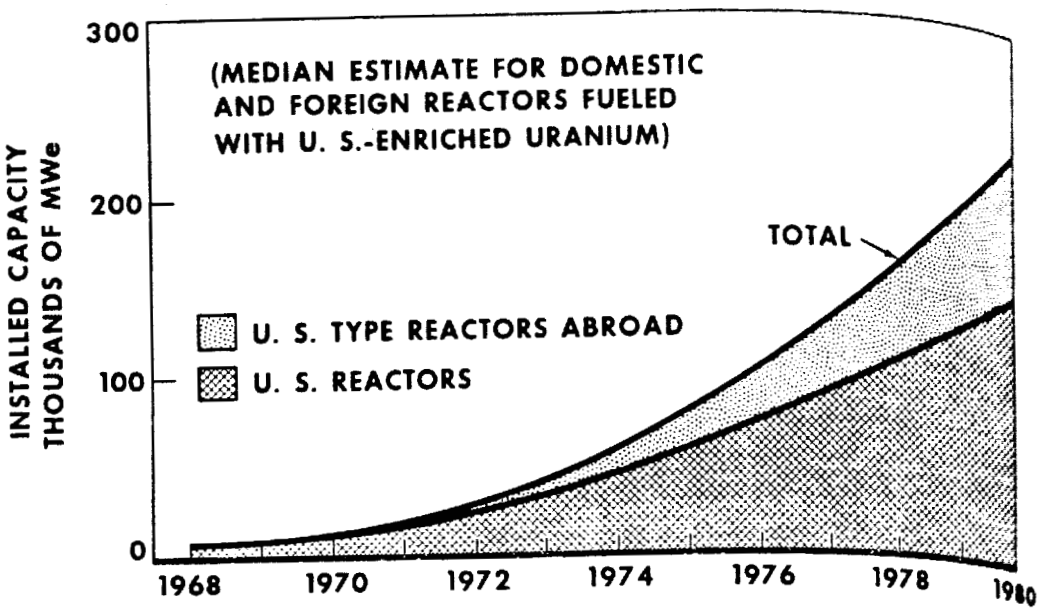


Reenactment of First Plutonium Weighing. September 10, 1967, was the 25th anniversary of the first weighing of the man-made element plutonium (element 94). The first weighing of a minute quantity—2.77 micrograms or 1/30 millionth of an ounce—took place on September 10, 1942, on the University of Chicago campus, in Room 405 of the George Herbert Jones Chemical Laboratory, which was a part of the wartime Metallurgical Laboratory. During the September 10 dedication of Room 405 as a National Historic Landmark, the historic weighing was reenacted using an ultramicrobalance constructed out of quartz fibers so thin as to be almost invisible.

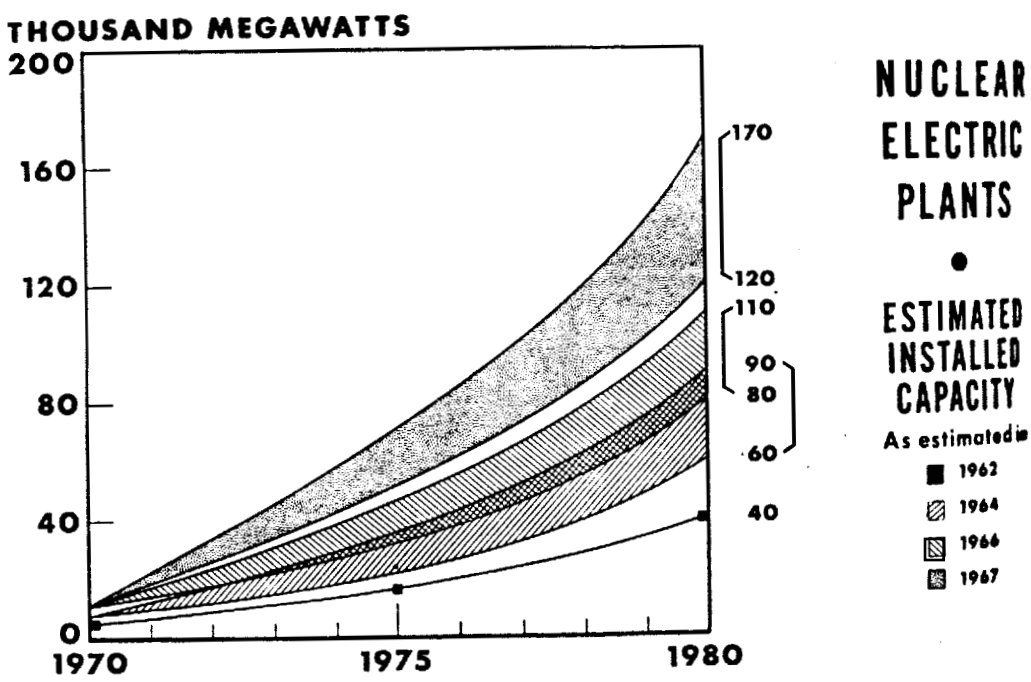
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PROJECTED GROWTH OF NUCLEAR POWER



● AEC withdrew, during the year, from the routine production and sale of one more radioisotope, strontium 87m. This brings the total to 37 radioisotopes which are no longer produced by AEC since the first withdrawal in 1961. At year's end, the AEC proposed its withdrawal from cobalt-60 production and sale. The Commission's established policy is to pass these activities over to the commercial sphere of the economy when commercial capacity exists, the charges are reasonable, and the quality is in keeping with the purchaser's needs. Several new radioisotopic products became available from AEC in 1967: iodine-125, tungsten-188, and high specific activity (1,000 curies per gram) iridium-192.



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Safeguards and Materials Management

• To strengthen its program for deterring and detecting diversions of nuclear materials to unauthorized uses, the Commission at mid-year effected two significant organizational changes. These included the establishment of a new office with overall responsibility for AEC's national and international safeguards programs and the establishment of a new regulatory division to administer safeguards for materials held by AEC licensees.

The Nuclear Defense Effort

• Twenty-five underground nuclear weapons-related tests were announced during 1967. Experimental techniques in underground testing continued to be improved to increase the value of the tests as a tool for nuclear weapons development, weapons design, and effects analysis.

• In mid-1967, a program of modernization and expansion of weapons production facilities was announced. Additional facilities, occasioned by the decision in October 1967 to deploy an anti-ballistic missile (ABM) system, will be required and are being evaluated. The additional requirement will become a part of the already authorized project. These will provide the facilities needed to produce new weapons systems required by the Department of Defense.

• Hot Creek Valley in central Nevada and Amchitka Island off Alaska, were selected as locations for possible use as supplemental, higher-yield underground testing sites.

• Eight AEC-instrumented nuclear test detection satellites are performing functions related to the limited nuclear test ban treaty. Improvements made in the detector systems and earth-orientation of the latest satellites now make possible the recording of optical and electromagnetic radiations from atmospheric nuclear detonations.

Naval Propulsion Reactors

• Congress has authorized 107 nuclear-powered submarines, including 41 of the Polaris missile-launching type and one deep submergence research vehicle, and eight surface ships.

• The 400th successful Polaris submarine patrol was completed in May 1967. The *Will Rogers*, last of the presently planned fleet of 41 Polaris submarines, deployed on her initial patrol in September 1967.

• The aircraft carrier *Enterprise* and guided-missile frigate *Bainbridge* completed their second Vietnam deployments, and the

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guided-missile cruiser *Long Beach* completed her first. The operation of these nuclear-powered surface ships continues to demonstrate, under actual combat conditions, the tactical flexibility and freedom for independent action as a result of virtually unlimited endurance at high speeds provided by nuclear power.

● Emphasis continued on research and development to provide advanced Naval reactor cores of higher power and longer life, with



Calcined Waste Product. At the National Reactor Testing Station in Idaho, the highly radioactive liquid wastes generated during the reprocessing of irradiated nuclear fuels for uranium recovery are being treated in a Waste Calcining Facility (WCF), using a fluidized bed principle. The granular solid product, which is compared with a pencil point in the inset picture, routinely is about one-tenth the volume of the liquid feed, as illustrated, and is sent to stainless steel bins in underground vaults. By mid-November 1967, the WCF had converted into the safer solid granular form 1.33 million gallons of highly radioactive corrosive liquid wastes from the reprocessing of aluminum-type reactor fuels. After that date, the WCF began calcining radioactive liquid wastes from zirconium-type fuels. The WCF, which started operation in December 1963, is the world's first and only production-scale facility which converts the highly radioactive aqueous wastes from nuclear fuel reprocessing into solids for long term storage.

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the ultimate objective of developing cores that will last the lifetime of the ship.

● The *Truxtun*, the Navy's second nuclear powered guided-missile frigate, was commissioned in May 1967 and joined the operating fleet.

Reactor Development and Technology

● The continuing decisions of utilities to build nuclear powerplants was reflected in the startup in 1967 of the 430-Mwe. San Onofre Nuclear Generating Station at San Clemente, Calif., and the 462–Mwe. Connecticut Yankee Atomic Power Plant at Haddam Neck, Conn. These are the first reactors of the larger-size light water central station nuclear powerplants to go into operation; however, most of the light water reactor plants scheduled to go into operation after 1967 range in size from 500 to 1,000 Mwe.

● Further improvement of light water reactors is being carried out by the nuclear industry and electric utilities; Government emphasis is now placed on continuing nuclear safety programs, improving fuel utilization through plutonium recycle, and developing engineering standards, practices, and procedures applicable to nuclear operations.

● Emphasis in the AEC reactor development effort during 1967 was on the liquid metal fast breeder reactor. It was a year of preparation of detailed program plans which can be used by the AEC and industry for integrated development effort, and it was a year which saw a greater involvement of the industry and the AEC laboratories in the fast breeder program.

● Development efforts continued on other reactor concepts which use fuel more efficiently than the present commercial light water reactors: the high-temperature gas-cooled reactor, the heavy water moderated and cooled reactor, the molten salt concept, and the light water breeder reactor.

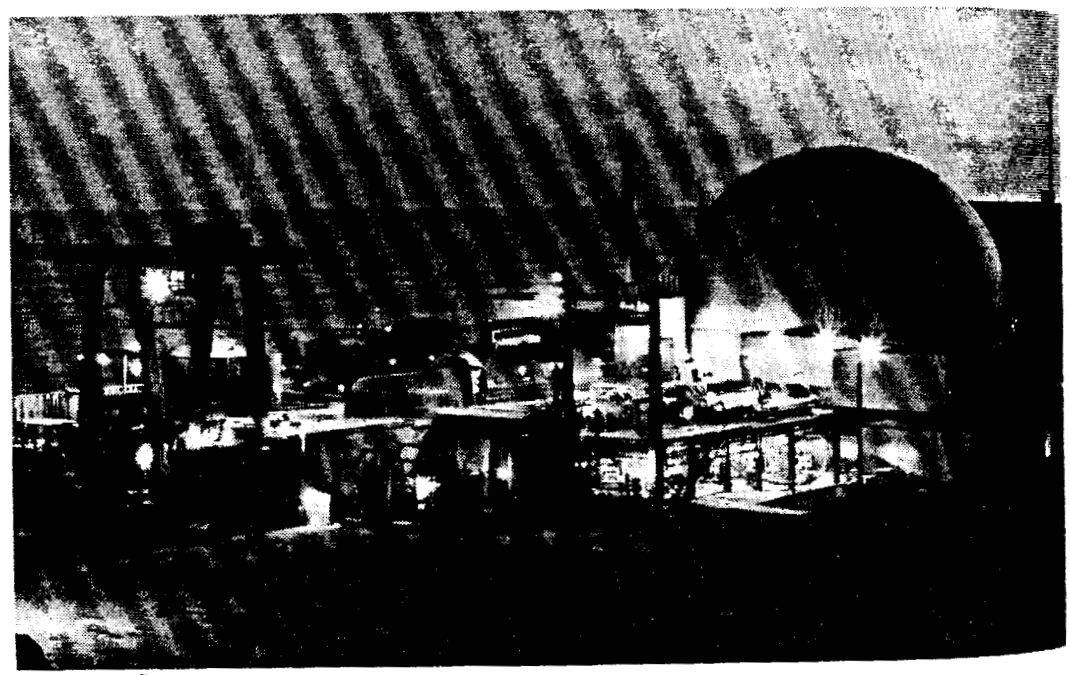
● The AEC initiated action to terminate the arrangement with the city of Piqua, Ohio, for operation of the 11.4-Mwe. organic cooled Piqua Nuclear Power Facility.

● The combined use of nuclear energy for the production of electricity and process heat took a major step forward in 1967 with the signing of contracts between the participants and placement of orders for certain of the plant components for the Bolsa Island Nuclear Power and Desalting Project. This large, dual-reactor electric and desalting plant is to be located on a 43-acre man-made island off Huntington Beach, Calif.

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● Throughout all of its reactor development efforts during 1967, the AEC continued to emphasize the development of criteria, guides, standards, and codes for materials, equipment, and processes associated with the safety and successful operation of nuclear power systems.



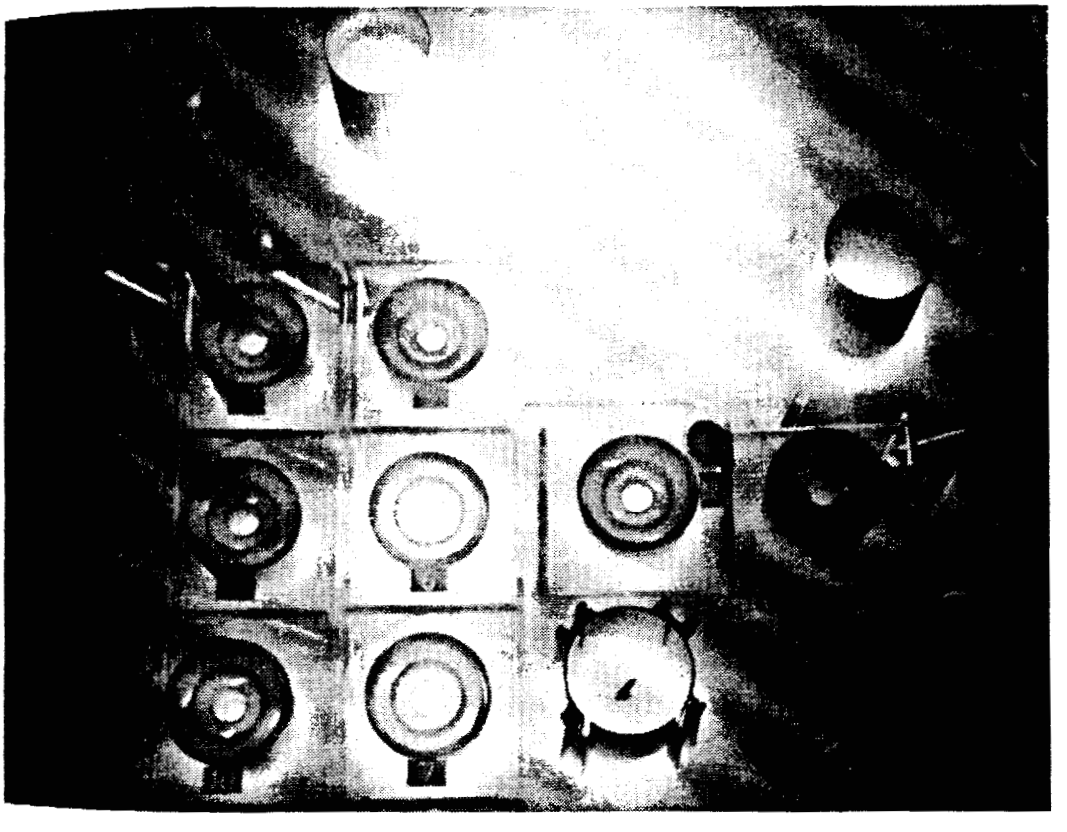


New Nuclear Power. When these photos were taken, the Nation's two newest nuclear central station powerplants were generating electricity. The 462-Mwe Connecticut Yankee Atomic Power Plant (*above*) at Haddam Neck, Conn., began commercial operation in August 1967; and the San Onofre Nuclear Generating Station Unit 1 (*below*) at San Clemente, Calif., produced its first electricity in July.

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Plutonium-244 Sample. In photo at *left* a Los Alamos Scientific Laboratory technician is shown unpacking 1.5 milligrams of highly enriched plutonium-244—one-fifth of the world's known supply—in May 1967. This material, produced in the Oak Ridge National Laboratory's High Flux Isotope Reactor (HFIR), is being used as a target to produce other nuclides in order to determine their energy and decay schemes. The sample material, in the shape of a ball, would be only slightly larger than one of the periods on this page. Photo *below* shows "spent" fuel elements stored under 20 feet of water in the HFIR clean pool. The brightest elements (1 and 2, rear center) were operated at full power (100,000 kw.) for approximately 22 days and were removed from the reactor approximately 48 hours before this photo was taken. The two cylinders, left of element one and right of element 2, are reactor control plates. Since first reaching 100,000 thermal kw. in September 1966, the reactor has operated 75 percent of the time.



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Licensing and Regulating the Atom

● The rate of applications for authority to construct nuclear powerplants accelerated in 1967. Twenty-nine new power reactors were proposed to the AEC by utilities. Nearly two-thirds of them are scheduled for operation by the end of 1972, and all by 1974. The trend toward multi-unit stations continued. Seven reactors in the 1,050–1,065 Mwe. range were proposed, pushing the average plant size for this year's applicants to more than 800 Mwe.

● The AEC issued construction permits for 14 nuclear power plants during the year, as compared with the five permits issued in 1966. The AEC had under review at year's end proposals for an additional 31 nuclear plants representing a potential capacity of 25,290 Mwe.

● The reactor regulatory process was further improved by expansion and realignment of the regulatory staff to streamline licensing functions and intensify development of siting and design criteria. Action was taken on several special regulatory review panel recommendations. Progress was made in developing reactor safety criteria, standards, and codes, with cooperation from industry and professional groups. The permanent chairman and vice-chairman of the Atomic Safety and Licensing Board Panel assumed their duties in 1967.

● Hearings by the Congressional Joint Committee on Atomic Energy on the licensing and regulation of nuclear reactors focused on the problems faced by industry in scheduling, and the AEC in approving, nuclear facility projects.

● The two nuclear energy liability insurance pools, under their retrospective rating plan, refunded to policyholders a substantial portion of the first premiums paid for such insurance in 1957, reflecting the excellent safety record of the nuclear industry.

● Louisiana and Arizona entered into agreements with the AEC to assume certain regulatory authority over nuclear materials, bringing to 17 the number of States in the AEC's State regulatory agreement program. Colorado is scheduled to enter into an agreement early in 1968 and several other States were moving toward similar agreements.

● The AEC simplified some of the materials licensing procedures and again had its radioisotopes licensing procedures under review in the light of independent review panel recommendations.

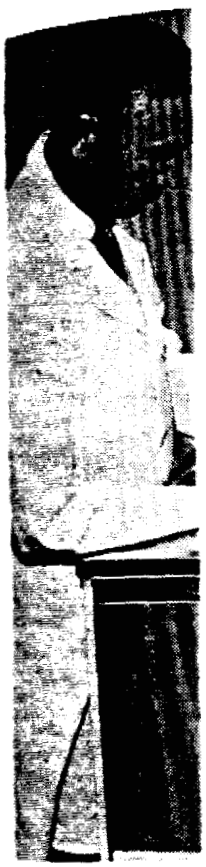
● The first Bureau of Labor Statistics survey of injury frequency and severity rates for the private sector of the atomic energy industry showed the work-injury experience to be better than the average for all manufacturing industries.

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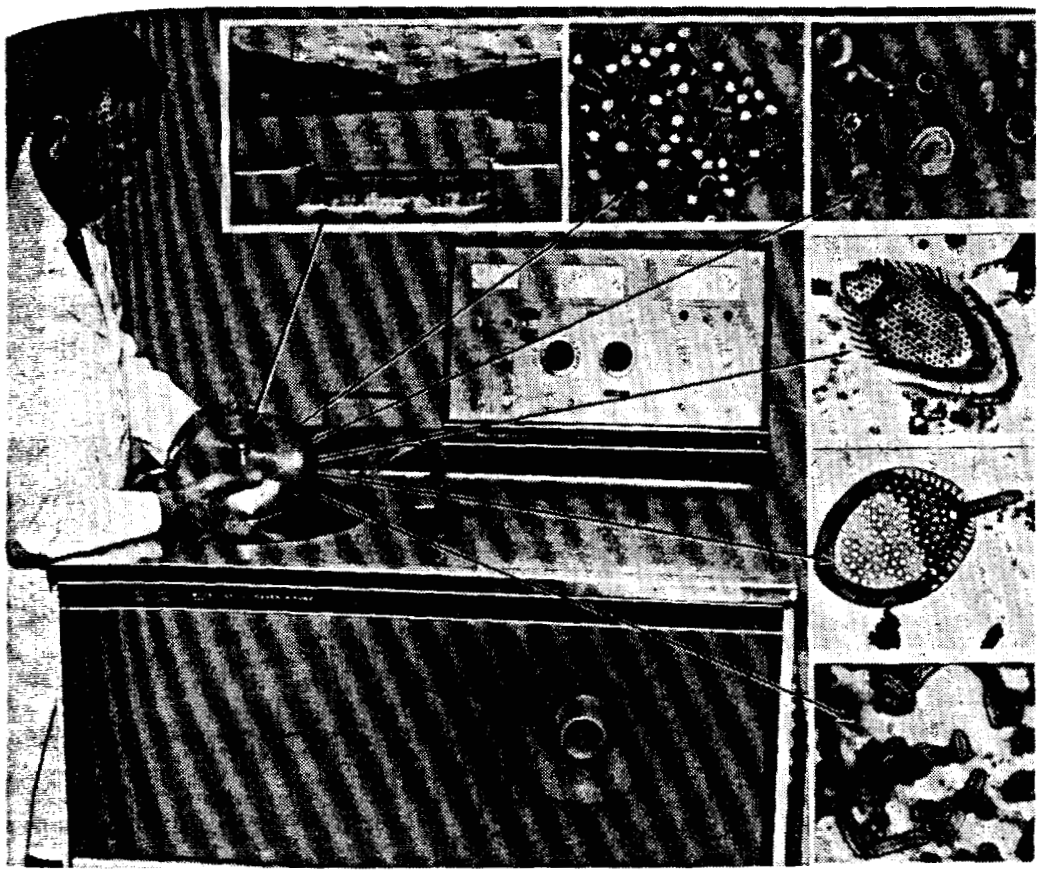


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Operational Safety

• The AEC and its contractors had the safest year in the AEC's 25-year history in 1967, according to preliminary statistics which became available after the end of the year. The previous record year was 1966. Early in 1967, the AEC was presented the National Safety Council's "Award of Honor" for the fifth consecutive year.

• An AEC–U.S. Public Health Service agreement was reached on routine measurement of radon levels around mill tailings in the uranium producing States. New AEC laboratory-developed techniques are in use to overcome technical difficulties in radon measurement for public health purposes.



Water Pollution Analyses. A new technology has been developed at the AEC's Oak Ridge (Tenn.) Gaseous Diffusion Plant to sharply separate and concentrate the constituents of natural waters and to determine the quantity of pollutant which may be associated with each. Of especial interest is the manner in which pollutants are concentrated, transported in waters, and how they may enter the food chain of man. High resolution, continuous-flow centrifuge rotors and seals, as illustrated above, have been developed to separate from a large water sample viruses (two inserts in *top row* of picture), algae (unusual algal scales in two *right-center* inserts), bacteria (*lower right*), minerals, clays, and dissolved substances. While this technology was first developed for investigations of water pollution by radionuclides, it is now also being applied to investigations of pesticide, chemical, and biological (viruses) pollutants and water treatment studies.

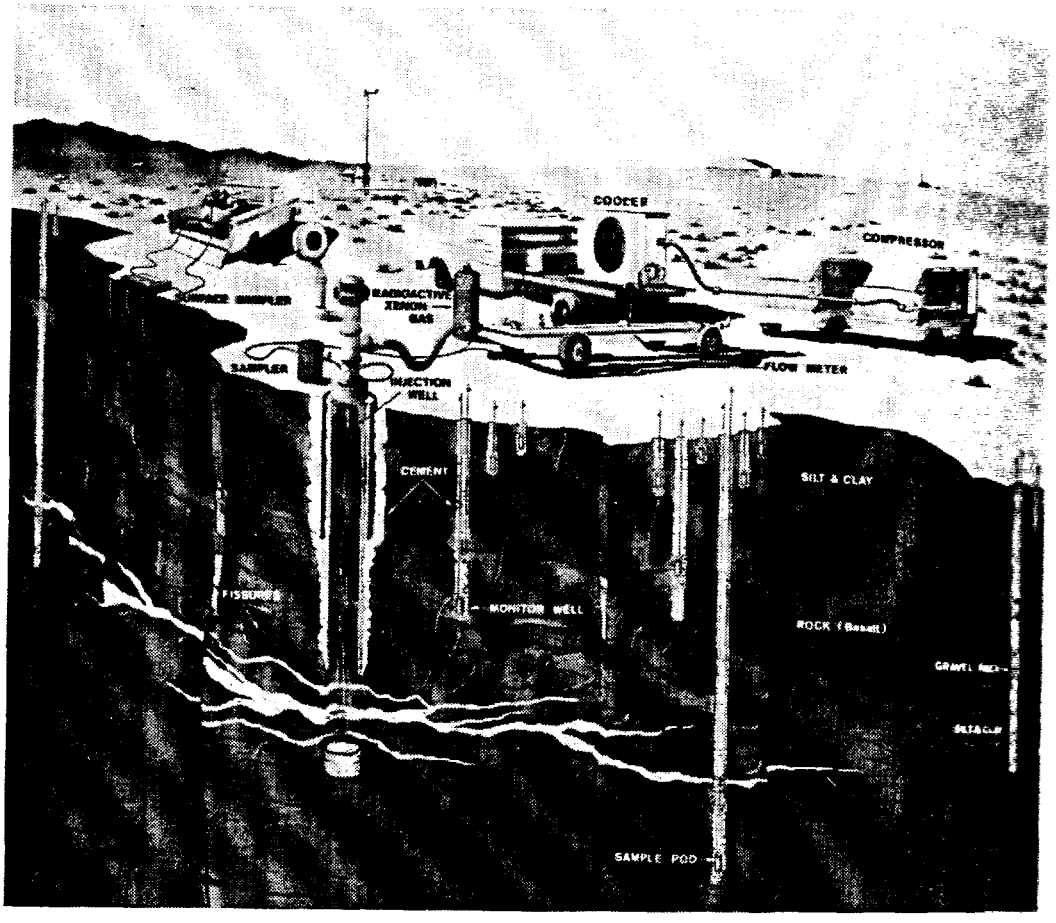
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Nuclear Rocket Propulsion

● Substantial progress was made during 1967 in the joint AEC-NASA nuclear rocket program which seeks to establish a firm base of technology to provide an advance in space propulsion performance for missions following Apollo.

● An experimental reactor called the Phoebus–1B was operated at power levels approaching 1,500 megawatts (thermal) for 30 minutes at the Nuclear Rocket Development Station (NRDS) in Nevada.

● The sixth in the series of NRX reactors (NRX–A6) was operated for 70 minutes, of which 60 minutes was at full design power of ap-

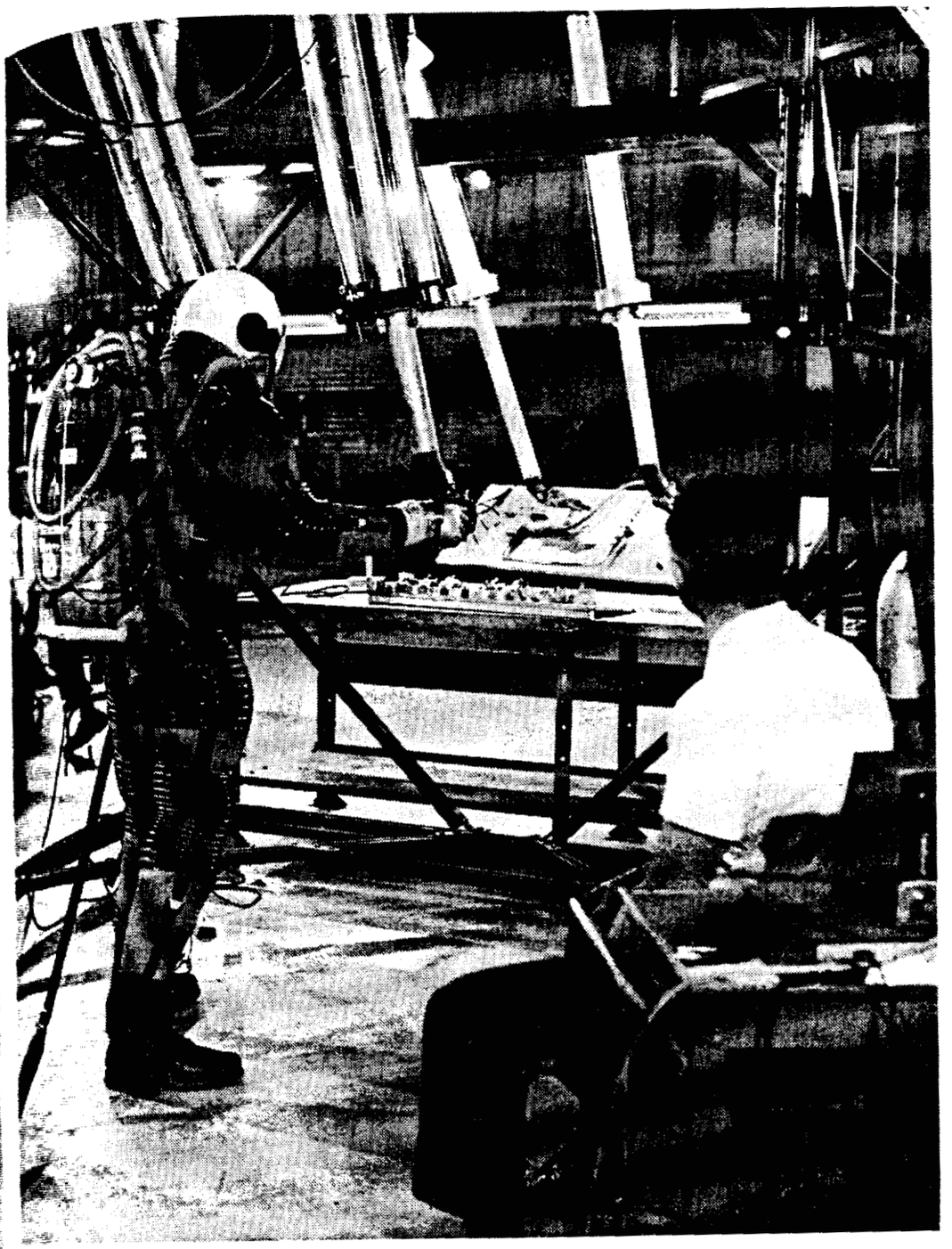


Gaseous Waste Disposal Test. An experiment was begun late in 1967 at the AEC's National Reactor Testing Station, Idaho, to test the feasibility of utilizing the lithosphere for disposal of gaseous waste that otherwise might pollute the atmosphere. One million cubic feet of air containing 1,000 curies of xenon-133 was injected into a porous zone in the basalt rock 120 feet below land surface. Monitoring wells at various locations surrounding the injection well are designed so that air samples can be withdrawn at selected elevations. In addition, samples can be collected at the atmosphere-lithosphere interface and from the atmosphere to determine the flux of the introduced gas from the ground and diffusion in the boundary layer of the atmosphere.



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"Hands" for Space Use. Tests to investigate the feasibility of using "mechanical hands" in space are being carried out by agencies of the National Aeronautics and Space Administration and AEC's Argonne National Laboratory. In photo, a NASA crew equipment development engineer performs a series of carefully planned tasks—ranging from "easy" to those requiring considerable manual dexterity—using Argonne-designed master-slave manipulators. The manipulators were originally devised for handling radioactively "hot" materials and equipment. The "slave" arm of the manipulator duplicates the operator's movements, allowing him to perform many of the operations normally done directly with the human hand. The prototype space suit is pressurized to 3.7 pounds per square inch. This is the pressure it will be required to maintain in the vacuum of space.

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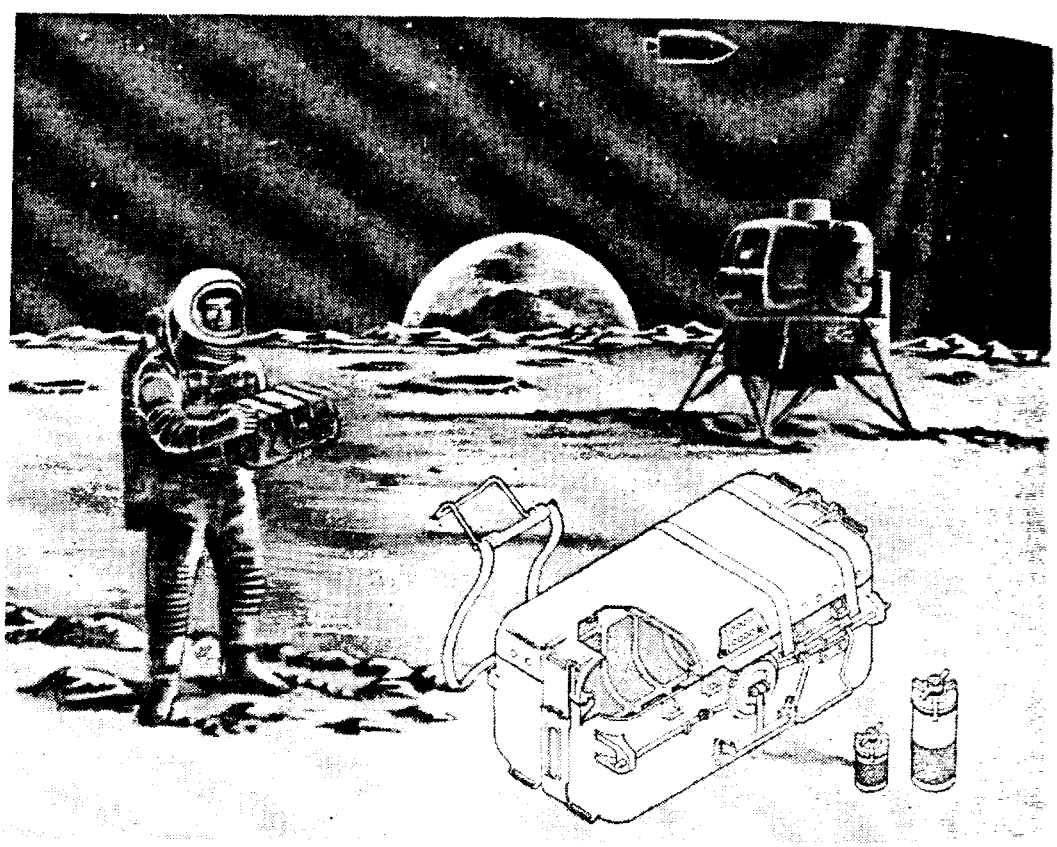
proximately 1,100 megawatts, thermal. This duration at design pow was twice that achieved in any previous nuclear rocket test.

● The first ground-experimental engine, a cold-flow assembly calle the XECF was installed in the new Engine Test Stand Number (ETS–1) at NRDS to verify that ETS–1 is ready for "hot" engi testing in 1968.

Specialized Nuclear Power Units

● The AEC continued testing nuclear power units for possibl space use in the 1970's, developing a technology for long-lived reacto and isotopic systems that will supply up to 50 kilowatts of electricity.

● A post-operation examination completed in 1967 revealed n life-limiting problems in a ground test unit of the SNAP–10A, after it had operated in a simulated space environment for 417 days. Th 500-watt electric SNAP–10A (orbited in 1965) is the only reactor uni that has been operationally tested in orbit.



Lunar Sampler. In this artist's concept, an Apollo astronaut prepares to collect lunar geological samples in a special container designed and fabricated at the AEC's Oak Ridge Y–12 Plant for the National Aeronautics and Space Administration. Two such containers will be taken on the first moon voyage. In foreground is a closeup of one of the boxes. At right are two cylindrical canisters designed to contain a small quantity of specimens under very high vacuum conditions. In background, the lunar excursion module awaits its rendezvous with the orbiting command module in space.

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• Fabrication of a second-generation SNAP–8 reactor was underway in 1967. SNAP–8 and SNAP–10A class reactors are potentially useful for power levels ranging from 1 to 50 electrical kilowatts.

• A SNAP–3 isotopic power system has been operating in orbit since the system was launched aboard a navigational satellite in 1961. It has already operated for a year beyond its design life, and has circled the earth 35,000 times.

• Several terrestrial isotopic power units have had extended periods of successful operation. SNAP–7C has been operating at a U.S. Navy weather station in Antarctica since February 1962; SNAP–7D has successfully withstood major hurricanes since installation on a floating weather barge in the Gulf of Mexico in January 1964; and SNAP–7E has been operating at a depth of 15,800 feet in the Atlantic Ocean since July 1964.

• Work continued on the development of a plutonium-fueled microwatt cardiac pacemaker to aid in the treatment of "heart block," a relatively common disease that causes interruption of the normal stimulation of the heart beat.

Isotopic Radiation Applications

• Five irradiators were scheduled for temporary loan to several foreign countries in support of food irradiation research projects. Encouragement of such programs by the AEC has resulted in substantial exchange of information and scientific data. More than 50 countries are now actively engaged in food irradiation research.

• Air pollution abatement objectives were supported by a new AEC research project using stable sulfur isotopes in studies of the source, quantities, and dispersal of stack effluent from metropolitan fossil-fuel burning industrial plants.

• During 1967, two alpha-particle probes were landed on the moon via Surveyor V and VI spacecrafts as part of a NASA program to determine the mineral composition of the moon's surface.

The Plowshare Program

• Project Gasbuggy, the first joint industry-government Plowshare experiment was conducted on December 10, 1967, to investigate the use of an underground nuclear explosion to increase productivity in a New Mexico natural gas field.

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natural gas; (*b*) Sloop, which would investigate the use of nuclear explosions to prepare copper ore bodies for solution mining techniques; and (*c*) Bronco, which proposed the use of nuclear explosions to break up oil shale strata for subsequent in-place retorting of the oil.

International Cooperation Activities

• The AEC's international cooperative program to promote the development of the peaceful uses of atomic energy continued to expand. Significant exchanges of technical nuclear information were developed; and the groundwork was laid for future cooperative effort as the Commissioners, individually and collectively, participated in meetings or discussions in 30 foreign countries.

• Agreements for Cooperation were amended or extended to provide the assurances covering long-range reactor fuel supply required by other countries planning nuclear power programs. The first long-term contract for toll enrichment services, whereby privately owned uranium will be enriched in uranium-235 in AEC facilities for a service charge, was signed with a Swedish electric utility.

• The U.S. continued its cooperative effort with the International Atomic Energy Agency (IAEA), to assure against the diversion of nuclear materials and equipment from peaceful to military uses. IAEA inspectors, for the first time, inspected a commercial chemical processing plant in the U.S.

• International studies on the use of nuclear power reactors for desalting water continued during the year. A previous U.S.-Israel study was revised to include a larger—300-Mwe. and 100-million-gallons-per-day capacity—plant for operation in Israel in 1975. The U.S.-IAEA-Mexican nuclear study group is expected to complete a report on the feasibility of a large nuclear power-desalting plant on the Gulf of California during 1968.

• India began studies, based on work done at the AEC's Oak Ridge National Laboratory, on the use of nuclear energy centers in association with industrial and agricultural-industrial complexes.

• As of mid-1967, the AEC had distributed abroad through sale, lease, and deferred payment sales, special nuclear and other materials in the approximate value of $266.4 million, resulting in revenues to the United States of $171 million.

Informational Activities

• The first step in a planned reorganization of arrangements for international exchange of nuclear technical reports was completed with establishment of a European reports clearinghouse in England. Additional regional clearinghouses are planned in other areas.

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● An Aerospace Nuclear Safety Center was established at th AEC's Sandia Laboratory, Albuquerque, N. Mex.; a Shock Wav Data Center began services to the scientific community from Law



Four Film Chips—Enough for a Dictionary. The complete text of the opened 6-inch dictionary can be recorded on the four pieces of high-resolution photographic film, called chips, shown in the girl's hand. Chips such as these are used to store a trillion bits of information in the world's largest computer storage device built for the AEC by International Business Machines Corp. Storing the data by conventional computer methods would require more than 1 billion punched cards, enough to reach around the world four times if laid end to end. The mass storage system is now installed at the Lawrence Radiation Laboratory in Livermore, Calif., to provide large volumes of data automatically to a network of computers.

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ence Radiation Laboratory, Berkeley, Calif.; and a National Neutron Cross Section Data Center was established at Brookhaven National Laboratory, Upton, N.Y. These changes brought to 28 the number of specialized information and data centers supported by the AEC.

• A new office of industrial cooperation was established during the year at Sandia Laboratory, Albuquerque, N. Mex. Its function, similar to that of the previously established offices at Argonne and Oak Ridge National Laboratories, is to encourage the commercial use of AEC-developed technological innovations.

• A revised and enlarged third edition of the "Source-book on Atomic Energy" was published.

• The AEC's "Atoms in Action" Nuclear Science Demonstration Centers were visited by more than 450,000 viewers and participants during 1-month presentations in Ankara, Turkey; Panama City, Panama; Tehran, Iran; and Quito, Ecuador. A special exhibit, "Nuclear Energy in Space," was presented during the Paris Air Show. AEC exhibits in the U.S. drew a total audience of more than 4,800,000 persons.

• The AEC's public information staff continued its meetings with executives of utilities planning nuclear powerplants, to discuss available informational materials for local public education programs; during 1967, there were 13 such meetings with utilities.

• The AEC's 10 domestic film libraries loaned films on atomic energy subjects for a total of 109,499 showings. Nineteen new motion pictures were added to the film libraries during the year. AEC films were used widely on television networks and through local channels.

• Two of the AEC's new films—"Atomic Power Today: Service with Safety," and "Brookhaven Spectrum"—were selected for international Gold Eagle Awards by the Council on International Nontheatrical Events.

• A comprehensive and thorough survey of AEC classification policy was completed during 1967. The AEC and the reviewing committee found that some classified areas of information could probably be declassified. Some have since been declassified and the national defense and security implications of declassifying the others are being considered. Since the beginning of the declassification program in 1946, 440,000 documents have been made available on an unclassified basis to industry and science.

• The AEC was granted 301 U.S., and 428 foreign, patents during the year. Eleven public announcements were issued by the AEC listing new U.S. and foreign patents. The Commissioner of Patents transferred 921 privately owned patent applications in the atomic energy

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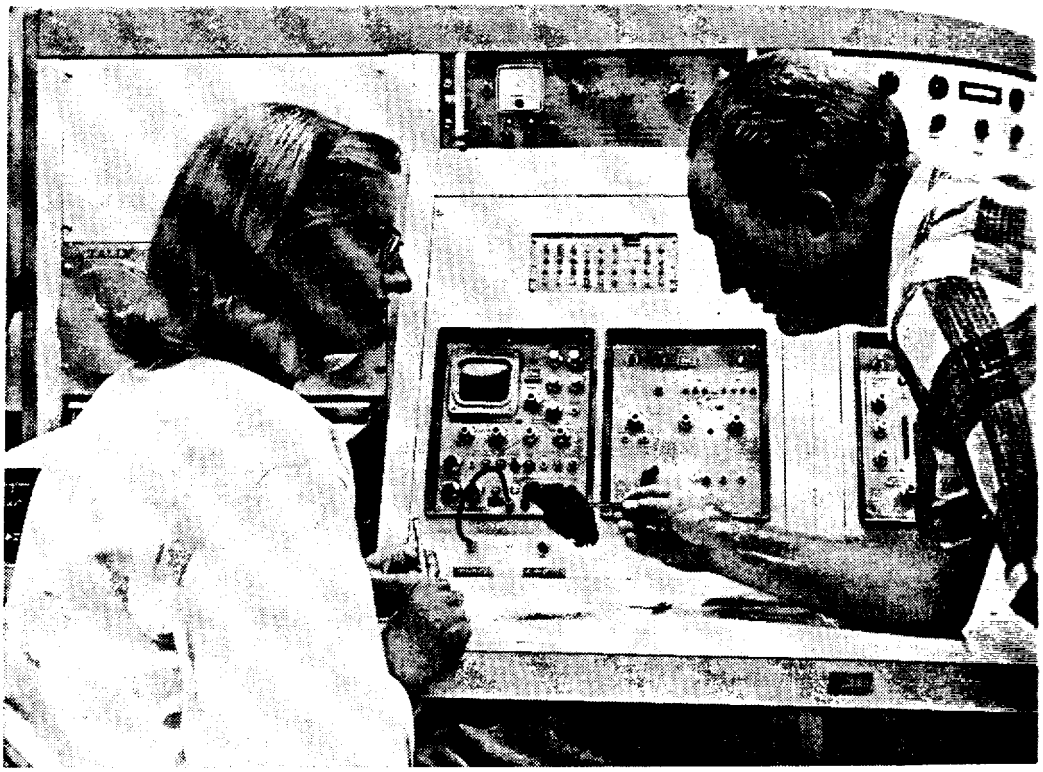
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field to the AEC for review; 35 nonexclusive licenses were grant on the U.S. patents available for licensing.

● Continuing research and development declassification h brought a decline in the number of access permits; there were 2 access permits in effect on November 30, 1967, compared to 42 year earlier.

Nuclear Education and Training

● During 1967, the AEC continued to broaden the base of nucle knowledge and technology by providing assistance to students, fa ulty, and institutions of learning. Increased emphasis was given to t use of AEC laboratories for training purposes. The burgeonin growth of the nuclear power industry prompted an intensified a tempt to evaluate the future needs for manpower and the traini



Antiquity Study. A student working on her Ph. D. thesis study in the field o physical anthropology is shown discussing a technical problem with her advis at the AEC's Health Services Laboratory at the National Reactor Testing Sta tion, Idaho. The work is being sponsored under a graduate fellowship agreem between the AEC and the Associated Western Universities. Samples of mumm hair obtained from the Nubian Sudan civilization, *circa* 350 to 1300 AD, wer irradiated nondestructively with thermal neutrons in an NRTS test reactor. Th activated trace elements identified in the hair by gamma spectrometry are bein studied to determine the environmental conditions, disease, and diet which wer peculiar to that civilization.

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cilities required to meet them. Additional emphasis was put upon graduate-level assistance, and programs were adjusted to meet the changing needs in the field of atomic energy.

Basic Research

• AEC-sponsored basic research in the life and physical sciences continued to provide new information of value not only to nuclear technology but useful to other branches of science as well.

• The Stanford Linear Accelerator Center (SLAC) was dedicated in September. The two-mile long linear electron accelerator had come into operation in 1966. Physics experiments already underway were expanded during 1967 to new areas with the first operation of the SLAC 40-inch hydrogen bubble chamber.

• Construction of a 12-foot liquid hydrogen bubble chamber at Argonne National Laboratory as a major addition to the Zero Gradient Synchrotron will provide scientists with a highy sophisticated instrument for high energy physics investigations.

• Construction was completed on three new biomedical program laboratories in 1967. These were: a single-story virus control facility at Oak Ridge National Laboratory; an addition to the AEC-National Cancer Institute co-carcinogenesis laboratory at Oak Ridge; and a variable dose-rate irradiation facility at the University of Tennessee-AEC Agricultural Research Laboratory. The latter is expected to contribute to large-animal research projects having applications associated with human radiobiology.

Industrial Participation Aspects

• Throughout 1967, the AEC continued to cooperate and communicate with industry through frequent meetings with leaders of industry associations having active nuclear energy interests. The Commissioners met with the Board of the Atomic Industrial Forum twice. These formal exchanges were complemented throughout the year by meetings between Forum committees and the AEC staff. Through such meetings, the objectives and viewpoints of industry and the AEC are given consideration.

• Among the other industrial groups with which the AEC met during 1967 are the Edison Electric Institute, the Chamber of Commerce of the U.S., the Manufacturing Chemists' Association, and the American Public Power Association.

• During 1967, the AEC urged industry to register with the Science Information Exchange (SIE) of the Smithsonian Institution its

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planned research and development in the fields of isotope applicati and radiation. The AEC, SIE, and industry worked out a categor reporting system believed to be informative without revealing pr prietary information on work going forward in specific companies.

Administrative and Management Matters

- An employment survey shows that atomic energy industrial acti ities in the private sector of the American economy are expandin Some 429 industry units reported a total of 35,457 employees in th atomic energy field as of March 1967—a 4.7 percent increase sinc March 1966. Contractor employees in 69 reporting units of Gover ment-owned establishments totaled 102,293—a decrease of 0.8 perce during the same period.
- The AEC's assistance in diversifying the economic base of th Richland (Wash.) area continued. A replacement contractor (Atlanti Richfield Hanford) plans a meat packing and cattle feedlot operatio and also will build a resort and convention facility. Three new diver sification commitment facilities—the first four buildings of Ba telle-Northwest's planned research complex, Douglas Aircraft's ne research center, and an International Telephone and Telegraph instr ment plant—were opened during 1967.
- The AEC's South Albuquerque Works at Albuquerque, N. Mex. was transferred to the U.S. Air Force for production of jet engin parts by the General Electric Co.
- Progress leading to an employer-Federal-State records an reports system for radiation-workers continued.
- The small business share of AEC subcontracts was more tha 43 percent during 1967; it remained above 40 percent for the nin consecutive year.

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Chapter 1

SOURCE AND SPECIAL NUCLEAR MATERIALS

The uranium industry's outlook continued to brighten during the year, and the industry purchased larger amounts of uranium concentrate for future delivery. For the first time in 8 years, developments of new reserves exceeded the tonnage mined. The utilities industry is now in a better position to decide on fuel supply arrangements for the reactors planned for the next few years as the AEC further implemented the 1964 Private Ownership Act by making available additional information on planned "toll enrichment" arrangements. Production of nuclear materials for defense needs continued to be reduced somewhat, but production of "peaceful use" radioisotopes continued to advance.

RAW MATERIALS

Because of the surge of nuclear powerplant orders, the uranium industry during the year greatly increased its exploration activity and undertook some expansion of mining and milling facilities. These actions reflect some change from other years which were marked by concern over the adequacy of the short-term commercial uranium market.

URANIUM PROCUREMENT

Purchases of uranium concentrate (U_3O_8) by the AEC during 1967, all from domestic production, were 1,037 tons less than in 1966. The amounts were: 1966—9,487 tons; and 1967—8,450 tons. Table 1 lists the uranium concentrate producing plants currently in operation and

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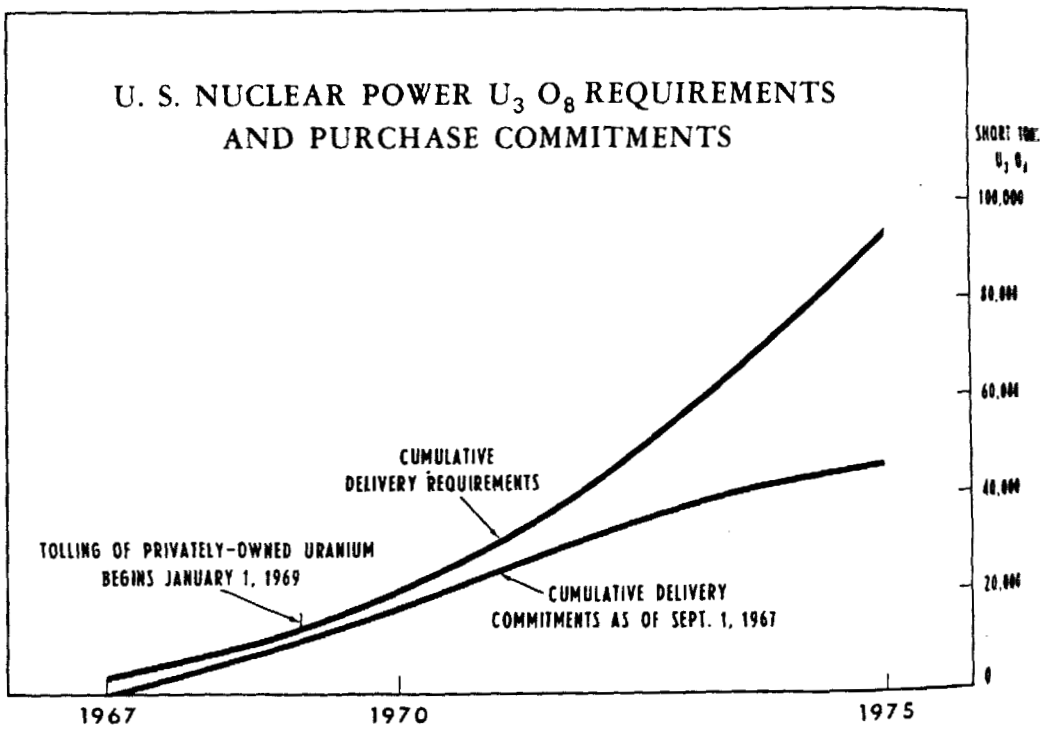
the estimated tons of U_3O_8 in concentrate remaining to be delivered as of December 31, 1967, under AEC contracts extending through 19

TABLE 1.—URANIUM CONCENTRATE PRODUCING PLANTS

Company under AEC contract	Mill location	Remaining deliveries under AEC contracts 1968-7[illegible] (tons U_3O_8)
Anaconda	Bluewater, N. Mex.	[illegible]
Atlas Corp.	Moab, Utah	[illegible]
Federal-Radorock-Gas Hills Partners	Fremont County, Wyo.	[illegible]
Homestake-Sapin Partners	Grants, N. Mex.	[illegible]
Kerr-McGee Corp.	Grants, N. Mex.	[illegible]
Union Carbide Corp.	Natrona County, Wyo.	[illegible]
Union Carbide Corp.	Rifle & Uravan, Colo.	[illegible]
United Nuclear Corp.	(Ores treated in Homestake-Sapin mill)	[illegible]
Utah Constr. & Mining Co.	Fremont County, Wyo.	[illegible]
Foote Mineral Co.	Shiprock, N. Mex.	[illegible]
Western Nuclear, Inc.	Jeffrey City, Wyo.	[illegible]
Other producing companies		
American Metal Climax	Grand Junction, Colo.	
Mines Development Co., Inc.	Edgemont, S. Dak.	
Petrotomics Co.	Carbon County, Wyo.	
Susquehanna-Western, Inc.	Falls City, Tex.	
Cotter Corp.	Canon City, Colo.	

Industry Procurement

Throughout 1967, reactor manufacturers and electric utility companies were active in contracting for their future needs for uranium



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Domestic producing companies, as a group, added substantially to the total commitments previously reported in 1966. The total tonnage of U_3O_8 contracted for by domestic buyers during the year with the years of delivery were approximately:

	Tons		Tons
1968	4, 900	1972	7, 900
1969	5, 000	1973	6, 200
1970	5, 900	1974	4, 400
1971	7, 200	Later	4, 200
Total	45, 700		

In addition, 2,400 tons of U_3O_8 were contracted for delivery to foreign buyers. Estimated delivery requirements and delivery commitments, which indicate the need for additional purchases for delivery in the early '70's and beyond, are shown in the chart "U.S. Nuclear Power U_3O_8 Requirements & Purchase Commitments."

During the year, a new Federal regulation limiting the exposure to radiation, particularly from radon gas and its daughter decay products, of underground uranium miners was put into effect (see Chapter 5—Operational Safety). The installation of ventilation equipment in the mines to comply with the regulation is not expected to have a severe effect on the cost of U_3O_8 production.

ORE RESERVES

Estimated U.S. uranium ore reserves at the beginning and end of 1967, recoverable at $8.00 per pound of U_3O_8 in concentrates, were:

	Tons of ore	Percent U_3O_8	Contained tons U_3O_8
Estimated reserves Jan. 1 1967	61, 000, 000	0. 23	141, 000
Estimated reserves Dec. 31, 1967 [1]	64, 000, 000	0. 23	148, 000
Increase in estimated reserves	3, 000, 000	0. 23	7, 000
Shipments to mills in 1967	5, 200, 000	0. 21	10, 700

[1] Reserves available at up to $10 a pound of U_3O_8 are estimated to be 310,000 tons, including estimated production of 120,000 tons of byproduct from copper and phosphate operations through the year 2000.

In addition, there were approximately 3,550 tons of U_3O_8 in ore stockpiles, and 4,580 tons in process and finished product, making a total at the mills of 8,130 tons of U_3O_8 at the end of the year.

New Reserves Exceed Production

Approximately 17,700 tons of contained U_3O_8 were added to the estimated reserves during the year. This was the first year since 1959 that additions to ore reserves exceeded the quantity mined. Most

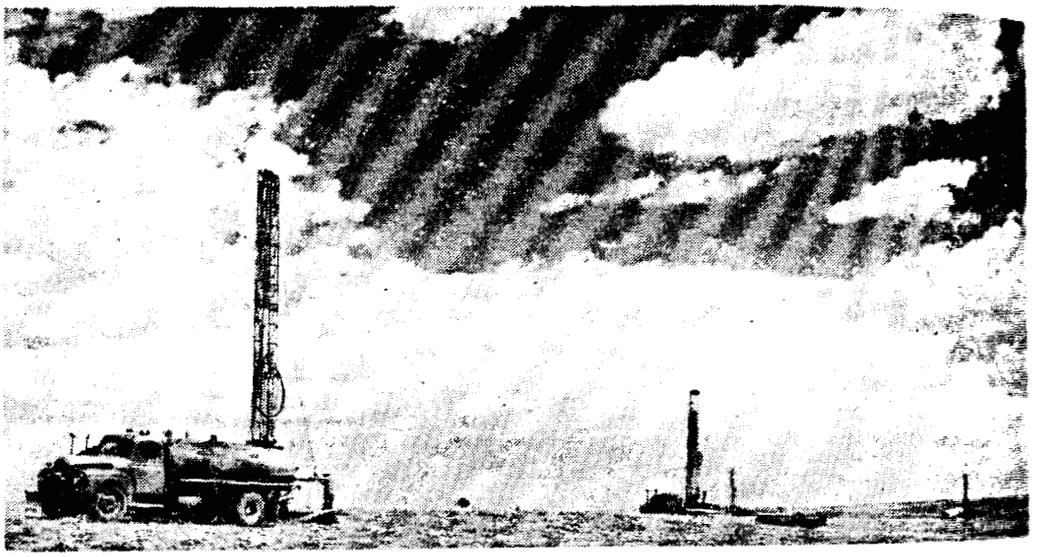
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of the increase in reserves, as well as some new discoveries which hav not yet been sufficiently evaluated to warrant inclusion in reserve est mates, have been in the known uranium producing areas and tributary to existing production facilities. Several of the incompletely evaluate discoveries appear significant and will undoubtedly add substantial to reserves when their extent is fully known. A longer period will be required before exploration in new areas which is now in the initia stages, can be expected to add materially to known reserves.

New Sources

Results of pilot plant work by the U.S. Bureau of Mines in coopera tion with the Kennecott Copper Co. at the company's Utah mine, and supported by the AEC, indicate that uranium may be recovered from copper mine waste dump leaching solutions. Though the potential pro duction rate is limited, it could exceed a thousand tons of U_3O_8 concen trate per year. In addition, the rapidly increasing rate of production of high analysis fertilizers from phosphate rock processing, mainly in Florida, appears to represent an increasingly important potential source of byproduct uranium for the future.

In 1967, exploration drilling amounted to approximately 11 million feet, far exceeding 1966 and earlier reported plans of the industry. Re

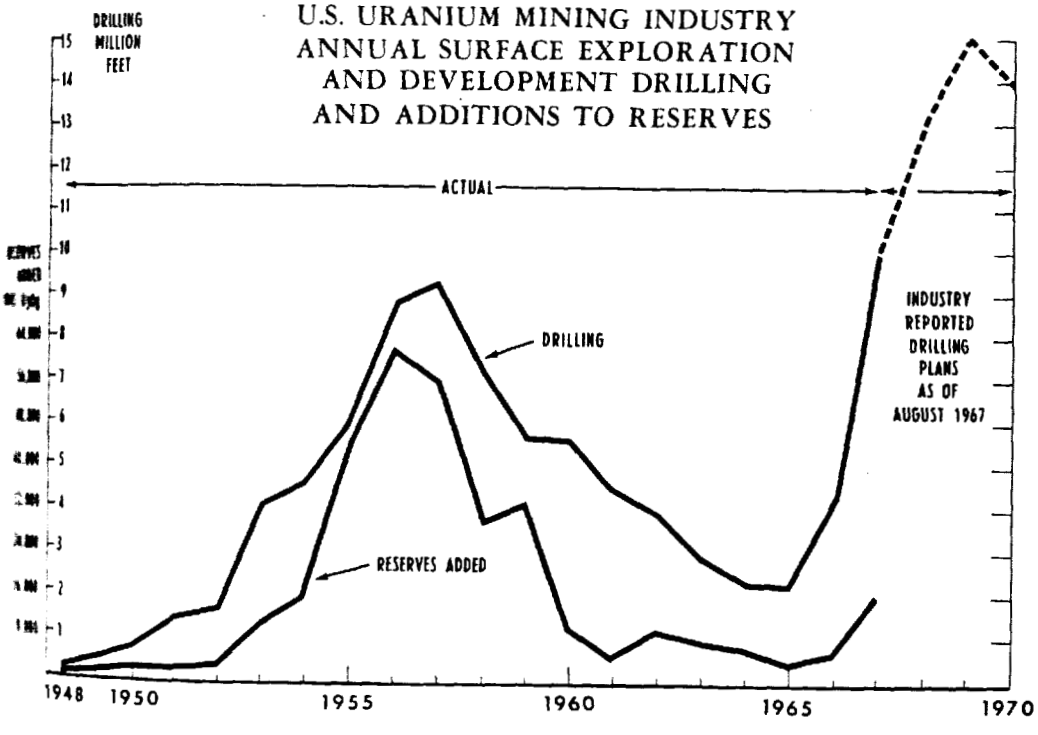


New Sources. Exploration activities for new sources of uranium ore were the greatest they've ever been during 1967—even surpassing the previous peak year of 1957. Photo shows three rotary drilling rigs, exploring for and developing uranium reserves in the Shirley Basin of Wyoming. The heavy trend toward using nuclear reactors for electricity generation, which started in 1966 and gained even greater impetus during 1967, has shown the need for greatly increasing the known uranium ore reserves to meet future nuclear fuel requirements.

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sponses from industry to inquiries regarding drilling plans indicate that this figure will be exceeded again in 1968 and will progressively increase. The industry has disclosed plans for more than 40 million feet of drilling during the 1968 through 1970 period. The graph, "U.S. Uranium Mining Industry . . ." below shows the past and planned drilling activity of the industry and the additions to reserves.

Exploration and development drilling by the private uranium industry in 1967 exceeded that of any prior year, including the peak year of 1957. This has borne out the AEC's confidence that the industry would respond to growing nuclear power requirements for uranium by undertaking a physical exploration program commensurate with the need. The AEC regards exploration for, and development of, new uranium deposits to meet commercial demands as a responsibility of private industry. However, in view of the large quantities of uranium that must be found and produced in the years ahead and the great potential savings in the cost of power if low uranium costs can be maintained, the AEC believes it is important that there be an adequate program of Government-sponsored research and development. This would be aimed toward achieving an improved understanding of the occurrence, characteristics, and distribution of uranium ore deposits, the underlying ore-forming processes, and the technology of discovery and exploitation. Therefore, during 1967, the AEC moderately expanded its level of support of research and development in the fields of geology, geophysics, prospecting instrumentation, and uranium re-



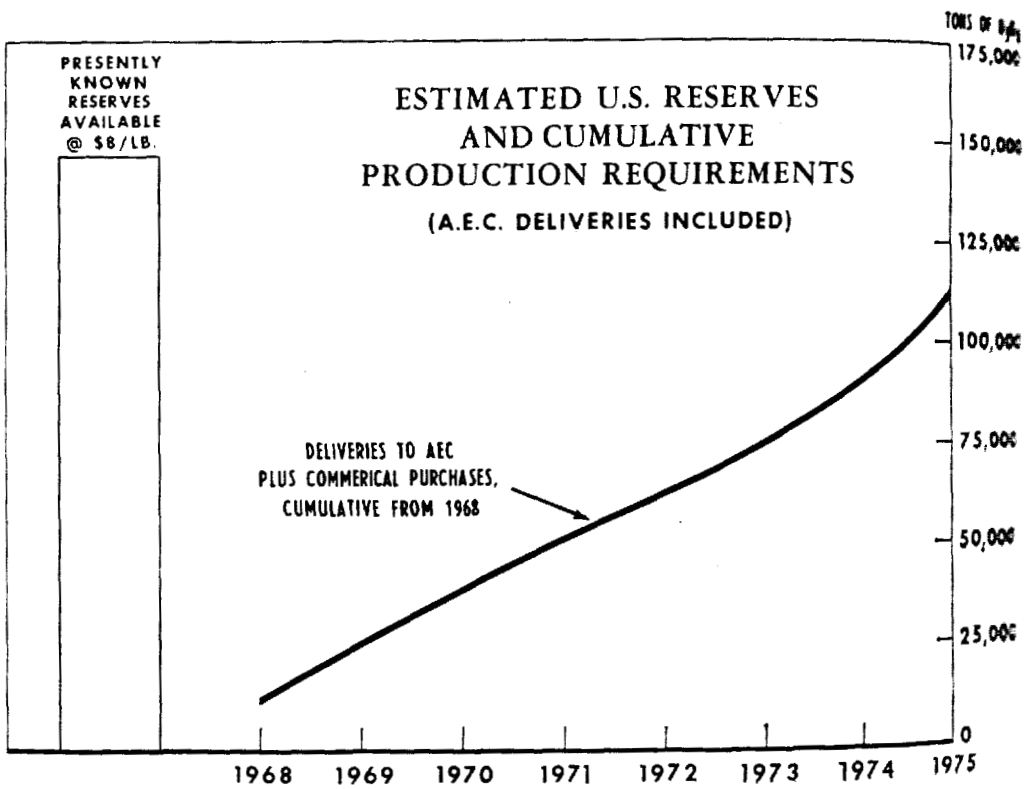
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covery techniques. The aim of this effort is to improve the technica base of private industry's exploration and production efforts. The graph "Estimated U.S. Reserves & Cumulative Production Require ments," shows presently estimated U.S. uranium reserves and reactor needs.

FUTURE POLICY

In view of the increasing interest by the electric utility industry in the supply of nuclear fuel, the AEC published, in the *Federal Register* of November 9, 1967, a statement on proposed future uranium supply policies and related activities and requested comments from the industry. In substance, the AEC reaffirmed its willingness to sell enriched uranium on a single transaction basis under certain specified conditions, with the natural uranium feed component of the charge based on $8 per pound of U_3O_8, at least through June 30, 1973. Foreign as well as domestic customers may purchase enriched or natural uranium under the terms outlined, all subject to the availability of AEC-owned uranium, which appears at this time adequate to offset any possible short-term shortages in supply.

No date has been established for removal of restrictions on the enrichment of foreign uranium for domestic use. The Commission is reviewing these restrictions in the light of recent developments.



URANIUM

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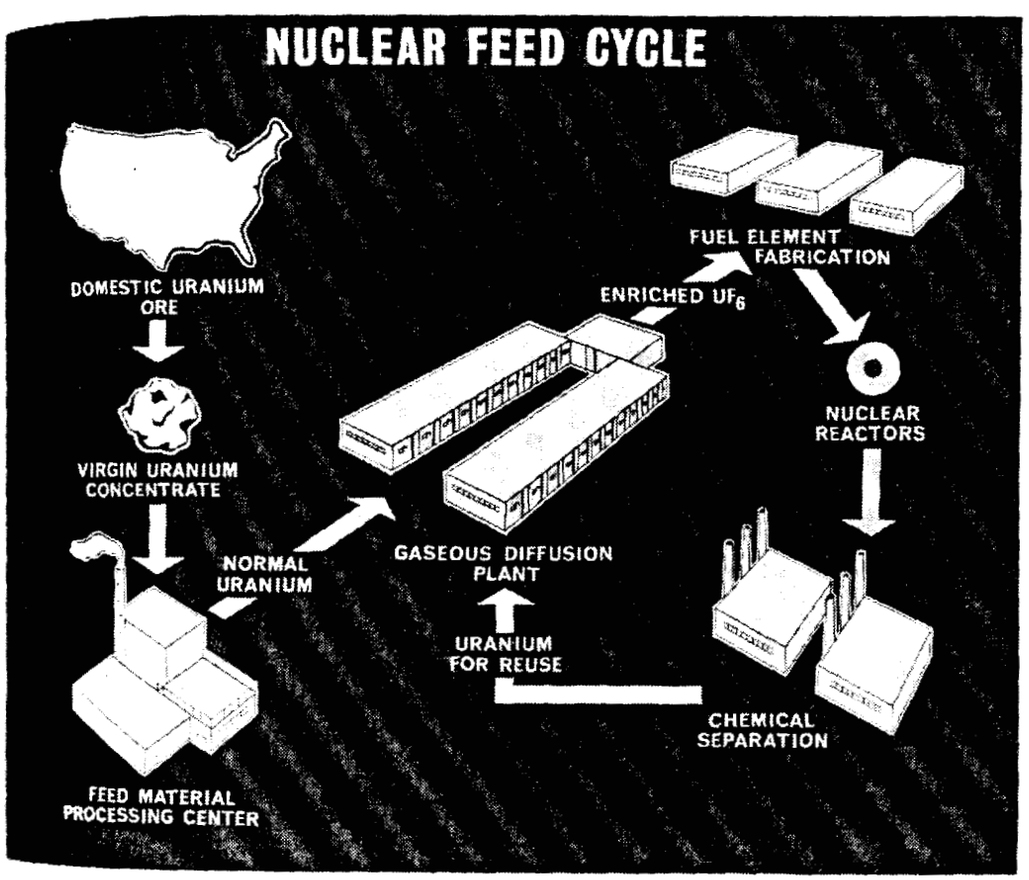
Nuclear Fuel Cycle
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URANIUM ENRICHMENT

The private sector of the atomic energy industry today can provide virtually all of the needs of the nuclear fueled power generating stations except uranium enrichment.[1] Four key factors that will provide the industry with an improved basis for planning its future uranium enrichment services and associated feed procurement were announced by the AEC during the year. These were: (*a*) the declassification of the capacity of the AEC-owned gaseous diffusion plants; (*b*) the

[1] Uranium enrichment requires the services of AEC's contractor-operated gaseous diffusion plants at Oak Ridge, Tenn.; Portsmouth, Ohio; and Paducah, Ky. There, uranium hexafluoride (UF_6) in a gaseous state is put through a series of barriers which partially separate the lighter and faster-moving uranium-235 (U^{235}) atoms from the heavier and slower-moving uranium-238 atoms that make up the bulk of the material. Under "toll enrichment"—which will begin in 1969—the customer will supply uranium feed and get back as product a lesser amount of uranium containing a greater concentration of the U^{235}, and optionally, the rest of the uranium (tails) containing a lesser concentration of U^{235}. For this service, the AEC will levy an enrichment service charge, or "toll," upon the industrial customer.



Nuclear Fuel Cycle. Diagram *above* shows (starting at *upper left*) the basic steps in the nuclear fuel cycle—from mining the raw uranium ore to reusing the uranium recovered during the chemical processing of "spent" fuel elements for new nuclear fuel after it has been once "burned" in a power reactor.

3 1 0 2 2 4

charge that has been established for uranium enrichment service (c) the establishment of the waste assay; and (d) the establishment of a standard table of enrichment services. Industry is now in a better position to project its fuel costs for the early 1970's.

TOLL ENRICHING

The offering by the AEC of toll enriching services under long-term contracts was authorized under the Private Ownership of Special Nuclear Materials Act of 1964 (PL 88–489); this method of acquiring enriched uranium is expected to be used extensively. The AEC has already signed one contract, with a Swedish electric utility company, for the provision of such services after December 31, 1968. Table 2 shows the pertinent actions and dates of the "Private Ownership Act."

TABLE 2.—TIME TABLE FOR COMMERCIAL CONVERSION

Private ownership permitted	August 26, 1964
Toll enriching of privately owned uranium begins	January 1, 1969
AEC terminates distributing special nuclear material for power reactor fuel by lease after	December 31, 1970
AEC guaranteed purchase price for plutonium ends	December 31, 1970
Mandatory private ownership of special nuclear material used for power reactor fuel	July 1, 1972

Gaseous Diffusion Plants Capacity

On June 14, 1967, the AEC declassified information on the capacity of its gaseous diffusion plants to produce enriched uranium. The action was taken to permit the domestic and foreign nuclear power industry to make judgments concerning the adequacy of the three gaseous diffusion plants to meet nuclear fuel requirements for power reactors.

The separative work production capability (in millions of kilogram units per year) of the existing gaseous diffusion plant complex in relation to electric power usage (in megawatts) is as follows:

Power usage	*Separative work production capability*
2,000	6.9
3,000	9.9
6,000	17.0

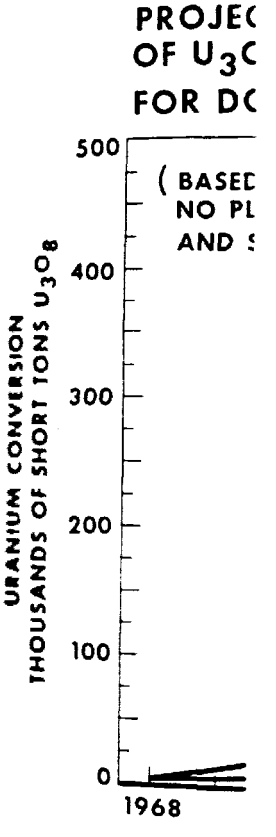
A "separative work unit" is a measure of the effort expended in the plants to separate a quantity of uranium into a portion enriched in uranium-235 (U^{235}) and a portion depleted in U^{235}. The number of separative work units required to produce enriched uranium for fuel for any specific nuclear powerplant is related to the concentration of uranium-235 required, the concentration of the feed material, and the waste (tails) concentration.

Charges for Uran

On September 1 for the toll enrich is $26 per kilogr "tails" assay is 0. $30 ceiling establi projected market operating the gas Incorporated in t costs including a investment in pla preproduced mate reasonable compe data on the actua 1967 and projecte

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[1] See p. 78, "Annual R-228, September 21, Energy Commission, W



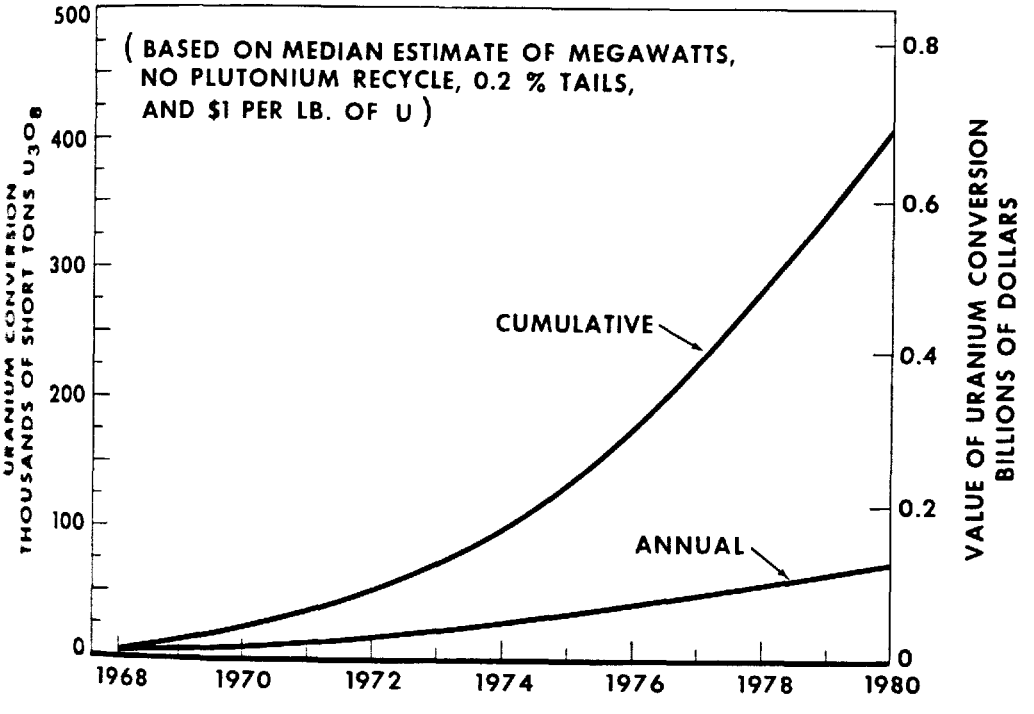
Charges for Uranium Enrichment Services

On September 21, 1967, the AEC announced that its current charge for the toll enrichment of privately owned uranium in the isotope U^{235} is $26 per kilogram unit of separative work and that the standard "tails" assay is 0.2 percent U^{235}. This $26 charge, which is below the $30 ceiling established in 1966,[2] is based upon extensive studies of the projected market for separative work and of estimated AEC costs of operating the gaseous diffusion plants from FY 1966 through 1975. Incorporated in the charge are allowances for all direct and indirect costs including appropriate depreciation and imputed interest on its investment in plant equipment, and the separative work portion of reproduced material. As public evidence that the charge will provide reasonable compensation to the Government, the AEC also published data on the actual cost of separative work in the first 6 months of 1967 and projected average costs of such work through fiscal 1975.

The figure of 0.2 percent U^{235} was used as the "tails" assay in deriving the feed and separative components incorporated in the standard table of enriching services. This table for example, provides that with

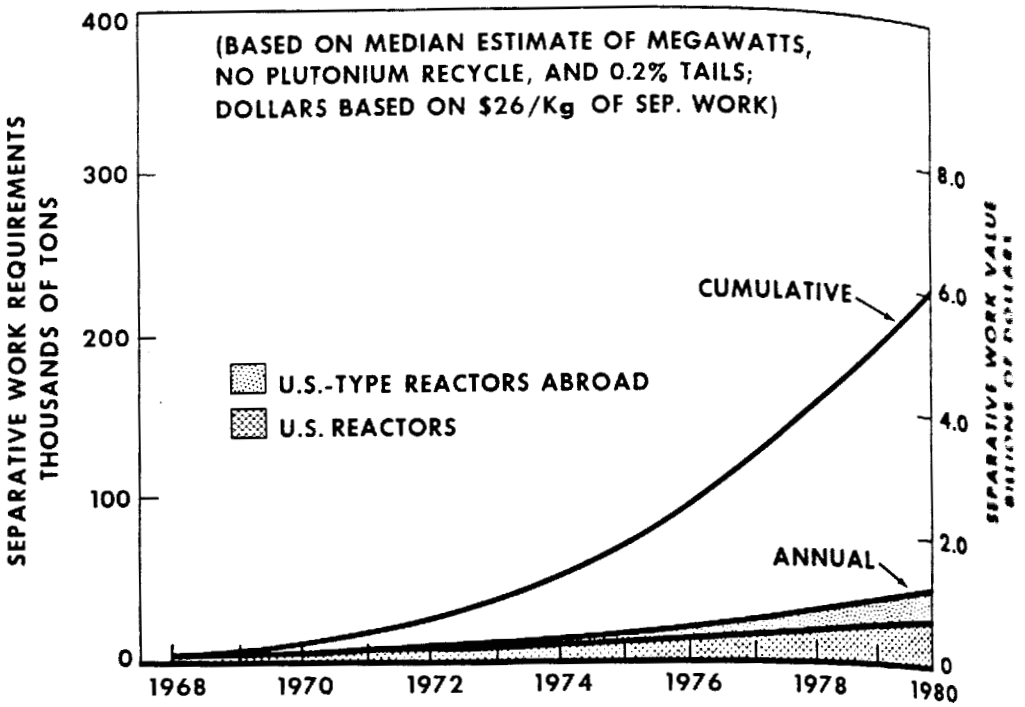
[2] See p. 78, "Annual Report to Congress for 1966"; and AEC public announcement No. C-228, September 21, 1967, available from Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

PROJECTED REQUIREMENTS FOR CONVERSION OF U_3O_8 TO UF_6 FOR FEED TO PRODUCE FUEL FOR DOMESTIC AND FOREIGN REACTORS

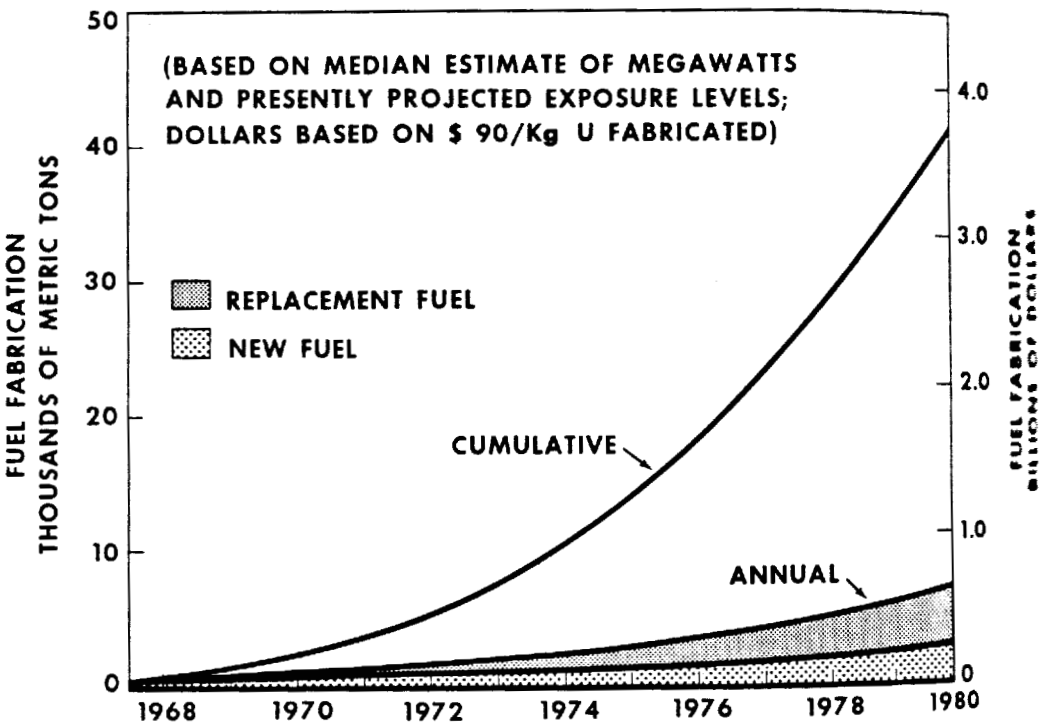


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PROJECTED SEPARATIVE WORK REQUIREMENTS FOR DOMESTIC AND FOREIGN REACTORS FUELED WITH U.S.-ENRICHED URANIUM



PROJECTED REQUIREMENTS FOR FABRICATION OF FUEL FOR DOMESTIC NUCLEAR POWER REACTORS



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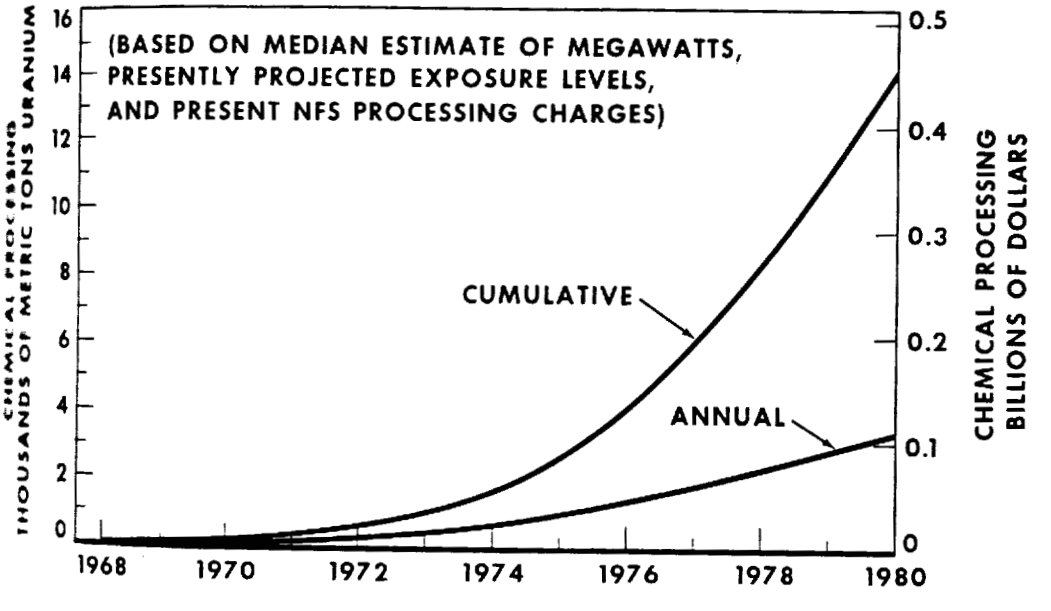
delivery of 5.479 kilograms of normal uranium feed (0.711% U^{235}) a payment of $111.96,[3] would be required for the AEC to provide one kilogram of 3.0 percent U^{235} as uranium hexafluoride (UF_6). The AEC schedule of charges for enriched uranium sold and leased was revised, effective January 1, 1968, to incorporate the $26 charge and the 0.2 percent tails assay along with a feed component charge of $23.46 per kilogram. The combined effect of the new separative work charge and tails assay, both being lower than the corresponding figures of $30 and 0.2531 percent in the previous schedule, reduces the customer's cost for each kilogram of enriched uranium by 5 to 7 percent. Most of this saving comes from reduced feed materials requirements. Correspondingly, the guaranteed price for plutonium and uranium-233 purchased by the AEC before January 1, 1971, have been reduced to $9.28 per gram and $13 per gram, respectively. The separative services table was published in the *Federal Register* of November 29, 1967.

Studies of Private Enrichment of Uranium

The AEC is studying the question of the feasibility and desirability of commercial enrichment of uranium.[4] The scope of the study includes the possible transfer for private operation of some or all of the

[3] Does not include shipping, packaging, etc., costs.
[4] See p. 357, "Annual Report to Congress—1966."

PROJECTED REQUIREMENTS FOR CHEMICAL PROCESSING OF FUEL FROM DOMESTIC NUCLEAR REACTORS



SEPARATIVE WORK VALUE BILLIONS OF DOLLARS

FUEL FABRICATION BILLIONS OF DOLLARS

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present gaseous diffusion plants as well as the construction of new en riching plants by industry. (Enrichment of uranium in the U.S. is presently done only at the AEC's three contractor-operated gaseous diffusion plants at Oak Ridge, Tenn.; Portsmouth, Ohio; and Paducah, Ky.) Five consultants with experience in the technical aspects of commercial operations, in Government, and in law and economics are providing advice to the AEC in considering this question.

The Atomic Industrial Forum has named a team to study the question from the industry standpoint. The AEC is cooperating with this endeavor by supplying certain information required for this study.

Gas Centrifuge Work. As a separate question, the AEC has determined that national security interests would best be served if privately sponsored work on the gas centrifuge process for separation of isotopes were discontinued. The AEC program on gas centrifuge development will, of course, be continued to advance isotopic separation technology and to evaluate the attractiveness of the process either at home or abroad.

On the basis of a number of years of development effort on isotope separation processes, the AEC has concluded that the gas centrifuge process will probably not be economically competitive with the U.S. gaseous diffusion process for the next decade or longer. However, if at some future time it is in the national interest to allow private participation in gas centrifuge developments, other than under AEC contracts, the AEC would then make available, subject to security regulations, economic and other required information needed for investment decisions by industry.

NUCLEAR MATERIALS PRODUCTION

Production of special nuclear materials continued during the year at reduced levels that were commensurate with scheduled requirements for military and civilian programs.

PRODUCTION CUTBACKS

Operations continued at both AEC production reactor sites, the Hanford Works at Richland, Wash., and the Savannah River Plant, near Aiken, S.C. A reactor shutdown announced in January 1967, was accomplished at Hanford and further reductions were made in use of electric power at the gaseous diffusion plants.

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Gaseous Di

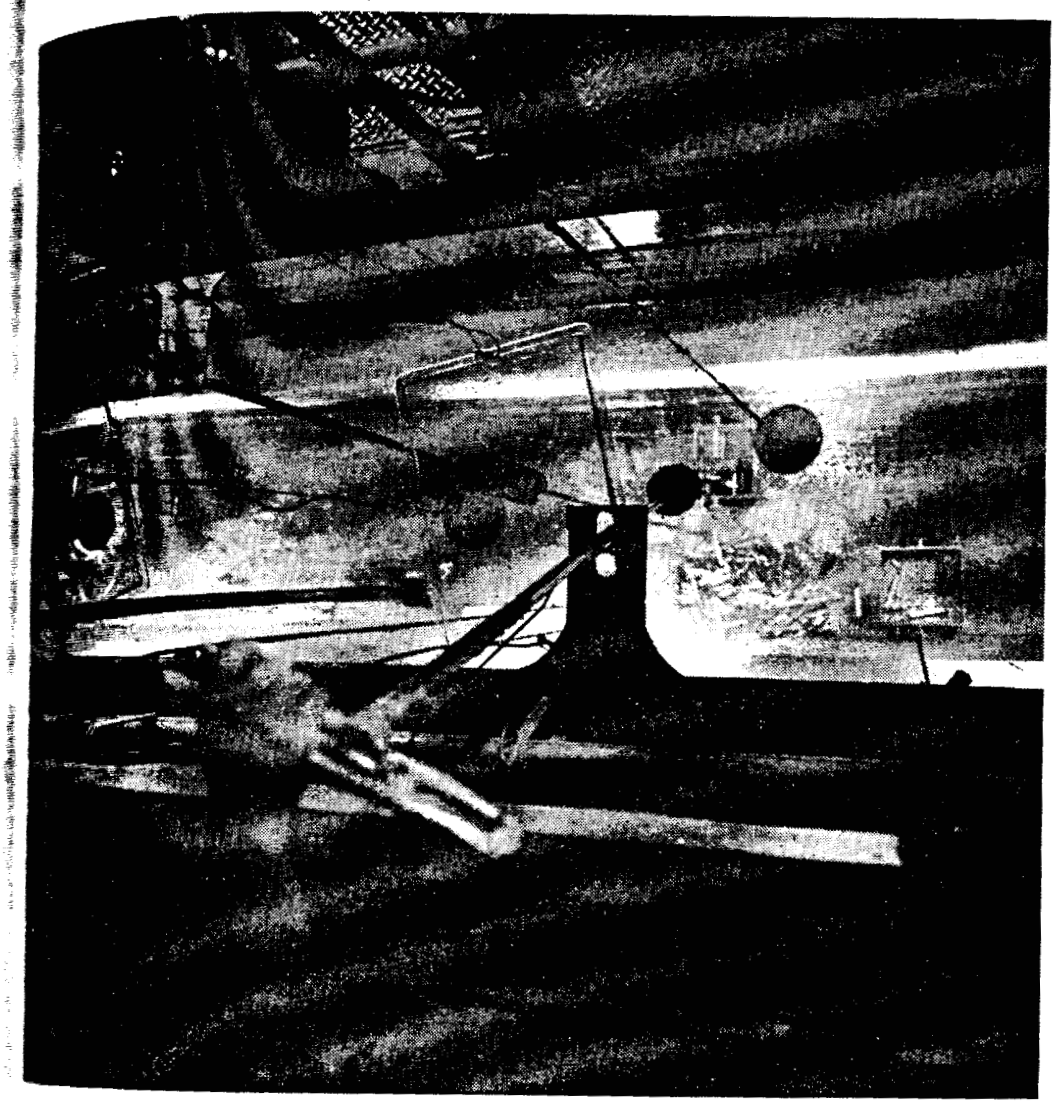
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Gaseous Diffusion Plant Operations

During 1967, the level of electric power usage at the AEC's Portsmouth, Ohio, gaseous diffusion plant was reduced by 320,000 electrical kilowatts (ekw.). The reductions were accomplished following negotiations with the Ohio Valley Electric Corp. and consisted of a reduction of 200,000 ekw. previously scheduled for late 1967 and a temporary reduction of 120,000 ekw. to be effective during the period September 1, 1967 through June 30, 1968. The permanent reduction of 200,000 ekw. is a part of the steps being taken to reduce total power usage at the three gaseous diffusion plants (Oak Ridge, Tenn., Padu-



Loading. A reactor operator at Hanford's "C" reactor loads fuel elements into transfer boxes under 20 feet of water following their discharge from the reactor after irradiation. The elements are intensely radioactive at first and the water shields workers from the radiation. After a short time in the underwater storage basin, the fuel elements are loaded into shielded railroad cars and taken to the chemical separations facilities for processing.

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cah, Ky., and Portsmouth, Ohio) to 2,000,000 ekw. by January 1, 196[illegible]. The actions reduced the electric power costs for the gaseous diffusion plants by about $6.4 million in 1967. (See also "Studies of Private Enrichment of Uranium" in previous section.)

Two Hanford Facilities Closed

The "D" reactor at Hanford, was shut down on June 26, 1967. The reactor, which had been in operation for 22 years, was placed in standby status. It was the fifth of the AEC's 14 production reactors to be shut down since President Johnson announced a reduction in plutonium production in early 1964.[5]

The Redox plant which discontinued separations of irradiated uranium fuels at the end of 1966, was placed in standby on June 30, 1967. The plant was shut down because of the reduced volume of irradiated fuel resulting from the closing of the production reactors. Built in Hanford in 1951, it was the first large-scale solvent (Hexone) extraction-type plant in the United States for recovery of plutonium and uranium from irradiated fuel.[6] The Purex plant is the only irradiated fuel processing facility now operating at Hanford.

REACTOR OPERATIONS

The "N" reactor at Hanford performed satisfactorily in its role as the Nation's first dual purpose—plutonium production and electricity generation—reactor. Programs to demonstrate the technical feasibility for multiproduct operations using the Hanford and Savannah River reactors are being developed and tested.

Five-Year Planning

A long-range process research and development program is underway to reduce costs and increase the versatility and flexibility of the Hanford and Savannah River reactors for production of nonweapons program nuclear materials. Work is continuing toward: (*a*) providing data on the need for, and availability of, nonweapon reactor products that can be produced in these reactors; (*b*) firming up the basic technology needed to support future programs to meet specific re-

[5] As a result of the 1964 Presidential announcement to cut back plutonium production, four of the AEC's 14 production reactors were shut down in 1964 and 1965—see pp. 17, 18, and 44, "Annual Report to Congress for 1964"; p. 73, "Annual Report to Congress for 1965"; and pp. 90–92, "Annual Report to Congress for 1966." On January 18, 1968, the AEC announced two more reactors—one each at Hanford and Savannah River—will be placed in standby.

[6] See p. 91, "Annual Report to Congress for 1966."

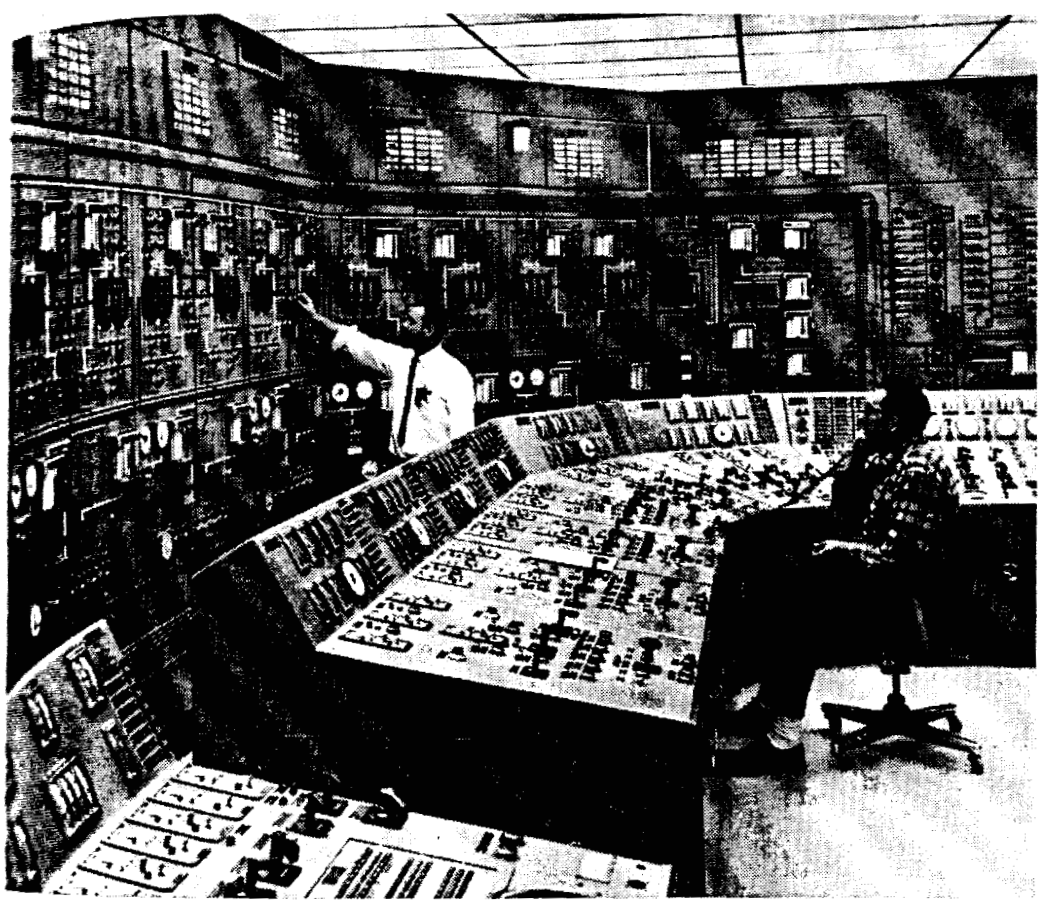
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quirements for these products; (*c*) reducing, or minimizing any mutual interference between the weapons mission and nonweapons material production; and (*d*) incorporating flexibility in the production operations to adjust rapidly to new mission priorities. Toward these goals, Savannah River has developed a mixed lattice loading (see "Savannah River Reactors" item on p. 39) which can produce varying quantities of several isotopes within a single reactor loading.

Hanford Reactor Operations

"N" Reactor. Operation of the "N" reactor and associated fuel production facilities was assumed by Douglas United Nuclear, Inc., on July 1, 1967. This completed the programed phase-out [7] of the General

[7] See pp. 19–20, "Annual Report to Congress for 1964" and pp. 25–27 of "Annual Report to Congress for 1965."



Reactor Transfer. Operating responsibility for the AEC's dual-purpose "N" reactor at the Hanford Works was transferred from General Electric Co. to Douglas United Nuclear Co. on July 1. This completed the phasing-out of General Electric as the single operating-contractor at Hanford. Photo is a view of the reactor control room showing the instrumentation that monitors conditions in the six heat-exchanger cells. Steam produced in the reactor during plutonium production is sold to the Washington Public Power Supply System which operates an 800-Mwe power generating plant adjacent to the reactor.

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Electric Co. as the single operating contractor at the Hanford Wor... The reactor was completely shut down for planned maintenance at t... time of transfer.

A coproduct demonstration program—concurrent production ... tritium (hydrogen-3) and plutonium—was initiated at the "N" ... actor in 1967 and proceeded smoothly. During this demonstrat... program, a high-power probe test was conducted during which ... operating level of 4,800 megawatts thermal (Mwt.) was attain... After this 1-day test on June 18, the reactor returned to norma... 4,000-Mwt operation.

Reactor operations were interrupted on June 22 by a fire in one ... the six heat exchanger cells. The reactor operated satisfactorily wi... the five remaining heat exchanger cells.

The "N" reactor was shut down from September 1 through Dece... ber 15 as a result of strike action by the Hanford Atomic Me... Trades Council (HAMTC). The work stoppage involved disagre... ment over interpretation of national standards of permissible radia... tion exposure and questions of whether "N" reactor personnel shou... be in a bargaining unit separate from that applying to personnel a... the other Hanford reactors.

Power Generation. Total electrical generation from the "N" reactor during 1967 was in excess of 2 million megawatt hours. Following installation of step-down transformers[8] on the Bonneville Power Administration's (BPA) transmission system, the WPPSS generating plant achieved its designed 800 megawatts electrical (Mwe.) output in May. The 800 Mwe.-level had been reached on December 9, 1966, but failure of a high-voltage transformer on the BPA system the next day made it necessary to reduce the full-power output.

Other Reactors. Operation of the other four Hanford production reactors continued through the year with new records for operating efficiency being established. In addition to weapon-grade plutonium, these reactors produced significant quantities of nondefense plutonium (for experimental and other uses), uranium-233, cobalt-60, and carbon-14. In making plutonium-238, a uniquely efficient quick-turnaround cycle was employed in which the charge and discharge of the neptunium-237 target elements is accomplished during full-power reactor operation. Hanford continues to be the only U.S. producer of carbon-14, and shipments to Oak Ridge National Laboratory totaled 370 curies in 1967.

The Hanford reactors also performed various specialty irradiation services for the Pacific Northwest Laboratory and off-site customers requiring large sample volumes and relatively flat flux. Included were

[8] See p. 87 "Annual Report to Congress for 1966."

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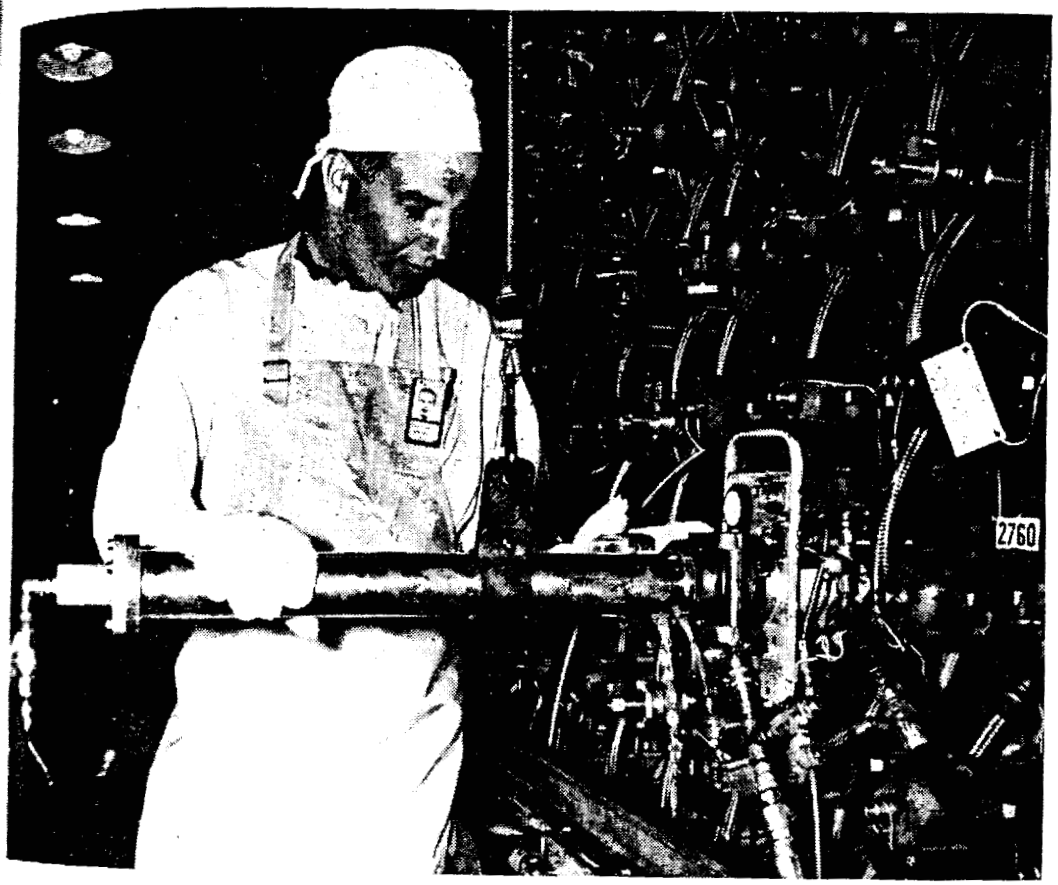
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SNAP-8 fuel development capsules, and the strontium-85 sources used in the NASA biosatellite launched from Cape Kennedy in September.

Savannah River Reactors

At the Savannah River Plant, the four reactors produced a number of special isotopes in addition to weapons materials. Substantial quantities of uranium-233 and high explosive plutonium containing 12 percent and 40 percent plutonium-240 were produced for peaceful programs. Also produced were significant amounts of cobalt-60, polonium-210, thulium-170, plutonium-238 and 242, americium-243, curium-244, and californium-252 as well as small quantities of einsteinium and fermium. Numerous special research and development irradiations were carried out for the AEC's national laboratories in the high flux irradiations for curium-244 production.

During the year, a multiproduct (mixed lattice) loading demonstrated the feasibility of producing varying quantities of uranium-233,



Isotope Production Test. A test to demonstrate the ability of production reactors to improve production of the isotope plutonium-238 by a short-recycle process is being conducted at Hanford. Photo shows an engineer using a device which permits the neptunium-237 target elements to be charged into the operating reactor without interruption of normal production.

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plutonium-238 and 239, tritium, polonium-210, cobalt-60, thulium-1[illegible] and other isotopes in a single reactor loading. The mixed lattice loading also was designed to accomplish high burnup [9] of the uranium-[illegible] fuel to increase the productivity of uranium-236 and neptunium-[illegible] in the fuel.

Curium-244 Production

In the current curium-244 (Cm^{244}) production program, irradiation of plutonium-239 was started in 1964 in order to increase the plutonium-242 (Pu^{242}) content of the material. A 2-year high-flux irradiation of the Pu^{242}-rich fraction was completed in mid-1967. In September 1967, the plutonium-242 was processed in the Savannah River chemical separations plant normally used for reprocessing spent irradiated high-enrichment reactor fuel. Approximately 5.6 kg. of Cm^{244} and 2.7 kg. of americium-243 (Am^{243}) were recovered as a crude curium-americium (Cm-Am) and rare earth mixture. About 9.1 kg. of Pu^{242} was also recovered for future use. The crude Cm-Am-rare earth mixture will be processed early in 1968 at the Savannah River Laboratory (SRL) to separate and purify the Cm^{244} and Am^{243}. The purified Cm^{244} will be used at SRL and Oak Ridge National Laboratory to determine the basic chemical and physical properties of Cm compounds and to develop suitable curium heat sources for isotopic power applications. The Am^{243} can be fabricated into targets for the future production of Cm^{244} and higher transuranic isotopes. A higher transuranic isotope, californium-252, which is present in milligram quantities will also be recovered from the Cm^{244} process effluents and made available for other research uses.

At Hanford, a crude fraction containing a kilogram of mixed curium and americium radioisotopes was recovered from the high level waste during chemical processing of Shippingport (PWR) fuels at the Redox plant, just before the shutdown of the Redox plant. This material will be processed to separate and purify the curium and americium fractions for research use.

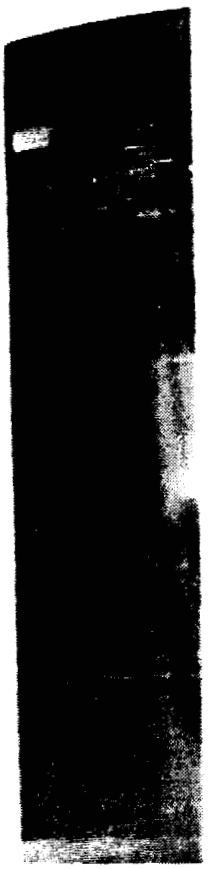
Californium-252 and Other Isotopes

Investigations have continued to develop improved means of producing the isotopes of high atomic number, such as curium, berkelium and californium (especially Cf^{252}). During 1967, the feasibility of [illegible]

[9] Burnup—A measure of reactor fuel consumption that can be expressed as: (*a*) the percentage of fuel atoms that have undergone fission; or (*b*) the amount of energy produced per unit quantity of fuel in the reactor.

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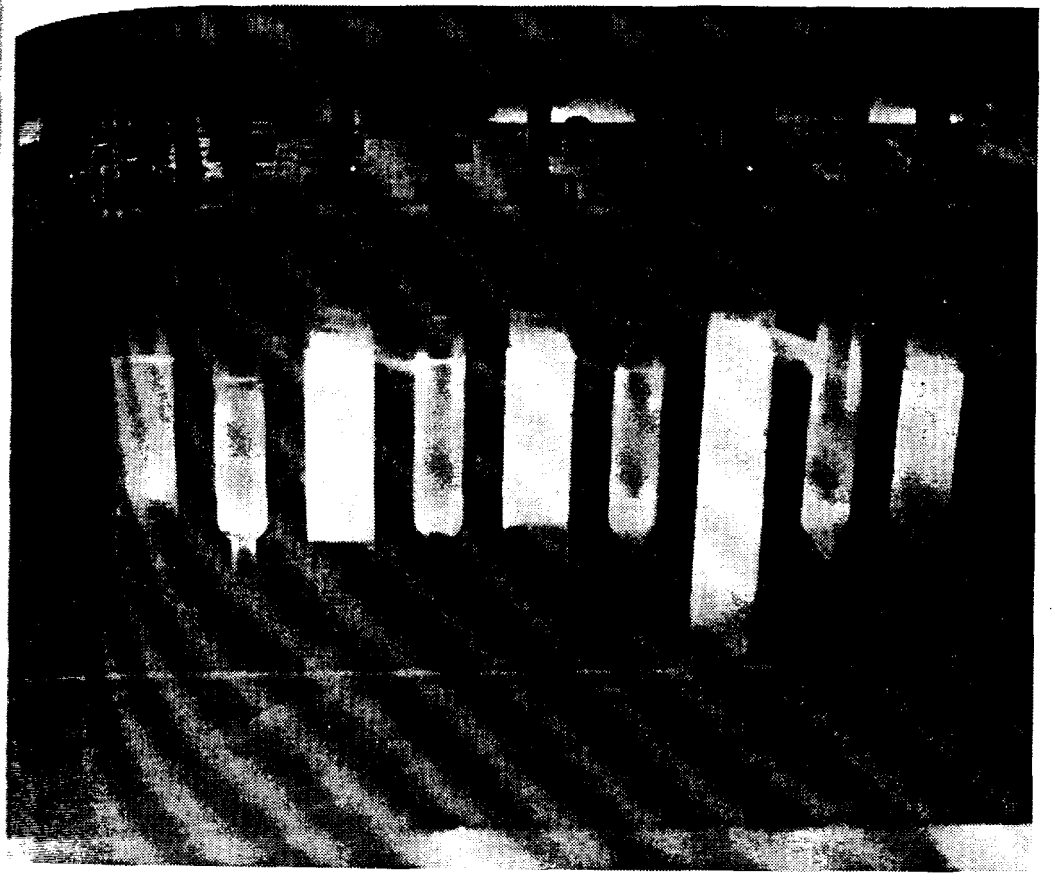
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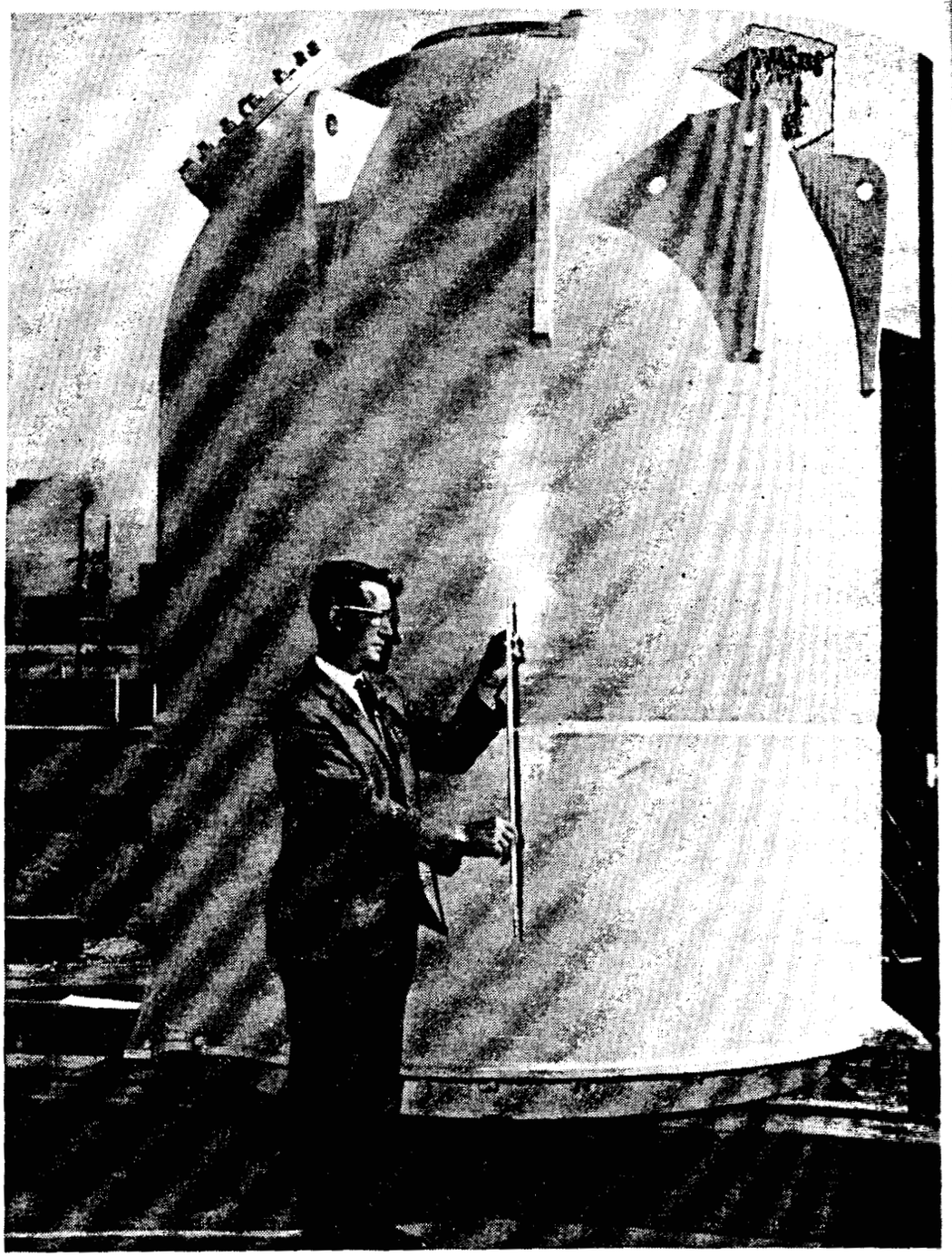
...ting an operating production reactor at the Savannah River Plant ...resonance operation [10] for the production of these and other isotopes ...has been established. In a resonance mode where special neutron ...energy conditions would be provided, substantial gains are predicted ...over thermal reactors in ultimate yield and rate of production for ...many of the higher isotopes. Because of low neutron flux and low ...neutron energy levels, and fuel cycle economics, nuclear power reac... ...ors are impractical for these operations. However, residues (pluto... ...nium-242, americium, and curium) from irradiated power reactor ...fuels can be used as feed materials in the resonance reactors to enhance ...the production of higher isotopes. Under resonance conditions,

[10] In a resonance reactor, a large proportion of the neutrons are above "thermal" energy which leads to more rapid conversion of certain target materials to desirable products.



...mical Processing of Curium-244. Curium-244, an isotopic power source for the ...ace program, is being produced in Savannah River plant reactors. Shown *above* ...a laboratory demonstration of the process for separating the curium from rare ...earth fission products by solvent extraction in a bank of miniature mixer settlers. ...The picture was taken by the light emitted by radiation-induced fluorescence of ...the process solutions. Most of the light was emitted by the solvent phase, a solu... ...of tertiary amine in diethyl benzene containing about 1.5 grams per liter of ...curium-244. A larger facility is under construction to recover 4.5 kilograms of the ...isotope. The facility will be operational in early 1968.

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HFIR Target Rod and Carrier. A contrast in the size of a simulated target rod from the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory and the carrier used to transport it is shown *above*. The rod, which would contain plutonium-242 and very radioactive americium-243 and curium-244 oxide particles, is 36 inches long—the carrier weighs approximately 50 tons. Thirty-one target rods are irradiated simultaneously in the HFIR for 12 to 18 months to produce heavy elements such as berkelium, californium, einsteinium, and fermium. They are transported one at a time in the huge carrier to the Transuranium Processing Plant (TRU) for chemical separation of fission products and transuranium elements. The plutonium, americium, and curium oxides are produced at the Savannah River Plant and then transported to ORNL for loading into the HFIR target rods as a part of the national transplutonium program (see pp. 283–288, "Annual Report to Congress for 1966").

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[a] See p. 104, "Annual

use of such material when eventually available could result in an annual production of hundreds of grams of Cf^{252}. The Savannah River Laboratory has made a preliminary survey of the potential demand for californium-252. Its intense neutron yield, low gamma emission rate, and relatively long half-life (2.5 years) make this radionuclide valuable for many applications in research, medicine, and industry. Prospective uses for Cf^{252} are in the fields of radiography, radiotherapy, neutron activation analysis, hydrology, petroleum exploration, research, and education.

Heavy Water Production

Production of heavy water at the Savannah River Plant to meet AEC requirements and commercial lease or sale amounted to 207 tons during 1967, an increase of 13 percent over 1966. Production had been subject to operating limitations during the past 4 years because of cracking and stress corrosion problems in the towers. These problems were corrected by an extended maintenance program and minor plant modifications. Production returned to normal early in 1967.

Heavy water sales to U.S. customers, primarily for research use and in the manufacturing of deuterium gas and deuterated compounds, totaled 6.0 tons, a 14 percent decrease from 1966 domestic sales. Foreign sales, including 46 tons to Euratom and 219 tons to Canada which previously had been held under lease, totaled 334 tons, a 44 percent increase over 1966. Foreign leases for the year totaled 14.5 tons. Domestic loans and leases in the United States, which were primarily intra-government transfers, totaled 62 tons.

FUEL PROCESSING

Previously scheduled to end on June 30, 1967, the AEC's service of providing for chemical processing of irradiated fuels for research and power reactors has been extended.[1] AEC first established the service in 1957 to cover situations where commercial processing service was not reasonably available. The extensions apply to light water and research reactor fuels through December 31, 1970, and for other power reactor fuels through December 31, 1977 since a private processing capability is not presently available.

[1] See p. 104, "Annual Report to Congress for 1966."

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Private Facilities

The first private processing facility, Nuclear Fuel Services, Inc. (NFS) at West Valley, N.Y., continued the processing of irradiated reactor fuel. The remainder of a 50-ton lot of fuel from Commonwealth Edison's Dresden (Unit No. 1) reactor in Illinois, 50 tons of fuel from the Yankee Atomic Electric Co.'s reactor at Rowe, Mass., and about 7 tons of fuel from Hanford's "N" reactor were processed during the year. The first international safeguards inspection of a commercial spent-fuel processing plant was conducted by a team from the International Atomic Energy Agency during August and September at NFS during processing of the Yankee fuel (see also Chapter 12, International Cooperation Activities).

The New York Atomic and Space Development Authority (ASDA) announced during August that it will proceed with engineering design for an installation at West Valley to extract neptunium from wastes generated by the NFS fuel processing operations. Present expectations are that such an installation would be operated by NFS under an arrangement with ASDA.

Facilities Planned. Activities concerning other commercial plants pertaining to fuel processing include: (*a*) the General Electric Co. has been issued a permit to construct a one-ton per day plant near Morris, Ill.; (*b*) Allied Chemical Corp. has announced plans to have a multi-ton-per-day facility in operation by 1973; (*c*) National Lead Co. announced that it has initiated preliminary engineering studies for a multi-ton-per-day facility; (*d*) Atlantic-Richfield Co. announced that it has plans under study for a multi-ton-per-day plant to be located on the West Coast and in operation in the 1970's; and (*e*) Gulf Oil Corp. has initiated studies on fuel reprocessing methods and markets.

Deliveries for Processing

The AEC's Idaho and Savannah River operations received "spent" fuel for processing from seven domestic and five foreign research and test reactors during the year as summarized in Table 3.

ISOTOPES RECOVERY AND SALES

Fission products are the nuclear fragments produced by the fission (splitting) of uranium and plutonium in atomic reactors. Nearly all of the primary fission products are radioisotopes which decay, in some cases through several sequential steps, to stable isotopes

...ained within the irradiated nuclear fuel elements, these fission ...ducts become constituents of the high-level radioactive wastes that ...lt from chemically processing irradiated nuclear fuels to recover ...onium and uranium. Some of radioactive fission products have ...ential applications as sources of radiation and heat. Some of the ...ble isotopes would have commercial value, provided they could be ...nomically separated from the radioactive wastes.

RECOVERY OPERATIONS

...S. requirements for fission product radioisotopes continue to be ...plied, as needed, primarily from the high-level wastes at Hanford. ...ese wastes are retained in specially designed underground storage ...ks and constitute the largest known source of fission products.[12] ...k Ridge National Laboratory (ORNL) processes fission products ...o the various forms needed for application; *e.g.*, cesium chloride, ...ontium titanate, strontium oxide, etc. ORNL is the focal point ...hin the AEC for sales of specially produced radioisotopes.

During 1967, 938 kilocuries of cesium-137 were shipped from Han...rd to Oak Ridge National Laboratory for fabrication into sources ...r large irradiators and for radioisotope sales. Hanford supplies

...See p. 106, "Annual Report to Congress for 1966"; see also pp. 55–57, "Annual Report ...Congress for 1964."

...E 1.–IRRADIATED URANIUM-ALUMINUM ALLOY FUEL DELIVERED DURING 1967 FOR PROCESSING

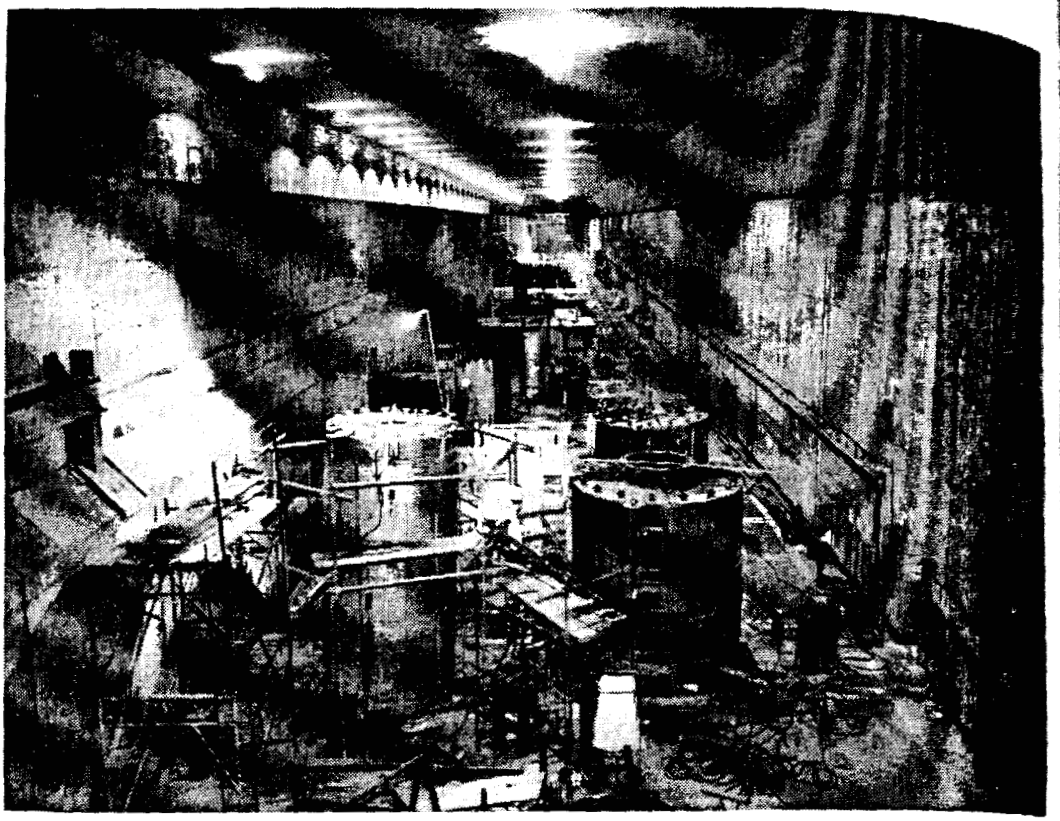
Shipper	Reactor	AEC receiving site	Number of elements	As received		
				Gross wt. alloy Kgs.	Total uranium Kgs.	Percent U^{235}
......	JRR-2.....	ID [1].....	48	195.2	8.2	86.6
...al Electric.....	GETR.....	ID.....	120	706.3	37.5	83.2
.....	R-2.....	SR [2].....	144	648.9	18.8	80.4
...C (Canada).....	NRX & NRU.	SR.....	447	1,972.1	80.9	66.5
...C (Canada).....	McMaster U...	SR.....	17	62.7	2.4	86.1
...ne Memorial ...titute.	Research.....	SR.....	24	75.8	2.9	84.4
...n Carbide Corp....	Sterling Forest.	SR.....	110	502.8	17.4	86.9
...n State University...	Research.....	SR.....	23	71.8	3.7	92.1
...n State University ...ennsylvania).	Research.....	SR.....	34	102.5	4.9	93.0
...versity of Buffalo ...(NY).	Research.....	SR.....	38	102.0	4.8	82.9
...versity of Michigan..	Research.....	SR.....	28	129.7	3.3	91.6

...ndon.

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promethium-147 in rare-earth concentrates to the AEC's Pacific Northwest Laboratory (PNL) for subsequent purification and conversion into the promethium oxide form used for both commercial sales and research and development purposes. Hanford's B-Plant, which has been modified for high-level waste treatment, will separate approximately 20,000 kilocuries of promethium-147 from aging bulk fission product concentrates during early 1968 as part of its startup operations. This promethium-147 will be stored to supply foreseeable PNL future requirements.



B-Plant Modifications. Waste management plans at the Hanford Works are to immobilize highly radioactive wastes by dewatering them to fixed salt cakes reposing in the same underground tanks where they now are being stored as mobile liquids. It will be necessary to remove the fission products, strontium-90 and cesium-137, which are long-lived heat emitters, from a substantial fraction of these wastes to prevent undesirably high temperatures building up in the salt cake. Photo shows part of the 900-foot long B-Plant canyon, which contains 40 process cells, each surrounded by several feet of concrete shielding, and placed below floor level, being modified to provide the capability for strontium and cesium removal from the wastes. These modifications, costing about $11 million, were completed in 1967. In the background are the cell cover blocks with their lifting bails for cell access and the 75 ton crane in the background. The B-Plant originally was one of the three radiochemical separation plants constructed at Hanford in 1943 for plutonium recovery, and was shut down in 1952 as plants using more advanced processes came on line.

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...ans Dropped for Commercial Plant

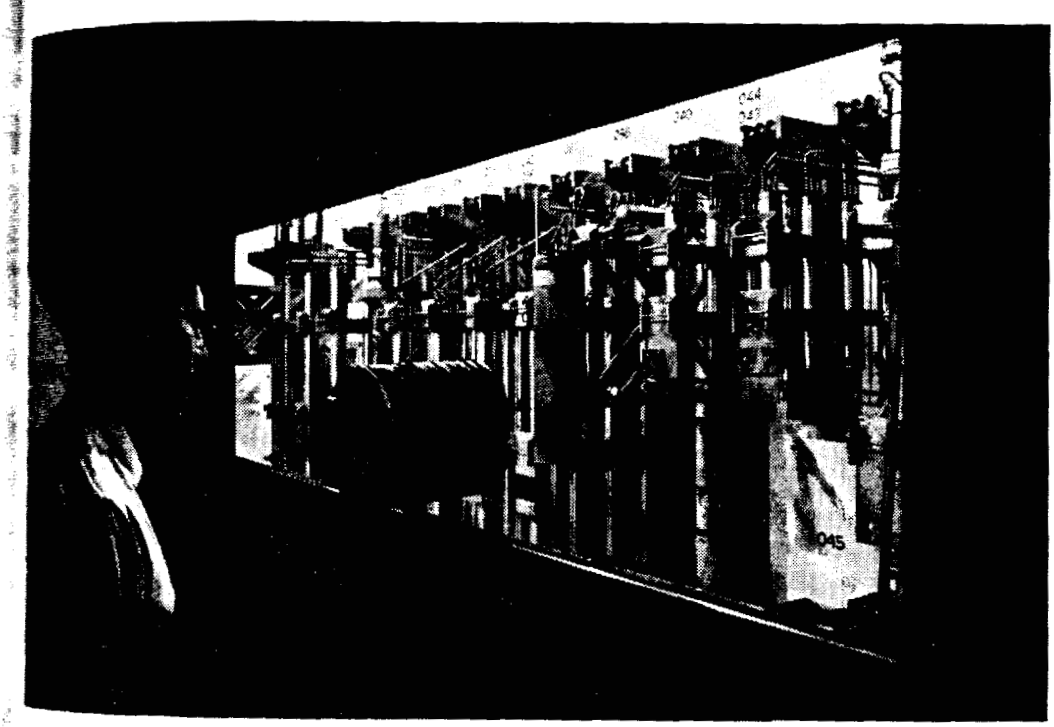
The development of anticipated uses and markets for fission product ...dioisotopes has been much slower than expected. Consequently, in ...nuary, Isochem Inc., and the AEC found it mutually convenient ... terminate the contract and the related land lease under which ...chem was to have built and operated a commercial plant to process ...d encapsulate useful fission products at Hanford.[13]

It appeared prudent to Isochem to delay this private venture for the ...brication of fission product radioisotopes into useful forms until an ...ceptable degree of economic success could be anticipated. (For other ...tails, see "Diversification and Transfer Activities" in Chapter 17—Administrative and Management Matters.)

...odium and Palladium

Rhodium and palladium are precious metals in short supply; they ...e also stable fission products that may be recoverable in nonradioactive form from high-level wastes. They also appear to be the only

[13] See p. 81, "Annual Report to Congress for 1965," and p. 107, "Annual Report to ...gress for 1966."



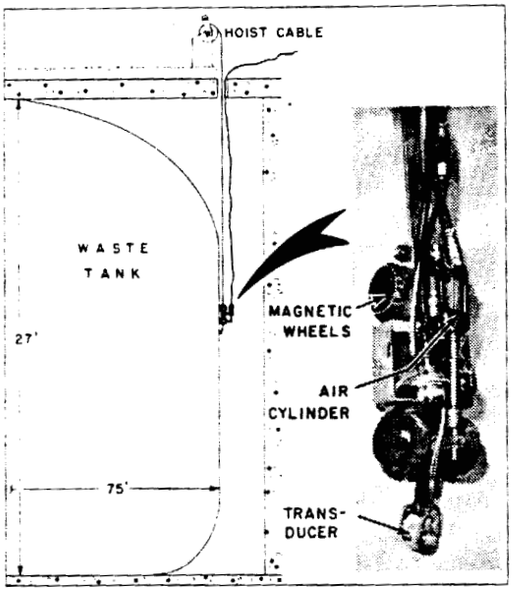
...tonium *Recovery.* View, taken through several inch-thick shielding glass, ...ows some of the process tanks used in the recovery of plutonium from scrap ...d process residue at the Hanford chemical processing operations. The chemical ...ocessing operation was transferred from Isochem Inc. to Atlantic Richfield ...anford Co. on September 4.

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fission products with an assured market if they can be economically recovered. There are significant quantities of these two elements contained in the high-level wastes stored at the Hanford and Savannah River sites and even larger amounts will be available from the processing of power reactor fuels. It has been estimated that approximately 280 grams of rhodium and 640 grams of palladium will be present in one ton of uranium fuel irradiated to 20,000 megawatt days.

Hanford has developed an ion exchange process for the concurrent recovery of rhodium and palladium from alkaline high-level wastes as well as processes to purify rhodium and palladium to be essentially

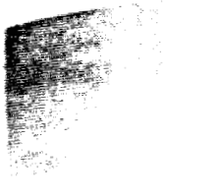




Radioactive Waste Storage. To detect any corrosive thinning of the steel walls of underground tanks containing highly radioactive wastes, du Pont engineers at the Savannah River Plant developed the remotely controlled wall thickness tester shown at *left*. An operator at the surface lowers the foot-long "bug" through an access hole on the tank perimeter. Its magnetic wheels grip the steel wall, and the carriage is then rolled up or down to the desired position. A solenoid-actuated air cylinder on the carriage presses a small ultrasonic transducer to the wall; water is jetted over the contact area, providing the necessary coupling. The transducer then emits an ultrasonic pulse that penetrates the wall and is reflected from its inner surface. Travel time is interpreted on an oscilloscope in terms of wall thickness. Photo *above* shows two new 1.3 million-gallon-capacity waste tanks under construction at the plant.

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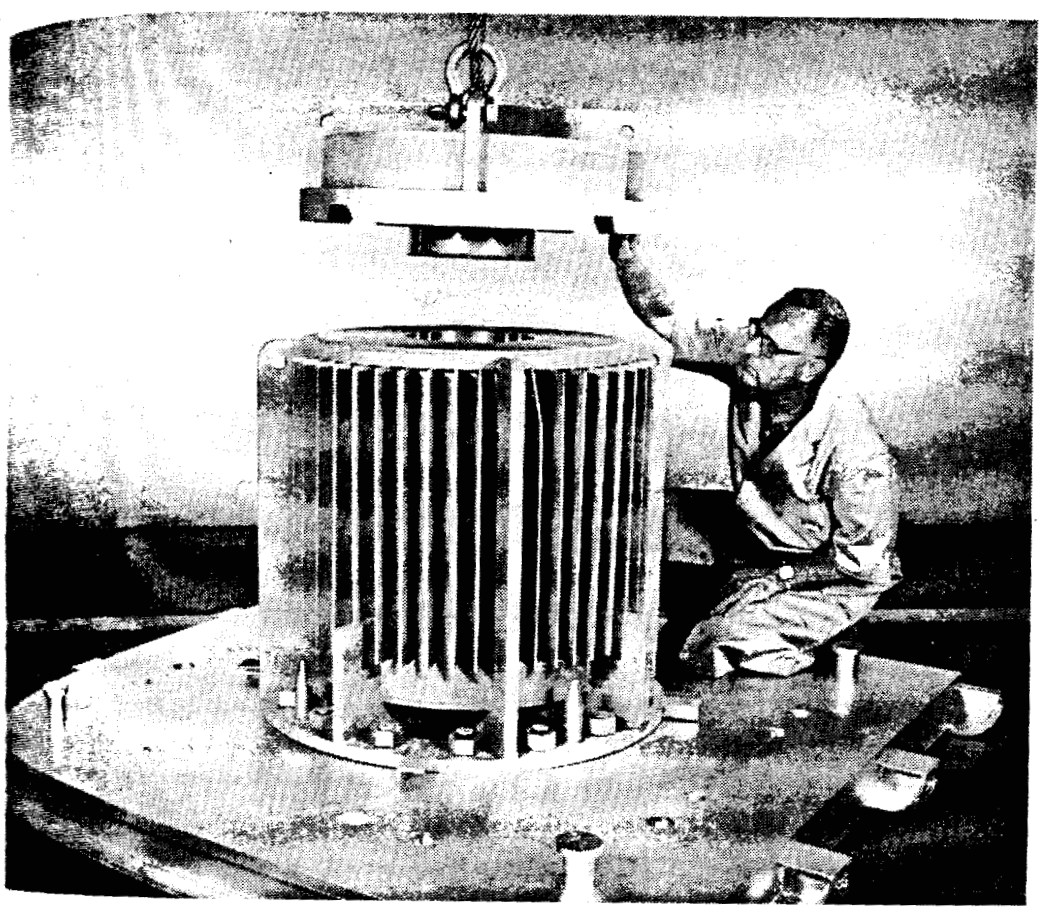
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of radioactive contaminates. At Savannah River, preliminary tests indicate that rhodium and palladium can possibly be recovered directly from alkaline waste solutions by using an active metal reactant (such as zinc), which reduces them to metallic fines. The economics are being investigated by pilot plant-scale operations.

RADIOISOTOPE SALES

To meet the needs of the Government, industry, and science for radioisotopes, AEC facilities are used to produce and package a wide variety of isotopes. The Isotopes Development Center at Oak Ridge serves as the primary sales point for these AEC products. As specific radioisotopes become reasonably available from commercial producers,



...tope Shipping Cask. Shown *above* is a prototype radioisotope shipping cask ...igned and built at the AEC's Paducah Gaseous Diffusion Plant for the Oak ...ge National Laboratory. The cask uses laminated uranium plate as the radia... shield and meets the applicable regulations for shipments of radioactive ...terials. The unit can safely transport up to 400,000 curies of cobalt-60 per ...ading. The new cask will be subjected to a series of tests to demonstrate its ...ility to meet applicable regulations for shipping spent reactor fuel. Design, ...rication, and testing of the casks are being conducted at the Paducah plant.

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the AEC withdraws from their routine production and distribution.

During the 11 months ending November 30, 1967, a total of 3,118,[illegible] curies of processed radioisotopes were distributed by Oak Ridge National Laboratory (ORNL). This represents a 26.7 percent increase in unit sales over the same 1966 period, mainly from increased sales of cobalt-60, strontium-90, and cesium-137.

Production and Sales Withdrawals

The AEC withdrew from the routine production and sale of one more radioisotope during the year, strontium-87^m generators, for a total of 37 radioisotopes since May 2, 1961. As a direct result of these withdrawal actions, the number of shipments made by ORNL during the first 11 months of 1967 fell to 3,664 from 5,044 in 1966, and 7,[illegible] in 1965. To recover full costs, it was necessary for the AEC to increase prices on 15 radioisotopes:[14] antimony-122, argon-37, barium-131, bismuth-210, gallium-72, iodine-130, palladium-109, praseodymium-142, rhenium-186, samarium-153, silver-111, tungsten-187, thulium-171, iodine-131, and xenon-133. On December 27, the AEC published in the *Federal Register* its proposal to withdraw from the routine production and sale of low-activity cobalt-60.

New Products

Several new radioisotope products became available from the AEC during 1967: iodine-123, tungsten-188, and high specific activity (1,000 curies per gram) iridium-192.

Iodine-123, is finding use in place of iodine-131 and -125 for medical diagnostic applications; it considerably reduces the radiation dose to the patient. Iodine-123 is produced by cyclotron irradiation of isotopically separated tellurium-123. An efficient recycle process has been demonstrated at ORNL which permits a reasonable product cost.

Tungsten-188 provides the parent for a tungsten-rhenium generator. The generator provides a longer half-life (70 hours) radionuclide with many of the same properties of technetium-99^m (6 hrs.). The production of the tungsten-188 involves double neutron capture which requires the use of the High Flux Isotope Reactor at ORNL as well as the use of isotopically separated tungsten-186.

The procedure for production of high specific activity iridium-192 (1,000 curies per gram) was developed at ORNL. The more commonly used, lower specific activity iridium-192 is available from private industry.

[14] A full list of prices is available from the Isotopes Sales Dept., Isotopes Development Center, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn. 37831.

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Chapter 2

SAFEGUARDS AND MATERIALS MANAGEMENT

Although nuclear materials have been carefully controlled and safeguarded from the very beginning of the atomic energy program, the AEC has recognized that, with the rapidly expanding peaceful uses of atomic energy, there is a need to review and strengthen its policies, procedures, and organization for safeguarding nuclear materials against diversions to unauthorized uses.

A final report of the 1966 *ad hoc* Advisory Panel on Safeguarding Special Nuclear Material [1] was received by the Commissioners during early 1967. The report included a number of recommendations related to the objective of strengthening the AEC's safeguards policies, procedures, and organizations. A number of actions have already been taken to carry out these recommendations.

SAFEGUARDS ACTIVITIES

The Commission, effective July 1, 1967, established a new Office of Safeguards and Materials Management which is responsible for all safeguard policy making as well as overseeing and coordinating the United States' domestic and international safeguards programs. The Commission also established a Division of Nuclear Materials Safeguards, under the Director of Regulation, to administer safeguards for all nuclear materials held by licensees.

Actions Taken

Since these organizational changes, the following actions have been taken:

1) Coordination of the safeguards-related programs of other interested government agencies such as the Department of Defense,

[1] See p. 116, "Annual Report to Congress for 1966."

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the Department of Treasury, the Department of Commerce, Central Intelligence Agency, and the Arms Control and Disarmament Agency, has begun.

(2) Steps have been taken to design and implement a broader safeguards research and development program in cooperation with other government agencies and other national and international efforts.

(3) The AEC has encouraged the establishment of an international school of safeguards to train inspectors. Such a school could help develop research programs.

(4) Steps are underway to join with the Department of Defense in reviewing safeguards currently applicable to materials and weapons transferred to the Department under provisions of the Atomic Energy Act of 1954, as amended.

The Commission also established an Advisory Committee on Nuclear Materials Safeguards [2] to provide it with advice in the development of: (*a*) policies regarding safeguards against the diversion of special nuclear materials; (*b*) safeguards standards and criteria; (*c*) safeguards procedures; (*d*) safeguards research and development; (*e*) methods of measurement and other procedures; and (*f*) standard reference material.

Other major actions to strengthen safeguards are under consideration.

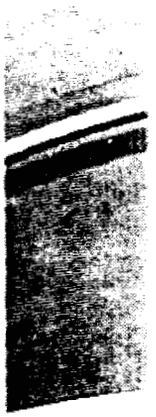
International Safeguards Activities

The International Atomic Energy Agency (IAEA) continued its application of Safeguards to four U.S. nuclear reactors under the 1964 U.S.-IAEA agreement [3] which provides for such safeguards. In connection with safeguarding the Yankee power reactor in Rowe, Mass., the IAEA exercised its right to follow the spent fuel, which contains plutonium, through the reprocessing operation at the Nuclear Fuel Services, Inc. (NFS) plant at West Valley, N.Y. The IAEA inspection included 73.97 kilograms (kg.) of plutonium recovered from Yankee Core IV and about 18.6 kg. of nonsafeguarded plutonium which was in process inventory at the time the inspection began. The inspection, which began on August 1, involved a team of ten men from several countries applying continuous coverage at the plant through mid-September. This provided the IAEA with valuable experience

[2] The list of members and their affiliations are included in Appendix 2.

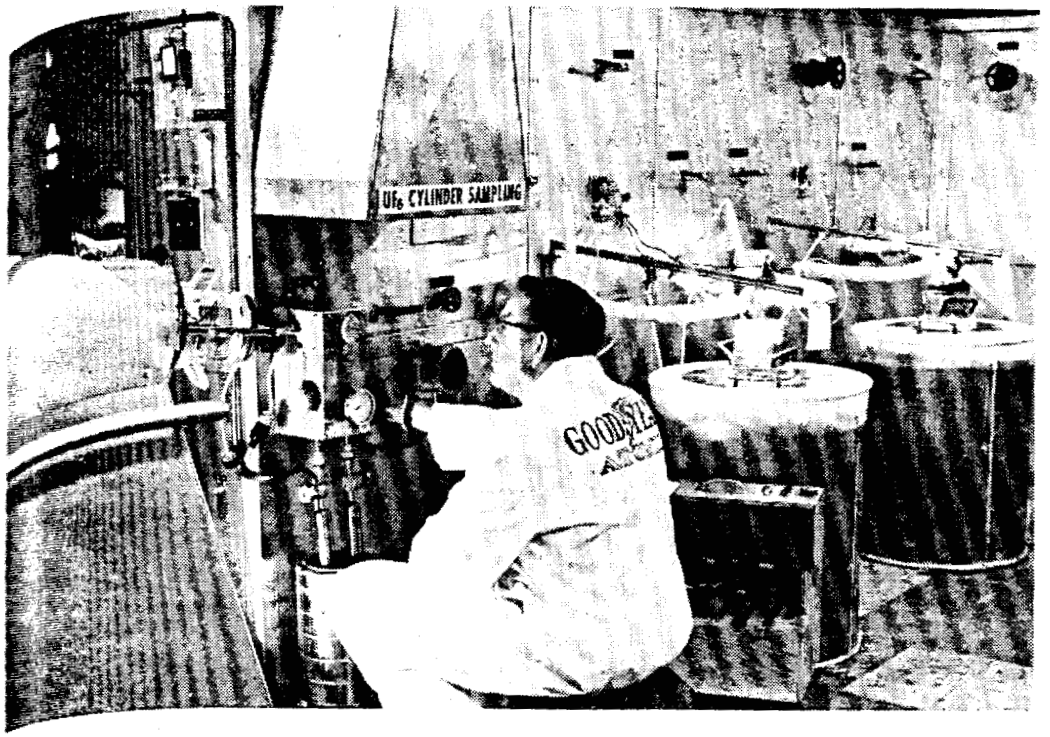
[3] The four reactors are: the Graphite Research Reactor and the Medical Research Reactor at Brookhaven National Laboratory; the Piqua, Ohio, power reactor, and the Yankee Nuclear Power Station at Rowe, Mass.; see pp. 205–206, "Annual Report to Congress for 1964."



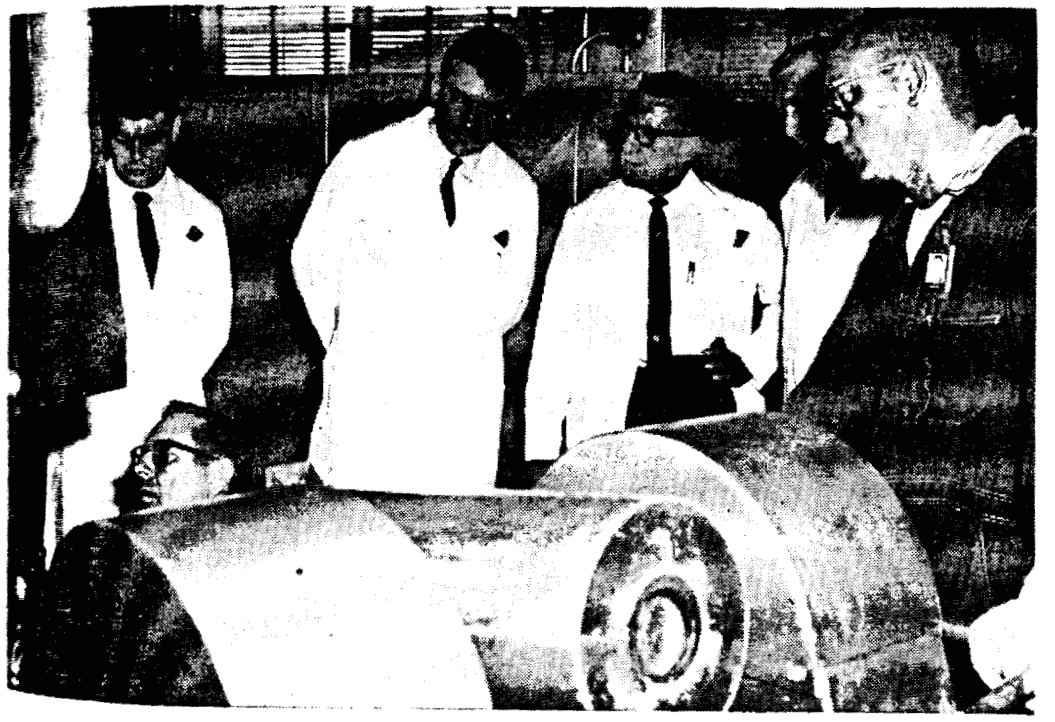


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Service Facility. Representatives of the nuclear power industry can now observe the official weighing and sampling of enriched uranium at the AEC's Portsmouth, Ohio, Gaseous Diffusion Plant. In the interests of common defense and security, such material must be safeguarded against unauthorized use. After December 31, 1968, the AEC will start providing uranium enrichment services to customers as a part of the implementation of the Private Ownership of Special Nuclear Materials Act of 1964. Customers will be able to observe the weighing of the feed materials they supply and the enriched products returned by the AEC, and also take samples of these materials. Photos show two views of the new weighing station at Portsmouth which has been located outside the plant's security perimeter.



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technical as well as logistic and organizational aspects of safeguard at spent fuel reprocessing plants.

The U.S.-Euratom Joint Technical Working Group met in t United States in June 1967 and in Brussels in October 1967 to discu the feasibility of applying resident inspection safeguards to fu fabrication facilities. During the U.S. meeting, a visit was made t the Argonne National Laboratory's plutonium facility, and durin the Brussels meeting a visit was made to the Eurochemic chemica processing plant to evaluate Euratom experience with resident in spection at this plant. Future meetings are contemplated to contin these discussions and to evaluate the technical effectiveness of saf guard systems.

Safeguards Research and Development Program

A broad safeguards research and development program designe to improve the effectiveness of the safeguards program both domesti cally and internationally has been initiated. The program is directe essentially toward two major categories—systems studies and tech nical studies. The systems studies are concerned with the mechanism by which scientific methods and techniques can be applied to saf guarding special nuclear material, and the handling of the data whic results from such applications. Technical studies are concerned wit the scientific aspects of measurement and detection of special nuclear material.

Priority is being given to an overall safeguards systems study. Th AEC plans to elicit the cooperation of industry in an effort to deri the data and information on which the AEC can base procedural an performance standards against which a nuclear facility's operatio and material control policies can be judged.

One major program being conducted under systems studies is a tes program of placing AEC resident inspectors in selected licensed facili ties in the United States. The activities of these inspectors and th effectiveness of these activities will be evaluated over a period of 1 to 1½ years. The technical studies will concentrate on measureme and detection of special nuclear materials. They will seek to develo methods and instrumentation capable of determining uranium an plutonium isotopic composition and content in irradiated and un irradiated fuel assemblies, process solutions, and scrap material. In vestigations of methods to calculate fuel burnup in power reactors continuing. New fuel reprocessing techniques are being investigated t determine if they pose intrinsic problems for material accountabilit

Availability

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Availability of Special Nuclear Material

During 1967, the Atomic Energy Act of 1954 was amended to eliminate the requirement that the President annually determine the quantities of special nuclear material to be produced and the amount to be available for distribution by the AEC under Sections 53 and 54 of the Act which relate, respectively, to domestic and foreign distribution of such material. The distribution provision had been included in the Atomic Energy Act to permit greater private participation in civilian atomic energy matters while at the same time affording assurance that sufficient special nuclear material, which was still in short supply in 1954 when this provision was enacted, would be available to meet military requirements.

The current amendment reflects the relative abundance of these materials as acknowledged by Congress when, in 1964, it approved the Private Ownership of Special Nuclear Materials Act (P.L. 88–489) which authorizes the AEC to enter into long-term contracts to sell special nuclear material and to perform enriching services for both domestic and foreign persons.

Although the statutory requirement for such Presidential determinations has been eliminated, the amount of special nuclear material to be produced by the AEC will continue to be controlled by the Congress and the Executive Branch of Government through the normal budgetary processes. In addition, the AEC will report annually to the Joint Committee on Atomic Energy the status of commitments to distribute special nuclear material to domestic and foreign users.

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Chapter 3

THE NUCLEAR DEFENSE EFFORT

The AEC, in coordination with the Department of Defense, conducts basic and applied research on nuclear weapons and device development, tests devices and weapons and their components, and produces nuclear weapons essential to the maintenance and advancement of the United States nuclear defense capability.[1]

NUCLEAR WEAPONS

During 1967, the AEC continued: (*a*) the development and production of nuclear weapons and components designed to meet Department of Defense (DOD) requirements; (*b*) the development of nuclear devices and improved data acquisition systems and diagnostic instrumentation techniques for underground testing; (*c*) in consonance with the limited nuclear test ban treaty safeguards,[2] its readiness to resume atmospheric testing; and (*d*) its participation in the DOD-sponsored nuclear detonation detection (Vela) research program.

WEAPONS DEVELOPMENT

Weapons development activities include the design and development, and testing of the nuclear portion, and the non-nuclear components, of atomic weapons. A major effort is being devoted to

[1] Twelve Mutual Defense Agreements for Cooperation are currently in effect (see Appendix 7—Agreements for Cooperation).

[2] The four safeguards announced as U.S. national policy prior to Senate ratification of the limited nuclear test ban treaty in 1963, are: (*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 they should be essential to national security or if the treaty should be abrogated, and (*4*) the improvement of our capability, within feasible and practical limits, to monitor the terms of the treaty and to detect violations.

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the development of new nuclear warheads required by the Department of Defense. Primarily, the weapons development work is conducted by the AEC's three weapons laboratories (Los Alamos Scientific Laboratory, Los Alamos, N. Mex.; the Lawrence Radiation Laboratory, Livermore, Calif.; and the Sandia Laboratory facilities at Albuquerque, N. Mex., and Livermore, Calif.).

Development and Test Complexity Increasing

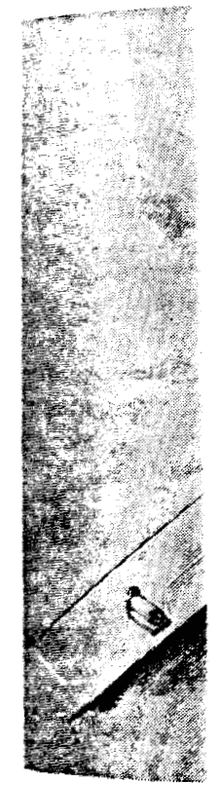
The laboratories continued to develop advanced experimental techniques in underground testing. These efforts increase the value of underground tests as a tool for checking nuclear device concepts for weapons design, and for effects evaluation. Other efforts were directed toward the development of weapon components through the use of new materials and fabrication techniques. Development continued on methods to improve and simplify command and control procedures and to prevent the possibility of unauthorized use of nuclear weapons.

Underground nuclear weapon development tests continued to be conducted during the year. These included tests of increased yield, instrumentation systems of increased complexity, and experiments directed toward hardening and determining vulnerability of weapons systems. Nuclear effects tests required in support of development programs also were conducted. In addition to those tests sponsored by the AEC, support was given to nuclear events sponsored by the DOD.

Basic and applied research continued in 1967, both to provide increased knowledge of nuclear phenomena and to meet program goals. This broad program enabled the laboratories to continue to advance the "state-of-the-art." Laboratory employment remained stable and the laboratories were able to recruit the necessary staff personnel.



Underground [illegible] cable required Electrical and *(above)* elimi the huge lengt of damage to Schematic dra onation. The t neutrons from tower. Some *(right)*; target from the sleds the detonation delicate instru



WEAPONS PRODUCTION

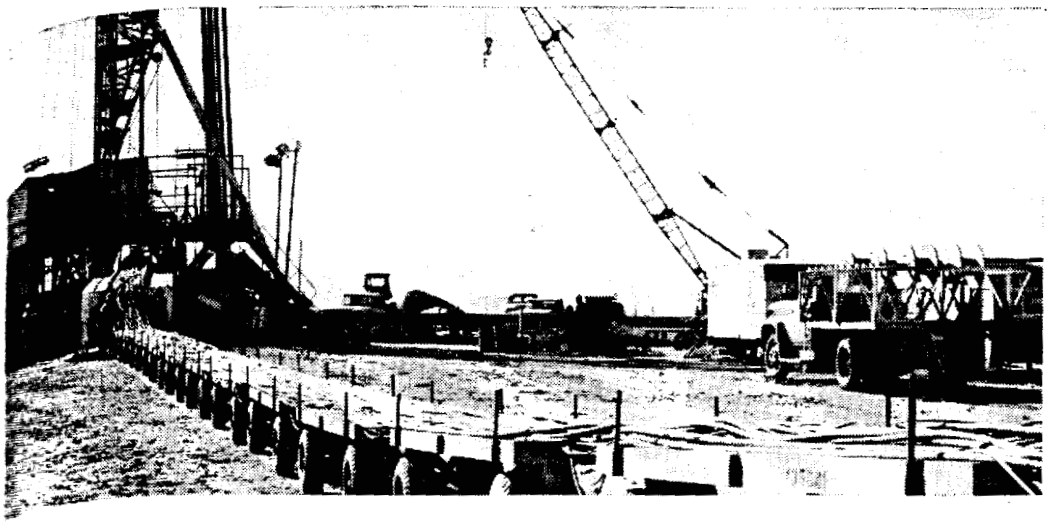
The 1967 weapons production effort, in support of requirements, was somewhat less than the 1966 workload.

Stockpile Improvement

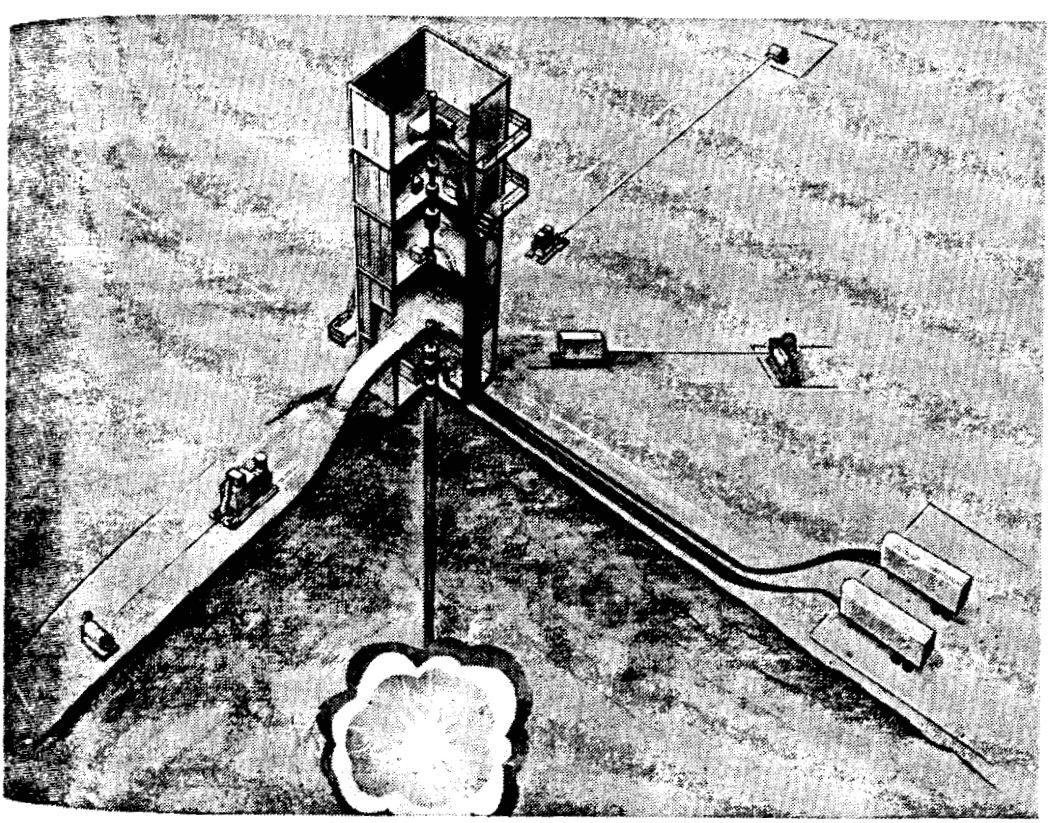
Weapons production activities, in addition to the production of new weapons, provided for improved replacement systems, modifications to existing systems, quality assurance and new materials systems testing, and retirement and disposal of obsolete weapons.

Continuing emphasis has been placed upon meeting production objectives at minimum cost. This facet of production begins with the

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Underground Tests. To simplify handling of millions of feet of coaxial and signal cable required for "down hole" operations at the Nevada Test Site, the Reynolds Electrical and Engineering Co. transports the long lengths of cable on carts (*above*) eliminating much of the manpower previously needed to manually handle the huge lengths of heavy cable. The "cart" innovation also reduces the chance of damage to the cables, thus increasing their usefulness in further testing. Schematic drawing *below* shows how scientific data can be obtained from a detonation. The tower is located over the "line-of-sight" vacuum pipe up which the neutrons from the nuclear explosion travel to the experiments housed in the tower. Some data is carried by coaxial cable to the instrumentation vans (at right); target materials bombarded by the intense flow of neutrons are recovered from the sleds which can be winched away from the tower within seconds after the detonation, before the earth shock or surface subsidence can affect the delicate instrumentation.



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design and development of weapons and their components. It includes cost consciousness in the design process and in the planning and execution of the weapons production phase.

Production Facilities To Be Modernized

In mid-1967, after extensive study of needs, a $100.5 million project to provide additional production capabilities was authorized. The modernization and expansion of facilities, expected to be completed by late 1971, will provide the facilities and improvements needed to produce new weapon systems required by the DOD. The major portions of the modernization will be undertaken at the Y–12 Plant, Oak Ridge, Tenn.; at the Rocky Flats Plant, Golden, Colo.; and lesser portions at the Pinellas Plant, Clearwater, Fla.; Savannah River Plant, S.C.; Pantex Plant, Amarillo, Tex.; and at the Burlington AEC Plant, Iowa.

The decision in October to deploy an antiballistic missile system is resulting in a further expansion of the weapons production facilities. This expansion will become a part of the presently authorized project

UNDERGROUND NUCLEAR TESTS

The AEC continued to conduct an underground nuclear test program at the Nevada Test Site (NTS). Such tests are permitted under the limited nuclear test ban treaty (signed August 5, 1963, by the United States, the United Kingdom, and the U.S.S.R.). Through a comprehensive series of underground tests, a capability has been developed to support a wide range of full-scale underground experiments. Additional new and improved methods were developed for conducting experiments underground.

Latchkey—Crosstie Series

The planned nuclear tests for the current Crosstie series (July 1, 1967–June 30, 1968) are grouped in four broad categories, three of which support the national defense effort: (*a*) weapons-related, including device development, tests; (*b*) Department of Defense nuclear effects tests; (*c*) joint AEC–DOD nuclear tests designed for research and development on improving detection methods and systems (Vela Uniform). The fourth category is Plowshare (peaceful uses of nuclear explosives) experiments (see Chapter 11—The Plowshare Program

Nuclear tests are reviewed, and will continue to be reviewed, in accordance with AEC-developed procedures for public safety. Tests are conducted only with the expectation that they can be executed within the constraints of the limited nuclear test ban treaty.

Test Event Summary

Fifteen weapons-related underground tests, including one DOD effects test, were publicly announced in 1967 under the Latchkey series (July 1, 1966–June 30, 1967). Ten weapons-related tests, including one DOD effects event, have been publicly announced in the 1967 Crosstie series. Two of the 25 weapons-related tests announced in 1967 were conducted in the higher-elevation Pahute Mesa area [3] of NTS where deeper emplacement holes allow higher yield detonations. (See Appendix 4 for names and dates of defense-related tests announced during 1967.)

Supplemental Test Sites

A site-selection program [4] to locate and develop underground test facilities to supplement the present Nevada Test Site has led to a choice of Hot Creek Valley in central Nevada and Amchitka Island in Alaska as locations for further investigation. No other areas are now under active consideration.

The use of supplemental test sites is not expected to affect the programs now conducted at the Nevada Test Site.

Central Nevada Site. Hot Creek Valley, about 70 miles northeast of Tonopah, is about 15 miles long and 5 to 7 miles wide. Extensive exploratory drilling, hydrologic testing, and geophysical investigations were undertaken at Hot Creek during the first half of 1967. The AEC plans to conduct an intermediate yield calibration test at Hot Creek in early 1968 to gain information on the seismic effects and to explore the possibility of conducting other detonations at the site. An austere temporary camp and a portable control point have been erected near Warm Springs, approximately 30 miles from the calibration site. The AEC does not plan acquisition of extensive real estate. Only one square mile of public land will be withdrawn from public use for the calibration test. Under the plan for future testing, similar small public land areas surrounding the emplacement holes will be withdrawn. Larger areas will be subject to safety control during the test periods.

[3] See p. 126, "Annual Report to Congress for 1966."
[4] See pp. 126–128, "Annual Report to Congress for 1966."

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Alaskan Island Site. Amchitka is an uninhabited island near the western tip of the Aleutian Chain, about 42 miles long and 3 to 5 miles wide. The remoteness of Amchitka Island avoids most of the safety problems (such as those directly related to seismic effects on buildings) and land ownership problems which would have confronted the AEC in Nevada. The AEC has cooperated closely with the U.S. Department of the Interior in measures to minimize the impact of human presence on the island with a minimum of disturbance to wildlife.



Atmospheric Test Readiness. The AEC, in association with the Department of Defense, maintains a state of readiness to quickly resume atmospheric testing if the limited nuclear test ban should be abrogated. As a part of this readiness, the specially instrumented NC–135 diagnostic aircraft (shown *above*) are used from time-to-time in joint scientific expeditions with other Federal agencies to provide experience for the crews and diagnostic technicians. Two of the atmospheric diagnostic aircraft, assigned to Los Alamos Scientific Laboratory and Sandia Laboratory, were used in March and April for a scientific experiment to obtain geophysical measurements of the earth's upper atmosphere and geomagnetic field. While Los Alamos personnel flew to Alaska, the Sandia crew flew to New Zealand with duplicate instruments to gather data simultaneously at two separate points on the auroral spectrum and cosmic rays at magnetic conjugate points. The Sandia group then flew on an equatorial path around the world to measure the distribution and intensities of cosmic rays and air glow as a function of altitude, latitude, and longitude. The flights in the northern and southern hemispheres provided the AEC technical and Air Force flight personnel additional experience in instrumentation and aircraft operation during a non-test period.

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...d to the natural environment. Amchitka was the site of the DOD-...nsored, deep underground Long Shot test [5] (Vela detection) in ...tober 1965. Long Shot caused no significant damage to the island ...its wildlife. The AEC awarded a contract for a drilling program ...oth exploratory and event emplacement holes) at Amchitka in ...March 1967 and, at year's end, drill rigs were operating on Amchitka. ...conjunction with that work, harbor facilities have been built and ...rfield facilities have been improved. A temporary 500-man camp ...s been set up on the southeast part of the island.

ATMOSPHERIC TEST READINESS CAPABILITY

The AEC continues to maintain and improve the capability for ...sumption of nuclear testing in the test ban treaty prohibited environ-...ents should it be directed to do so in the event of an abrogation of ...e treaty, or in the interest of national security. If necessary, the AEC will be able to resume testing in the atmosphere, underwater, ...in space, within a minimum reaction period. This capability was ...itially attained on January 1, 1965.

Overseas facilities (Johnston Atoll and the Hawaiian Island com-...lex) and their technical equipment are being held in readiness. ...uring 1967, maintenance and reliability improvement efforts were ...ept abreast of laboratory-generated advances in technology.

Non-nuclear airdrop readiness exercises were conducted to maintain ...e diagnostic capability, increase technical proficiency, and to exer-...se the airborne diagnostic capability.

VELA PROGRAM ACTIVITIES

The Vela program is a joint AEC/DOD program supervised by ...e DOD's Advanced Research Projects Agency (ARPA). It is a ...search and development effort conducted to improve the U.S. capa-...ilities of detecting, locating, and identifying nuclear detonations. ...e total AEC effort devoted to Project Vela is less than 1 percent ...f the weapons program operating budget.

Vela Uniform

The Vela Uniform program uses both nuclear and chemical explo-...ons to provide data needed to evaluate the U.S. capability to detect

[5] See pp. 107–108, "Annual Report to Congress for 1965."

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underground nuclear tests. The DOD has the administrative, funding (less nuclear device and diagnostics), and technical responsibility for this program. The AEC is responsible, in connection with nuclear tests, for: (*a*) construction and firing; (*b*) determining yield and conducting post-shot drilling; (*c*) instruments for close-in measurements; and (*d*) public safety. Four underground nuclear experiments have been conducted under this program.[6]

Measurements of ground shock accelerations and other effects, and the operation of both short and long-range seismic recording stations continued during 1967 in conjunction with NTS underground tests.

Status of Salmon-Sterling Site

During part of 1967, the Mississippi facilities used for the Salmon (1964) and Sterling (1966) tests were maintained on a standby basis. ARPA has now requested that the AEC drill into the Salmon-Sterling cavity to determine its suitability for possible future use. This will be done in early 1968.

Other Vela Uniform Experiments

An underground experiment, called Scroll, is planned for 1968 at the NTS as a low-yield event in a low-moisture content and high-porosity soil medium.

Another test called Payette, has been proposed as a fully decoupled[7] event of low yield in a large underground cavity in salt. A feasibility study is underway to establish the best methods and the economics of constructing such an underground cavity.

Project Gasbuggy, a joint Plowshare-industry experiment (see Chapter 11) near Farmington, N. Mex., in December included Vela Uniform experiments. Adjacent boreholes that would not interfere with the Gasbuggy project were drilled and instrumented to record characteristics of close-in seismic coupling in a sand-shale medium, and surface seismic measurements.

Vela Satellite Program

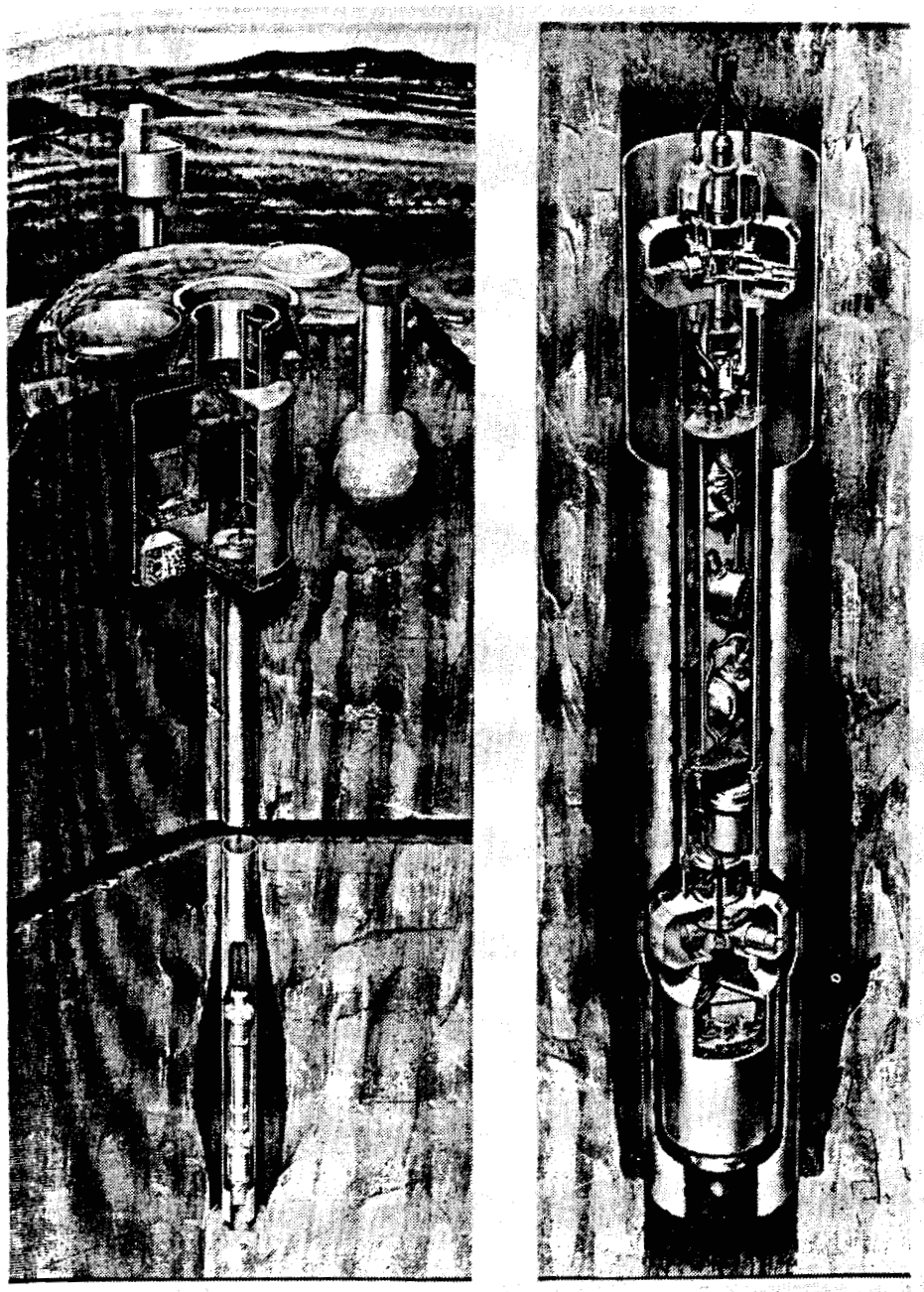
The AEC continues to participate in the joint DOD-AEC Vela Satellite program. Under the program, Sandia and Los Alamos Scien-

[6] Vela Uniform events conducted to date were: Shoal, October 26, 1963, near Fallon, Nev.; Salmon, October 22, 1964, near Hattiesburg, Miss.; Long Shot, October 29, 1965, Amchitka Island, Alaska; and Sterling, December 3, 1966, in the Salmon event cavity.

[7] "Decoupled" is the use of an underground cavity in such a way as to reduce the amount of shock and earth movement imparted to the surrounding medium. In this way, the true magnitude of the explosion may be concealed or the effects may be reduced below the capabilities of a detection system.



Unmanned ... prototype un... emplaced by ... to monitor, i... installed for ... Vernel, Utah ... (as much a... electronic sy... maintenance ... the bore-hol... gyros and r... ponents for ...



INSTALLATION SITE BOREHOLE PACKAGE

manned Seismic Observatory. Diagram on *left* shows the installation of a ototype unattended seismological observatory (USO) designed, fabricated, and placed by Sandia Laboratory personnel as part of the Vela Uniform program monitor, identify, and locate underground disturbances. Two USO's have been talled for a year's evaluation, one near Fairbanks, Alaska, the other near nel, Utah. The seismometer package is at the bottom of a cased borehole much as 200 feet deep). The small shelter just below the surface houses tronic systems and timing and recording devices—accessible to personnel for intenance and servicing required about every 90–110 days. The cut-away of bore-hole package (on *right*) shows the system of seismometers, alignment s and rotating mechanisms, upper and lower locking feet, and other com- ents for sensing and reporting seismic pulses.

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tific Laboratory are doing research and development toward a means to detect and identify nuclear explosions in space or down into the atmosphere through satellite-based systems.

Status of Orbiting Satellites

Eight AEC-instrumented, orbiting Vela nuclear test detection satellites are performing test ban monitoring functions. The newest pair (Launch IV) were placed in orbit on April 28, 1967, using a Titan IIIC booster system. The two new sentries are earth-oriented in 180°-spaced positions on a nearly circular orbit of about 65,000 nautical miles radius, comparable to the previous six. Earth-orientation aids in the recording of optical and electromagnetic radiations from nuclear detonations that might be conducted in the atmosphere. Improved detector systems for neutrons, gamma rays, and X-rays for high-altitude and space surveillance are employed. Instruments also obtain data on background radiations, primarily those emitted from the sun.

The six earlier satellites were placed in orbit in pairs with Atlas-Agena booster systems in October 1963, July 1964, and July 1965. In addition to performing their test ban monitoring functions, they have reported a wealth of new scientific data on the solar wind and its interaction with the magnetic fields around the earth.

A fifth launch of twin satellites is scheduled for the future. They will have increased nuclear test detection capabilities and will involve earth-oriented spacecraft. The launch will use a Titan IIIC booster.

Vela Surface Detection Program

The AEC, with LASL conducting the research and development, participates with the DOD in studies on the ground-based detection of nuclear explosions in space. The joint program is directed primarily at the air fluorescence detection method. The concept is based on the measurement of the fluorescent light produced in nitrogen when high-altitude air is bombarded by X-rays from a nuclear explosion.

Results of a joint AEC-DOD lightning study, conducted at LASL in the summer of 1965, have led to improvements in the ability to discriminate between nuclear weapon detonations and lightning flashes.

Chapter 4

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Chapter 4

NAVAL PROPULSION REACTORS

Congress has authorized 107 nuclear-powered submarines, including 41 of the Polaris missile-launching type and one deep submergence research vehicle, as well as eight nuclear-powered surface ships. Of these, 74 nuclear-powered submarines, including all 41 Polaris missile-launching type, and four surface ships—the aircraft carrier *Enterprise*, the guided-missile cruiser *Long Beach*, and the guided-missile frigates *Bainbridge* and *Truxtun*—have been placed in operation and have steamed over 10 million miles without ever having to abort a mission because of a failure in the reactor plant.

NUCLEAR FLEET

The two reactors for the Navy's next attack aircraft carrier, the *Nimitz* (*CVAN 68*), are the highest-powered, longest core-life reactors under development in the naval reactors program. Each will produce about as much power as four of the *Enterprise*-type reactors. With these reactors, the *Nimitz* will be able to steam for 13 years without refueling. In addition to the *Nimitz*, the Department of Defense has indicated that it expects to request two additional nuclear-powered aircraft carriers in future shipbuilding programs, making a total of three new nuclear aircraft carriers in addition to the now-operating *Enterprise*.

During 1967, the *Enterprise* and *Bainbridge* completed their second Vietnam deployments, and *Long Beach* completed her first. The operation of these nuclear-powered surface ships continues to demonstrate, under actual combat conditions, the tactical flexibility and freedom for independent action as a result of virtually unlimited endurance at high speeds provided by nuclear power. *Truxtun*, the Navy's second nuclear-powered guided-missile frigate, was commissioned in May 1967 and joined the operating fleet.

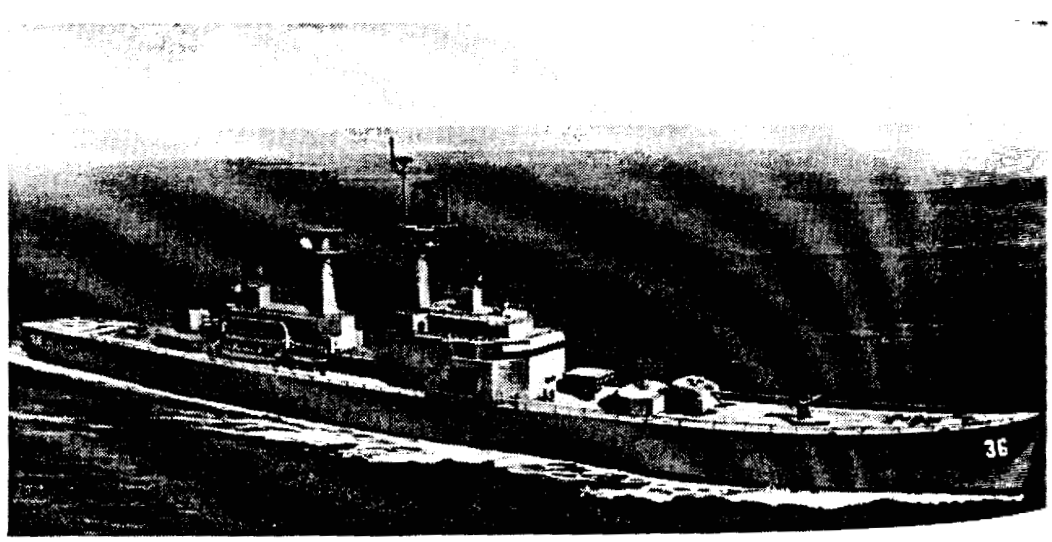
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Deep Submergence Research Vehicle (NR–1)

A nuclear-powered deep submergence research and ocean engineering vehicle (NR–1) is presently under development. The capability of this vehicle—which will be manned by a crew of five and two scientists—will be an order of magnitude greater than any other develope





Nuclear Fleet Additions. Artist's conception *above* is of the *Nimitz* (*CVAN 6*
the Navy's second nuclear-powered aircraft carrier. Her two reactor cores wi
last for approximately 13 years of normal ship operation, produce in excess o
200,000 shaft horsepower, and propel her at speeds in excess of 30 knots. She i
expected to require refueling only once in a normal ship lifetime. *Below* is a
artist's conception of *DLGN 36*, the Navy's third nuclear-powered guided-mi
sile frigate. Her initial fuel loading will propel her for over 10 years before re
fueling becomes necessary. Congress authorized two additional nuclear-powere
guided-missile frigates in the FY 1968 Department of Defense Authorizatio
Bill in place of two non-nuclear guided-missile destroyers requested by the DOD

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planned to date because of the vastly increased endurance made possible by nuclear power. NR–1 is designed to operate on and near the ocean bottom for periods of time limited only by the provisions carried onboard.

Submarines

The 400th successful Polaris submarine patrol was completed in May 1967 following 60 days of operation by the *Lafayette* (*SSBN 616*). Since the initial Polaris patrol by the *George Washington* (*SSBN 598*) in November 1960, Polaris submarines have completed more than 23,000 days on patrol. The *Will Rogers*, last of the presently planned fleet of 41 Polaris submarines, deployed on her initial patrol in September 1967, marking the successful completion of this major shipbuilding program.

Emphasis continues on research and development to provide advanced naval reactor cores of higher energy density and longer life with the ultimate objective of developing cores that will last the lifetime of a ship. New cores now being installed in nuclear submarines will last for more than 10 years of normal operation and propel the ship for approximately 400,000 miles.

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Chapter 5

REACTOR DEVELOPMENT AND TECHNOLOGY

Having attained its goal, with regard to light-water reactors, of providing the technological base for a competitive nuclear power industry, the AEC is now concentrating efforts to furthering advanced reactors, primarily breeder concepts. Such reactors would make more efficient use of uranium, thus helping to conserve this natural resource. In a cooperative program, industry and the AEC are assessing the continuing development of advanced reactors and establishing standards and codes that will assure and strengthen the safety and success of reactors. New emphasis has also been given to the use of nuclear energy for desalting and other industrial processes.

ASSESSMENT OF NUCLEAR POWER

The AEC, in cooperation with laboratories and industry, has undertaken a review and reassessment, with the encouragement of the Congressional Joint Committee on Atomic Energy (JCAE), of the program for the development of civilian nuclear power. Developments in the civilian nuclear power program since 1962, and the AEC's objectives, policies and procedures affecting the future development efforts of the AEC, were identified in a report [1] issued in February 1967.

The AEC is now making detailed technical and economic analyses of the different reactor concepts that might be used for the production of electricity and for dual-purpose operations. These analyses, initiated in 1967, will continue into 1968.

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[1] "Civilian Nuclear Power—1967 Supplement of the 1962 Report to the President", for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $0.40.

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First Analysis Report on Water Reactors

The first analysis report to be completed was the "Current Sta... and Future Technical and Economic Potential of Light Water R... actors." [2] The report was prepared under the direction of an A... task force by representatives of S. M. Stoller Associates, New Y... City, and the Jackson and Moreland Division of United Engineers a...

[2] "Current Status and Future Technical and Economic Potential of Light Water ... actors," will be available in early 1968 from the Superintendent of Documents, U.S. G... ment Printing Office, Washington, D.C. 20402.



Advanced Test Reactor. Technicians load fuel inside the pressure vessel of th... Advanced Test Reactor (ATR) at the National Reactor Testing Station i... Idaho. This view, taken through an access port, shows the upper end of th... 4-lobed serpentine core, situated 19 feet below the reactor's top head. The straight... "pipes" are two of the nine inpile tubes which will provide spaces for inserti... samples of reactor fuels and structural materials to be performance-tested i... the ATR's high neutron flux environment (up to 2.5 x 10^{15} neutrons per squa... centimeter per second). The 12 curved pipes contain detector instruments us... to control reactor power. A unique feature of the ATR is its nine independent... adjustable testing zones. The AEC's newest and largest materials test reacto... achieved first criticality (a sustained and controlled chain reaction) on July ... 1967. Full power operation is scheduled for early in 1968. The ATR is operate... for the AEC by Idaho Nuclear Corp.; the principal nuclear contractors for th... design and construction were Ebasco Services, Inc., and the Babcock & Wilcox C...

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Constructors, Inc., Boston, Mass., with the cooperation and assistance of four light water reactor manufacturers: Babcock & Wilcox Co., Atomic Energy Div., Lynchburg, Va.; Combustion Engineering, Inc., Windsor, Conn.; General Electric Co., Advanced Product Operation, Sunnyvale, Calif.; and Westinghouse Electric Corp., Advanced Reactor Div., Pittsburgh, Pa. The final report is to be printed in early 1968.

Other Task Force Studies

Other task forces are evaluating: (*a*) advanced converter reactors, (*b*) steam and gas cooled fast breeder reactors, (*c*) liquid metal fast breeder reactors, and (*d*) the role of thorium. These studies include technical assessments as well as consideration of the future nuclear electric complex and the utility outlook.

Upon completion of the evaluations of individual reactor concepts, the various concepts will be compared so that the future roles of the various civilian power reactor systems can be identified.

Standards and Industrial Codes

The AEC has been engaged in an extensive program, in cooperation with the nuclear industry, professional societies, and the U.S.A. Standards Institute,[3] to draw together and consolidate the existing technological base, in the form of recognized and proven criteria, standards, and codes, to better assure the safety and success of reactor projects. Standards are the yardsticks against which approaches to design criteria are measured. They are statements of technology, practices, and specifications in the areas of design, construction, inspection, quality control, proof-testing, and operation. They embody the procedures and practices used for obtaining and confirming performance requirements.

Standards such as those being developed by this program are needed to define the existing technical base upon which the advanced development programs will build, and for immediate and direct application to priority AEC programs. They may also form an important base for industry, regulatory bodies, and their related standards activities involved with other types and applications of reactor plants.

A sense of the magnitude of the program is reflected in the fact that between 3,000 and 5,000 engineering specifications are needed for a typical reactor project. Standards provide the basis for these engineer-

[3] Membership of the U.S.A. Standards Institute consists of representatives of organizations having a direct or substantial interest in a specific field; it is supported by industrial, technical, and governmental organizations.

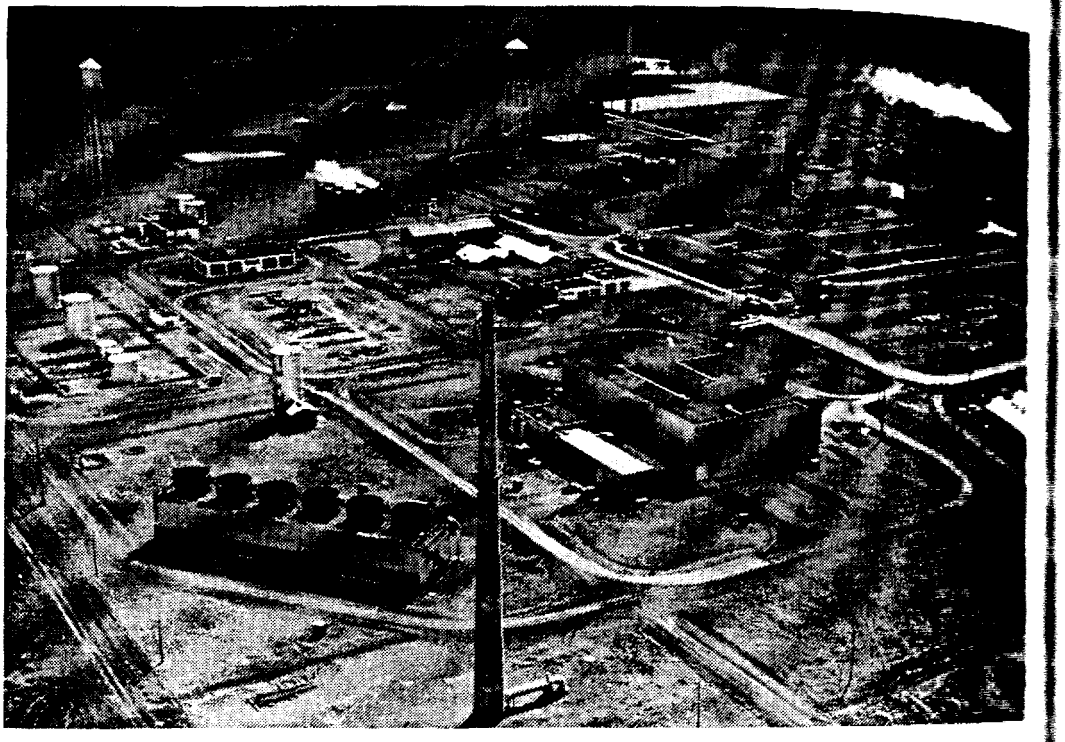
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ing specifications. Only about 100 basic reactor standards have b
approved by industry standard groups to date. Many existing eng
neering standards in use in other fields are being adapted for nuclea
applications, and many company standards are being used. Howeve
recognized acceptable industry-wide standards do not exist in ma
areas unique to nuclear applications. To provide adequate safe
assurance and compensate for the uncertainties in technology and eng
neering practices, conservative reactor siting policies and extens
application of engineered safety systems have been necessary.

Areas of Application

The technical areas involved encompass design, analytical metho
material, equipment, processes, fabrication, construction, quality a
surance, inspection, testing, maintenance, repair and operation.

Within the AEC reactor development programs, strengthening a
tions are being taken to establish and enforce systematic disciplin



Test Reactors Complex. Aerial view of the Advanced Test Reactor (ATR
building, its cooling tower, and stack at the National Reactor Testing Statio
in Idaho. The basic ATR facility in *foreground*, was completed during 196
the giant 250,000-kilowatt thermal (Kwt.) reactor achieved first criticality
ing July. The other two large buildings house the 40,000 Kwt. Materials Te
Reactor (MTR) *left background* which has been in operation since 195
the 175,000-kilowatt Engineering Test Reactor (ETR), *right background*
operation since 1957.

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procedures to assure: (*a*) that the technical criteria, standards, codes, and requirements are defined and employed; and (*b*) that recognized standard practices are used where applicable and, where not, they are being developed.

Safety research and development programs have been augmented toward improving understanding, development, and application of safety-related practices.

Programs have been established at Oak Ridge National Laboratory (ORNL) for water reactor systems, and at the Liquid Metal Engineering Center (LMEC) for liquid metal-cooled fast breeder reactors, to consolidate, maintain current, and promulgate engineering standards for major programs.

Initial emphasis is being given to the standards and practices associated with the integrity of reactor primary systems. Detailed uniform standards in this area for AEC-owned reactor programs are being reviewed and distributed.

Need for Breeder Reactors

During the 1965–67 period, utilities ordered central station nuclear powerplants with a net total capacity of over 45,000 megawatts of electricity (Mwe.). In addition, plans have been announced for constructing other nuclear plants having a total capacity of 10,200 Mwe. Of the plants ordered or planned, all but one (a 330 Mwe. gas-cooled unit) have been boiling or pressurized-water (light water) reactors. (See Appendix 5—Central Station Nuclear Powerplants, for listings of stations in operation, under construction, or on order.) The large number of the light water reactors being sold has resulted in placing more emphasis on the need to develop breeder reactors, because current light water reactors use only a very small portion of the total energy available in uranium resources.

Breeders Produce Own Fuel

Uranium, when mined, has two usable fuel forms—uranium-235 (U^{235}), a fissionable material existing in very small quantities in nature, and uranium-238 (U^{238}), a fertile material. A fissionable material, plutonium-239 (Pu^{239}), is formed by neutron irradiation of U^{238}.[1]

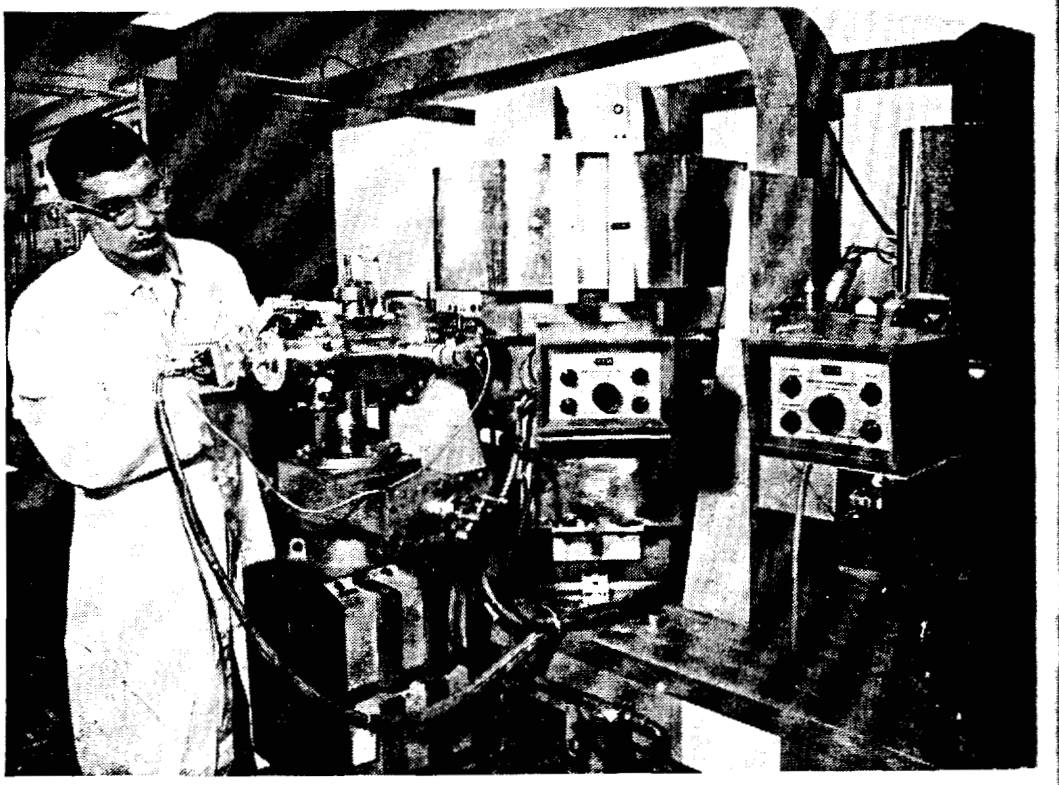
[1] Uranium-238 + one neutron → uranium-239; uranium-239 → neptunium-239; neptunium-239 → plutonium-239. Uranium-239 and neptunium-239, both highly unstable substances with relatively short half-lives of 23 minutes and 2.3 days, respectively (the time taken for one-half the atoms to undergo radioactive decay) are formed as intermediate products; beta particles are thrown off in the process (an electron emitted from the atomic nucleus), as neptunium-239 throws off a beta particle to form plutonium-239.

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The heat generated within a nuclear reactor is produced by the fi sioning, or breaking apart, of atoms. Therefore, nuclear reactor fue must be naturally fissionable or be capable of being converted into fi sionable material (see discussion of "Uranium Enrichment" in Chap ter I—Source and Special Nuclear Materials).

Breeding is a highly efficient form of conversion of nonfissionable uranium (U^{238}) to fissionable plutonium (Pu^{239}), or converting nonfis sionable thorium (Th^{232}) to fissionable uranium (U^{233}). Breeder rea tors produce more fissionable materials than they consume.

Successful development of breeder reactors should permit the uti zation of from 60 to 90 percent of the uranium mined as compared t present utilization of about 1 percent. A proportionally lower fu cycle cost of less than 1 mill for each kilowatt-hour (kwh) of ele tricity is predicted. This can be compared with a predicted cost o



Fuel Burnup Study. A two-stage mass spectrometer in use at the National Re actor Testing Station by Idaho Nuclear Corp. is providing data to enable reactor operators to accurately measure fuel burnup and reactor operating history. The instrument can determine the absolute yields of selected stable and long-lived fission products in irradiated samples of Uranium-233 and -235, and plutonium 239 and -241. Among the more important fission products measured in this pro gram are isotopes of krypton, zirconium, molybdenum, ruthenium, xenon, cesium and various rare earths. The photo above shows the two-stage mass spectrometer with surface ionization source at *left*, first stage magnet at *top center*, second stage magnet at *top right*, and readout console at *far left*. The magnets ride on air cushions to prevent vibration and permit accurate focussing.

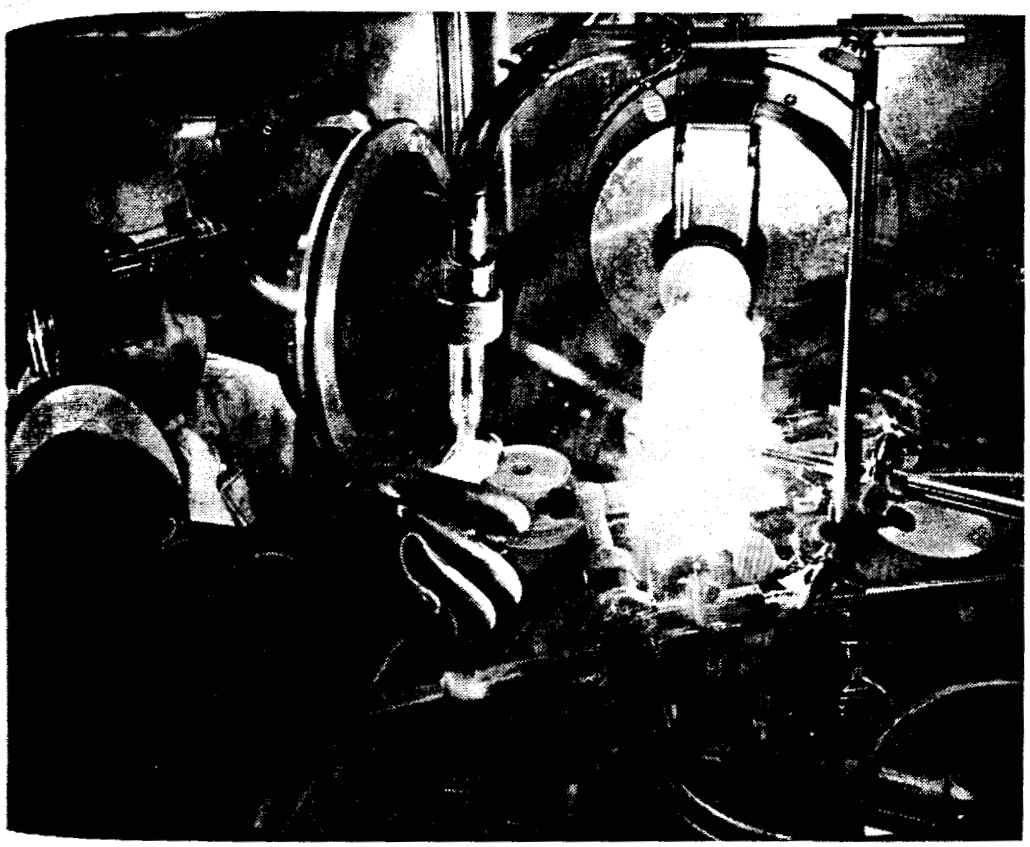
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more than 1 mill/kwh for the light water reactor central station plants to be operating by 1972.

In addition to lower fuel cost for uranium, since the breeder reactors can use plutonium for fuel, these reactors provide a market for the plutonium manufactured in the process of "burning" uranium in light water reactors.

BREEDER REACTOR DEVELOPMENT

With industry's acceptance of the light-water reactors, the AEC has now given the highest priority to the development of liquid metal-cooled fast breeder reactors (LMFBR). The overall objective is to achieve, through research and development and technology and engineering, developments that will make it possible to design, construct, and safely, reliably, and economically operate fast breeder reactors for use in central station nuclear powerplants.



Plutonium Alloy Test Sample. Component metals for a reactor fuel alloy are loaded inside a tantalum capsule in preparation for thermal analysis. One of the more promising of the alloys presently being studied at the AEC's Mound Laboratory is a mixture of plutonium, uranium, and zirconium. The plutonium and uranium form an ideal breeder fuel; the zirconium is added to provide desirable mechanical characteristics at high temperatures.

During 1967, there was concentration on: (*a*) preparing a detailed program plan for each of the technical elements of the program; (*b*) achieving involvement of industry and national laboratories from the initial planning stages; (*c*) acquiring critically short technical manpower; (*d*) identifying areas of immediate priority; and (*e*) initiating the programs and the facilities required for the development of the LMFBR concept.

LMFBR PROGRAM

The general guidance for the liquid metal-cooled fast breeder reactor (LMFBR) effort as well as for the other reactor development programs, is to successfully achieve program objectives with minimum expenditure of funds, time and technical resources. The participation of industry and development of industry's capabilities will be encouraged toward development of meaningful industrial competition. There will be maximum use of previous investments in resources and protection of the Government's interests and responsibilities.



Ultransonic Scanning. An ultrasonic scanning device capable of locating and identifying objects in opaque, high-temperature liquid sodium is being developed by Atomic Power Development Associates, Inc., Detroit, Mich. Pattern recognition at relatively close range has been demonstrated in sodium at 600° F. using 2.5 megacycle per second sound waves. The *top* view of the photo shows an aluminum target used in the development program; the *bottom* view is a photo reproduction of the printout.

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The LMFBR Program Office at Argonne National Laboratory (ANL), has initiated detailed program plans for the overall program and for the following technical program elements: (*a*) plant design; (*b*) components; (*c*) instrumentation and control; (*d*) sodium technology; (*e*) core design; (*f*) fuels and materials; (*g*) fuel recycle; (*h*) physics; and (*i*) safety. Each of the plans includes an assessment of the state-of-the-art, defines the objectives, establishes criteria and requirements for the programs, and describes the technical program required to achieve the objectives, including estimated costs and schedules.

ndustrial Participation

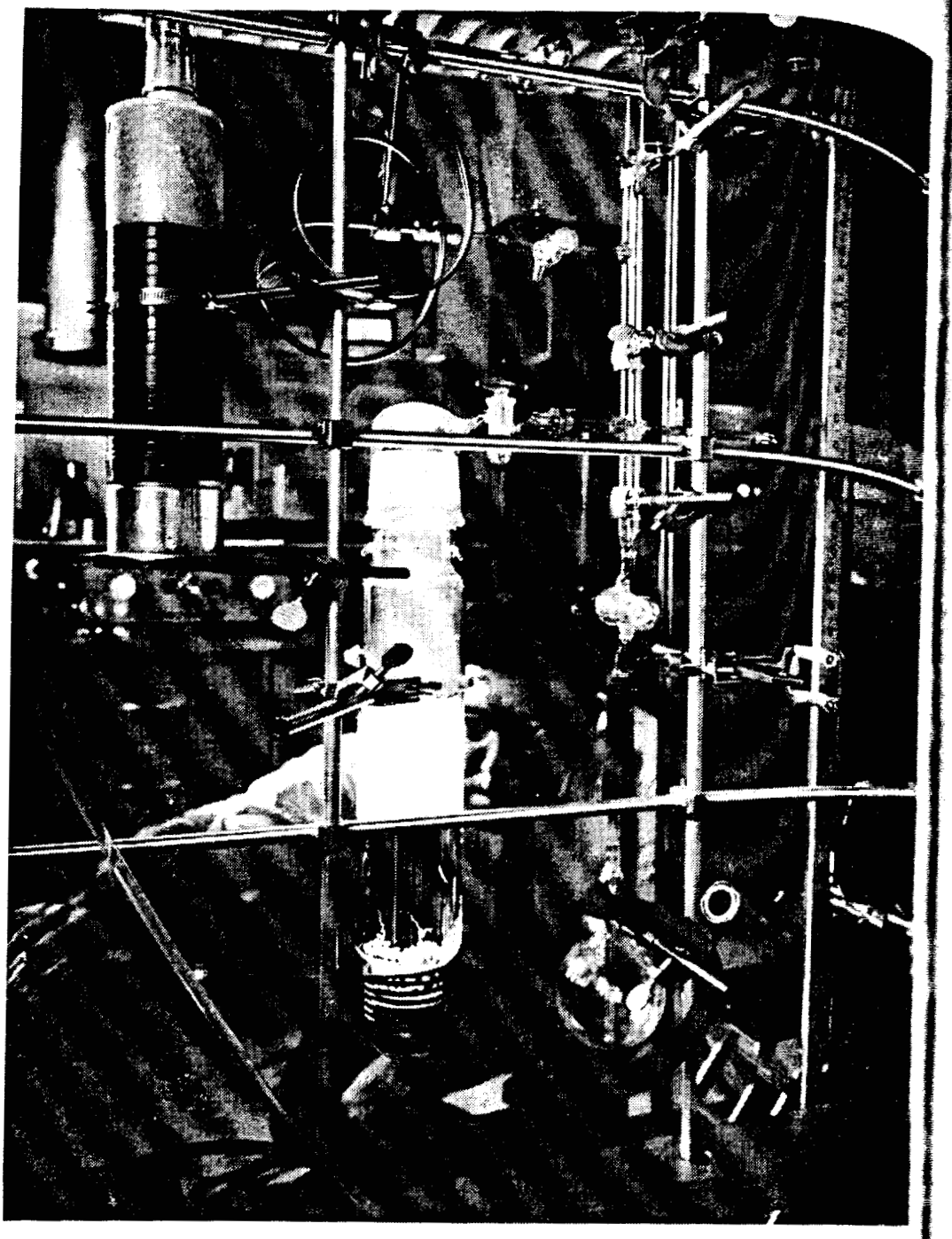
The AEC's overall mission includes fostering the development of a competitive and self-sustaining nuclear industry. During 1967, considerable progress was made in identifying the strengths and weaknesses in the nuclear industry applicable to the liquid metal-cooled fast-breeder reactor.

The achievement of a competitive and self-sustaining industrial capability for the LMFBR powerplants requires that industry be involved, to the maximum extent possible, in LMFBR development programs. The AEC is encouraging industry to participate: by reviewing and commenting on program plans; by participating in the design and construction of AEC facilities; by undertaking research and development work both to support the LMFBR program and to strengthen their LMFBR capabilities; and by taking the initiative in the design and development of demonstration plants eventually to be built and operated by this industry.

The design, construction, and operation of demonstration plants is an important part of the LMFBR program, and one in which the AEC-industrial team must work closely together. To the extent possible, AEC programs will be geared to the demonstration plant schedule so that necessary technology and engineering information will be available when needed. The precise timing and number of the demonstration plants must eventually be resolved among industry, the utilities, and the AEC.

Industry is expected to perform a major portion of the development activities so that technical "know-how" and capability will be developed in the industrial realm in order to achieve the strongest possible industrial base.

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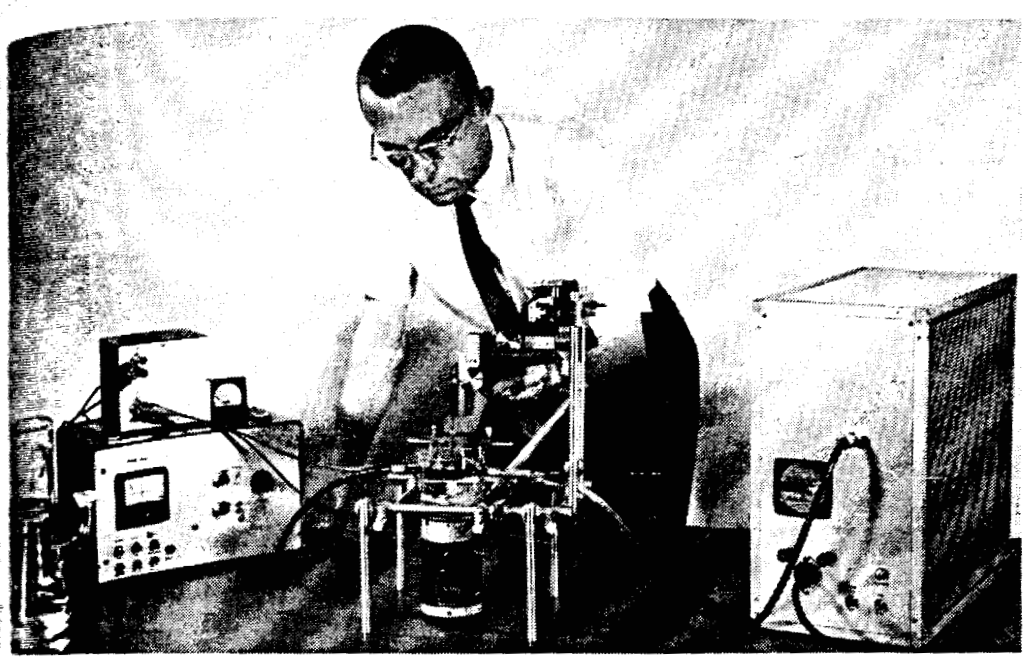


Sodium Distillation. Very few techniques are available for the analysis of impurities in sodium. As part of the program to develop such techniques, a method to remove radioactive sodium from nonvolatile impurities by high-vacuum distillation has been developed by Atomic Power Development Associates, Inc. The sodium is contained in a molybdenum crucible in the bottom of the glass distillation flask-condenser. An induction heater is used to heat the sodium while the apparatus is maintained at less than 10-microns absolute pressure. The distillation was developed as part of the analytical techniques for determination of oxygen, iron, nickel, and chromium in radioactive sodium. Note the typical sodium vapor glow in the upper portion of the condenser and the condensed sodium just above the heating coil.

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Examples of Industrial Participation

One example of industrial participation is in LMFBR physics research. Major existing facilities for LMFBR physics program efforts; i.e. critical assemblies and linear accelerators, are owned by the Government, located at Government sites, and operated by the AEC's national laboratories. The high cost of the facilities has discouraged industrial ownership. Some of the facilities have been operating for only one shift a day because of limited staff. The urgent need for LMFBR physics data has made their increased use desirable. During 1967, the AEC requested certain industrial firms to nominate qualified members of their staffs for assignment to these facilities for assistance in the design and analysis of experiments. This has occurred in connection with the Zero Power Reactors (ZPR's) at the National Reactor Testing Station (NRTS) in Idaho and at ANL. Nominees were also requested for assignment to the Cross Section Evaluation Center at Brookhaven National Laboratory. As



Thermals Studies. Research at Oak Ridge National Laboratory has led to development of equipment capable of producing transmission electron-microscopy specimens from radioactive bulk materials in less than 30-minutes, a saving of several hours over previous techniques. The equipment accepts one-eighth inch diameter specimens, which are mechanically sliced from the test material, and reduces the thickness from 10–20 thousandths to 10 millionths-of-an-inch electrolytically. A photocell detector stops the polishing at the right point. Because of the semiautomatic nature of the equipment, the operator is freed for the other tasks. Study of the specimens has increased researchers' knowledge of the internal structure of metals and experimentation with stainless-steel metals is expected to be of benefit to the fast breeder reactor programs.

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a result of this AEC-industrial cooperation, representatives of industry are contributing to the LMFBR physics research program. At the same time, they are enhancing their own and their companies' expertise in fast breeder reactor technology. A utility engineer has been given a long-term assignment to the project group at Argonne National Laboratory which was established to give management and technical direction to the 1,000-Mwe. plant studies being conducted by five reactor plant manufacturers (see "1,000-Mwe. LMFBR Studies," p. 85).

Some of the Government-owned facilities of importance to the LMFBR program, of which some are presently in operation and others planned or under construction, are the Experimental Breeder Reactor No. 2 (EBR–2), the Zero Power Plutonium Reactor [5] (ZPPR), and the Zero Power Reactor [5] (ZPR–3) at National Reactor Testing Station; the planned Fast Flux Test Facility at the Hanford Works, Wash.; the Liquid Metal Engineering Center with its Sodium Components Test Installation Liquid Metal Information Center, and the Sodium Pump Test Facility in Santa Susana, Calif.; the fast neutron generator at Argonne National Laboratory; and the linear accelerator at Oak Ridge National Laboratory. Private facilities which can make significant contributions to the program, primarily in the technology of fuels and materials and LMFBR physics research, are the Enrico Fermi Atomic Power Plant (Fermi) in Michigan, and the Southwest Experimental Fast Oxide Reactor (SEFOR) in Arkansas.

Experimental Breeder Reactor No. 2 and Fermi

The EBR–2 at NRTS is the primary fast flux irradiation test facility of the AEC for fast breeder reactor fuels and materials development. The plant was shut down as planned on December 31, 1966, to increase the reactor core size by one-third. Operation resumed in April 1967. However, technical difficulties, including a reduction in the reactor power coefficient of reactivity, fission gas release from an experimental fuel irradiation capsule, and a driver fuel element, copper in the primary sodium, and more than predicted irradiation swelling of the blanket fuel, required that the reactor be shut down for extended periods during 1967. This prevented accomplishment of planned operations. Further, as a consequence of these difficulties, reactor operational procedures have been modified, and additional tests, including core physics, instrumentation, and primary sodium compatibility have now been incorporated as a part of the routine operation of the reactor. The

[5] Zero power reactors (ZPR) are experimental facilities operated at such low power levels that a coolant is not needed and little radioactivity is produced. They are used primarily to experiment with core configurations.

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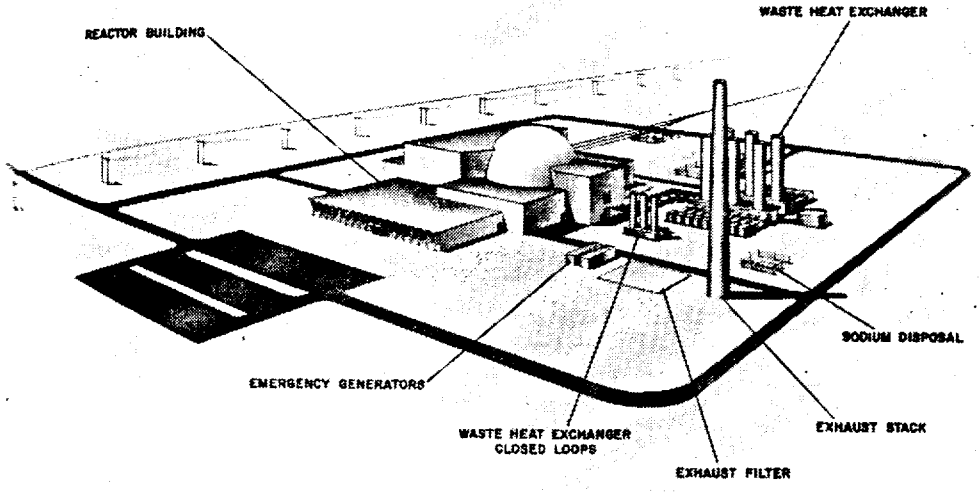
...hest priority has been assigned to resuming operation of EBR–2 ...h maximum possible availability consistent with reactor safety. ...vestigation of an obstruction in the coolant system and subse- ...uel failure prevented operation of Fermi for all of 1967.

...st Flux Test Facility (FFTF)

Plans progressed in 1967 on the design of the Fast Flux Test Fa- ...ity (FFTF) at Hanford. This facility is being designed to test ...els and materials which will be used in demonstration plants and ...mmercial fast breeder reactors by exposing the material to a "sea" ...fast neutrons,[6] thereby creating the radiation environment of a fast ...eder reactor.

Congress has authorized $87.5 million for the FFTF. During 1967, ...AEC initiated action to select the contractors for architect- ...ineers, construction management services, and the reactor plant ...igner. Contractor selections will be made in 1968. Construction of ...FFTF is expected to start in 1969. Full power operation should ...in early in 1974.

[6] Fast neutrons will be obtained by operating the FFTF without a moderator material ...at the neutrons released by the nuclear reaction remain as close as possible to their ...inal energy level.



...F *Concept.* Drawing shows the conceptual layout of the Fast Flux Test ...ity (FFTF) which will be built at the Hanford Works in Washington. ...ific Northwest, which operates the Pacific Northwest Laboratory for the ... has been assigned FFTF project design and construction management. ... FFTF will provide a fast-neutron environment similar to that expected ...eder reactors of the future and will be used as a national testing complex ...fuels and materials that are candidates for use in fast reactors.

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Liquid Metal Engineering Center (LMEC)

For the sodium breeder program, the AEC has established a Liq... Metal Engineering Center (LMEC) at Canoga Park, Calif., and op... ated by Atomics International (AI).[7] The LMEC assists in the ... tailed evaluation and test of reactor components; equipment and ... strumentation; in the identification, collection and evaluation ... engineering standards and specifications; codes and practices for l... uid metal reactor systems and components; and in the operation of t... Liquid Metal Information Center.

The current testing capability of the center includes: (*a*) the Sodi... Components Test Installation, where tests are conducted on test mo... ules and prototype heat exchangers and steam generators; (*b*) t... Large Component Test Loop, for thermal-shock testing of sodium re... tor system components, small valves, equipment, and instruments; ... the Control Rod Test Tower, for proof-testing reactor control rod a... semblies; and (*d*) the Auxiliary Component Test Installation, fo... testing auxiliary components such as small pumps.

The LMEC also is to include a Sodium Pump Test Facility (SPTF... for testing large sodium pumps, instruments, large valves, and oth... components at fluid temperatures up to 1,200° F. During 1967, C. ... Braun & Co., Alhambra, Calif., was selected as the architect-engine... for design of the SPTF.

The development program for large sodium pumps was expand... in 1967 to include bearing and seal test studies to be conducted ... AI at the LMEC. Procurement of materials to be tested was initiate... In addition, the AEC prepared requests for proposals from indus... for participation in the development of sodium valves and piping.

Fast Breeder Reactor Physics

The AEC is carrying on an extensive fast breeder reactor phys... program, as well as a fuels and materials development program, ... obtain the basic data needed for the design, construction, and ope... tion of safe and economic nuclear powerplants. Major attention ... being given to the compatibility of the fuel and structural materia... in a sodium coolant environment.

The main facilities for the fast breeder reactor physics progra... are the ZPR's, ZPR–3 at NRTS and ZPR–6 and –9 at ANL.[8] ...

[7] Previously a division of North American Aviation, Inc. During 1967, North Amer... Aviation and Rockwell-Standard Corp. merged to form the North American Rockwell ... AI retained its operating decision name.

[8] Summaries of some of the work being done with these facilities are included in ... supplemental report, "Fundamental Nuclear Energy Research—1967" (see last ... of this chapter).

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ZPPR at NRTS, and the SEFOR, a 20-megawatt thermal (Mwt.) reactor at Fayetteville, Ark. SEFOR is a joint undertaking of the Southwest Atomic Energy Associates, Gesellschaft für Kernsforschung (West Germany), Euratom, the AEC, and the General Electric Co.

The ZPR's are now in use. ZPPR and SEFOR are scheduled to begin operations in 1968.

1,000-Mwe. LMFBR Studies

Contracts were awarded General Electric, San Jose, Calif.; Combustion Engineering, Windsor, Conn.; Westinghouse Electric, Pittsburgh, Pa.; Babcock & Wilcox, Lynchburg, Va.; and Atomics International, Canoga Park, Calif.; for separate studies of 1,000-Mwe. LMFBR plants. These studies are to provide guidance in identifying the research and development programs necessary to achieve the technology for building a safe, reliable, and economic 1,000-Mwe. LMFBR plant in the 1980's.

OTHER BREEDER REACTORS

The AEC's program to develop liquid metal-cooled fast breeder reactors (LMFBR) has the highest priority. However, work is currently underway to investigate other reactor concepts which appear to have potential for breeding. These include gas and steam fast breeders, the molten salt breeder reactor, and the light water breeder.

Molten Salt Breeder Reactor

There are two major elements in the molten salt breeder reactor program—one is operation of the Molten Salt Reactor Experiment (MSRE) at Oak Ridge National Laboratory, and the other is research and development in support of the molten salt breeder concept. The MSRE is being used to demonstrate the feasibility of the molten salt reactor concept.[9] It first achieved a self-sustaining nuclear reaction in 1965. Reactor power was increased step by step until it reached the maximum power level of 7.5 Mwt. in May of 1966. The MSRE achieved a total of 5,663 equivalent full power hours of operation during 1967, mostly at maximum power and temperature.

The Molten Salt Breeder Reactor (MSBR) offers the potential for low cost electric power with a thermal neutron spectrum, fluid fuel

[9] A reactor that uses molten salt and uranium for both fuel and coolant.

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system, operating on the thorium-uranium-233 cycle. This system would be a true back-up to the high priority LMFBR's fast neutron spectrum, solid fuel system operating on a uranium-plutonium cycle. The approximately 1.05 breeding ratio predicted for the MSBR, combined with a low fuel specific inventory and continuous on-line fuel processing, could result in low fuel cycle costs and favorable overall economies. However, a significant research and development program will still be required for a realistic evaluation of the potential of molten salt reactor systems for economical power production in large central station plants.

Light Water Breeder Reactor

The Light Water Breeder Reactor (LWBR) concept is based on an advancement of the seed-blanket technology of the Shippingport Atomic Power Station in Pennsylvania which was built, and is operated, under the direction of the AEC's naval reactors program. Developmental work on the LWBR is being carried out at the AEC's Bettis Atomic Power Laboratory in Pittsburgh, Pa.

Based on the work done to date, it is expected that a successful light water breeder core design can be developed and that a successful breeding demonstration of this core can be accomplished in an existing light water reactor plant, such as Shippingport. The only major changes to an existing plant would be those associated with the LWBR core.

The seed-blanket concept is the only known approach which uses the already-developed light water reactor technology and can make available significantly more than one to two percent of the energy potentially obtainable from uranium or thorium ore resources using present types of light water reactors. The successful development of this reactor concept could ultimately make available for power production about 50 percent of the energy potentially available in the country's thorium fuel resources—a source of energy many times greater than the known coal, oil, and natural gas reserves of the United States. A successful breeding demonstration would prove that a large number of light water reactor plants already built or planned could be converted into breeders, thereby increasing this country's energy resource base. During 1967, technical work in the areas of physics, fuel element development, and reactor engineering has been advanced to the point where fabrication of a breeding demonstration core can begin in 1968. This technology has been made available to industry through publication of nearly 100 technical reports.

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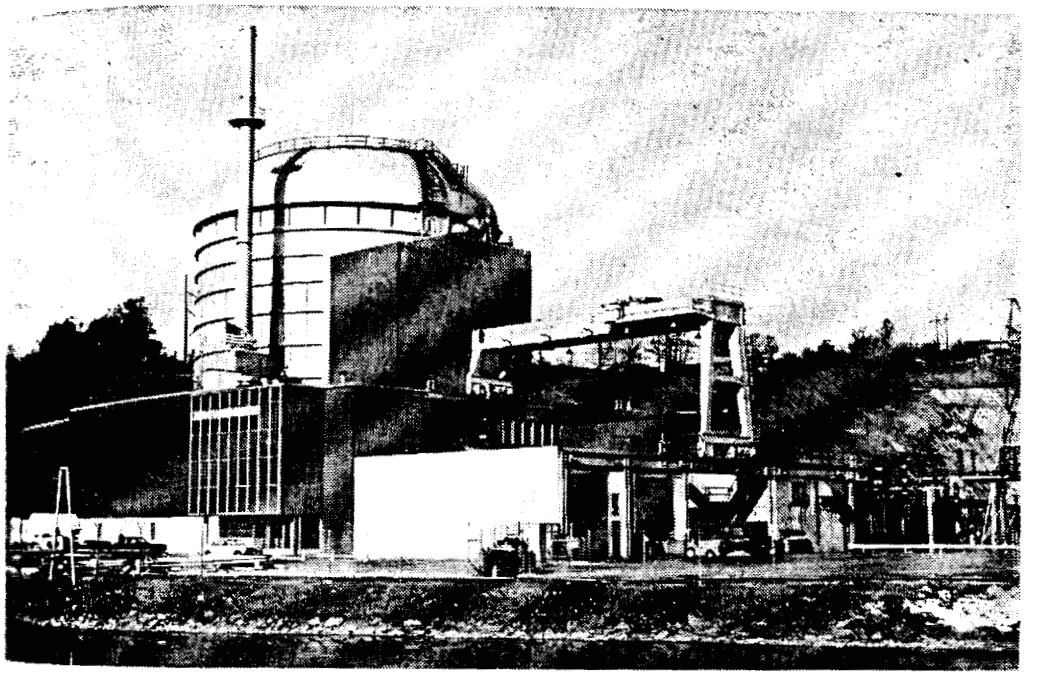
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NON-BREEDER REACTORS

While there is no shortage of natural uranium or thorium, it anticipated that there may be a shortage of low-cost natural ura- in the future. Therefore, if nuclear power is to make a major and ing contribution to future energy needs, a technology for more ient use of these resources must be achieved. While the breeder re- tor presents the highest potential utilization of nuclear fuel, certain es of non-breeder reactors can use available resources more effec- ely than the light water reactors now well accepted by industry. erefore, the AEC is engaged in the development of basic technology certain promising advanced reactor concepts. These include the h temperature gas-cooled reactors and the heavy water moderated tors.

HIGH-TEMPERATURE, GAS-COOLED REACTORS

Primary facilities involved in the development of high-tempera- e gas-cooled reactor (HTGR) systems are the Peach Bottom



ch Bottom in Operation. The 40-Mwe. high-temperature, gas-cooled reactor TGR) nuclear powerplant at Peach Bottom, Pa., was placed in commercial ration during 1967 on the system of Philadelphia Electric Co. The plant, in- rating an HTGR reactor system developed by Gulf General Atomic, was by Philadelphia Electric Co. and 52 other U.S. electric utility companies prising High Temperature Reactor Development Associates. The project was ed out under the AEC's Power Reactor Demonstration Program. Bechtel was engineer-constructor for the plant.

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Atomic Power Station in operation at Peach Bottom, Pa., the Fort St. Vrain Nuclear Generating Station to be built at Platteville, Colo., and the Ultra High Temperature Reactor Experiment (UHTREX) at Los Alamos Scientific Laboratory.

Peach Bottom Atomic Power Station

The Peach Bottom Station was developed by the General Atomic Division[10] of General Dynamics Corp., San Diego, Calif., for the Philadelphia Electric Co. and the High Temperature Reactor Development Associates under the AEC Power Reactor Demonstration Program.[11] The Bechtel Corp., San Francisco, Calif., was engineer-constructor. It has the highest thermal efficiency of any nuclear plant in the United States (above 35 percent). It is the first nuclear power system to achieve the high efficiency steam conditions of 1,000° F. and pressures up to 1,450 pounds per square inch.

The Peach Bottom reactor first achieved criticality[12] on March 1966. This was after delays caused by two construction fires and technical problems, principally with the steam generators and fuel handling machine. On January 27, 1967, the plant first generated electricity in excess of the plant's own operational needs. Full design electric power was generated on May 16, and the plant went into commercial operation on June 1, 1967. At year's end, the plant had operated for more than 158 days full-power equivalent.

Fort St. Vrain Reactor

The 330-Mwe. Fort St. Vrain gas-cooled reactor project was initiated July 1, 1965, as a joint Government-industry effort under the AEC Cooperative Power Reactor Demonstration Program, and is to be built for the Public Service Co. of Colorado by the Gulf General Atomic, Inc., San Diego, Calif. The contract specifies that for the project to continue into the construction phase, certain findings must be made with regard to the time the plant can be placed in operation, plant availability, and power production. The detailed technical evaluation required to make these findings are underway.

In addition, the determination to proceed with the Fort St. Vrain plant is to be made after Peach Bottom has achieved full power and

[10] Late in 1967, the General Atomic Division became a wholly owned subsidiary of the Gulf Oil Corp. and its name was changed to Gulf General Atomic, Inc.

[11] The Power Reactor Demonstration Program is a program under which the AEC provides various types of assistance to industry in return for which technical and economic data are made available to the AEC for use by industry and the AEC in further development of nuclear power. Individual projects are financed jointly by the AEC and industry.

[12] Criticality is the state of a nuclear reactor when it is sustaining a chain reaction.

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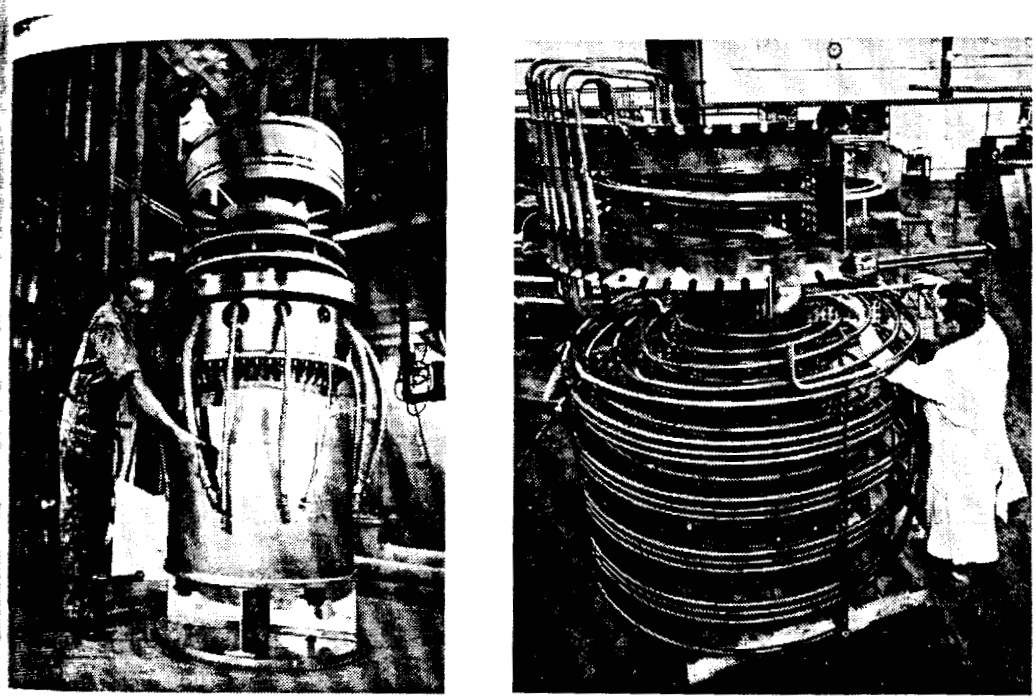
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operated for a period of 9 months and a minimum of 1,000 hours operation at power. On July 20, 1967, the Peach Bottom plant completed 1,000 hours of operation. The 9 months period will be completed on March 3, 1968.

The application for a construction permit was submitted to the AEC October 1966 and is under review.

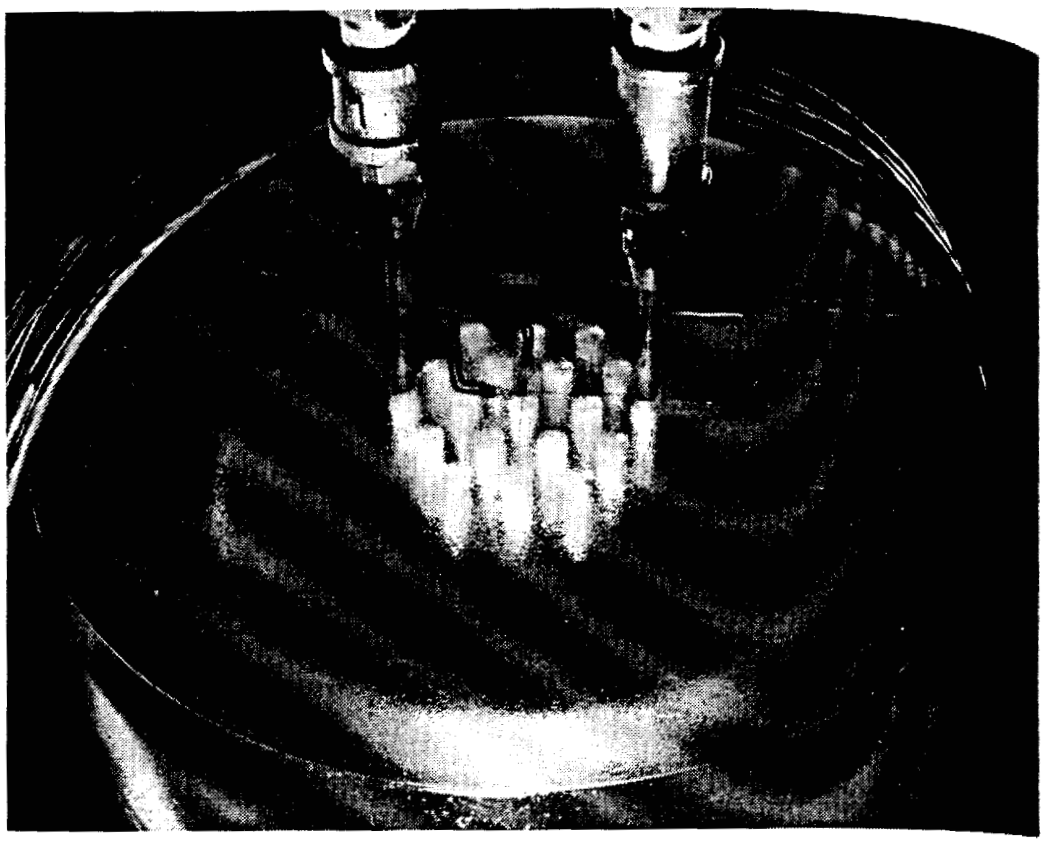
During 1967, Gulf General Atomic placed orders for most of the components for the Fort St. Vrain plant, and fabrication of the components is in progress.

Prestressed Concrete Reactor Vessel. One of the major features of the Fort St. Vrain HTGR plant is the use of a prestressed concrete reactor vessel (PCRV). The PCRV has been developed extensively in England and France for gas-cooled reactors. However, in the U.S., the only operating central station gas-cooled reactor, Peach Bottom, has a steel reactor vessel. Emphasis has been on the development of steel vessels for water-cooled and liquid metal-cooled reactors, and on pressure tubes for heavy water moderated reactors.



Fort St. Vrain Plant Components. Photo on *left* shows a helium circulator prototype assembly for the Fort St. Vrain Nuclear Generating Station in a test facility at the Valmont Station of Public Service Co. of Colorado which the circulators undergo full flow and temperature conditions, using both steam and water turbine drive. These circulators will be used in the 330-Mwe. high-temperature, gas-cooled plant to be built by Gulf General Atomic for the Public Service Co. under the AEC's Power Reactor Demonstration Program. On the *right* is a mock-up of a steam generator module for the Fort St. Vrain station. The model is full-size in diameter, half-size in height, and shows some of the spiral-coil cross-flow tube bundles.

A concrete vessel can be considered for use with most types of n actors, and it has several potential advantages. It can be fabricated a the site and built in very large sizes. It has the advantage of redun dancy of the independent strength-members, and failure of any par ticular prestressed cable embedded in the concrete will have negligib effect on the other cables or the entire structure. The use of the PCR





HTGR Component Research. In pho *above*, an epoxy model of a concre pressure vessel is placed in a scatter light polariscope at Oak Ridge N tional Laboratory. Scattered li photoelasticity is a general three-d mensional non-destructive method f experimental stress analysis. A he lium-neon, continuous wave laser i used in this polariscope as a li source because of its high intensity a top view of the model shows the norm simulation. This work is a part o the prestressed concrete reactor ve sel (PCRV) work for the AE high-temperature, gas-cooled reacto (HTGR) program. At *left*, an ad vanced HTGR fuel element is show in a Gulf General Atomic cutaway model. The hexagon-shaped graphite bloc elements have holes in which the coated nuclear fuel particles are place

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some of the major developmental items which will have to be considered by the AEC in its analysis and review of the Fort St. Vrain plant.

Ultra-High Temperature Reactor Experiment

Construction of the Ultra-High Temperature Reactor Experiment (UHTREX) at the Los Alamos Scientific Laboratory was completed during the year. The reactor went critical August 3, 1967, and during the initial operational period the power is being limited to 2-kwt. for the execution of criticality experiments. The UHTREX is a 3-Mwt. helium-cooled graphite moderated reactor which will be used as a test facility to irradiate the type of fuel proposed for use in the HTGR program. The uranium carbide fuel is in the form of small spheres coated with carbon embedded in graphite, and has been designed for an operating temperature of 2,400° F. This is about 1,000° higher than specified for present gas-cooled reactors. Since some fission products are expected to be released from the fuel and contained within the UHTREX system, data will be provided on fission product release to the helium coolant, transport, and deposition within the system, and on system maintenance problems. The circulating helium is continuously purified, and fission products are removed and stored for later safe disposal. The reactor is built within a containment shell designed to contain fission products which otherwise might possibly be released to the environment under accident conditions. UHTREX does not have to be shut down for refueling; the reactor core can be rotated to allow fuel to be added while the reactor is operating at full power.

Heavy Water Reactors

In March 1967, the AEC reoriented the heavy water reactor (HWR) program from emphasis on the heavy water moderated, organic cooled reactor concept (HWOCR) to a heavy water moderated, water (light or heavy) cooled concept to take a maximum advantage of the large industrial technological base attributed to the wide acceptance of light water reactors by the nuclear utility industry. As a result, the HWOCR concept development was discontinued and the AEC's heavy water reactor program was redirected toward establishing and maintaining a research and development program based on water plant technology which would allow HWR's to be exploited in the event the introduction into the U.S. power picture is warranted.

The objectives of the HWR program are to advance the technology of the heavy water moderated water cooled reactors which show they can best meet the economic, technical, and fuel utilization requirements of these reactors, and on areas which will support the design and

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UHTREX Fuel Loading. The last fuel element necessary to achieve the first self-sustaining nuclear chain reaction in the Ultra-High Temperature Reactor Experiment (UHTREX) at Los Alamos Scientific Laboratory is shown being inserted into the fuel element charge conveyor for remote insertion into one of the 312 fuel channels (each having a capacity of 4 elements) in the reactor core. The 3-Mwt. helium-cooled, graphite moderated reactor went critical in August. The unclad graphite fuel elements are hollow cylinders 5.5 inches long. Contained in the graphite matrix of the element is the 93.15% enriched U-235 fuel in the form of UC_2 particles coated with three layers of pyrolytic carbon. The fuel elements for the first UHTREX loading are divided into eight groups whose uranium content per element ranges from 3.5 grams to 12.3 grams. The reactor will operate at 2,400° F.—about 1,000° higher than presently specified for water-cooled reactors.

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feasibility of systems in the 1,000-Mwe. and larger sizes needed for power and desalting.

An HWR program office has been established at the AEC's Pacific Northwest Laboratory (PNL) near Richland, Wash. It will assist the AEC in defining, administering, and integrating the multi-task research and development program to meet the objectives of the HWR program. During 1967, the program remained in the technical planning phase whereby the development efforts being performed under the AEC and Atomic Energy of Canada, Ltd. (AECL), cooperative program and other related efforts were consolidated and integrated to better meet the objectives of the reoriented heavy water reactor program.

Piqua

The Piqua Nuclear Power Facility at Piqua, Ohio, is a 45.5 Mwt., organic-cooled and moderated reactor designed to generate about 11.4 Mwe. The plant was built as a cooperative venture between the City of Piqua and the AEC under the Power Reactor Demonstration Program and operated intermittently from June 1963 until January 1966 when it was shut down. At that time it was discovered that a considerable amount of solidified organic material similar to coke had formed within the reactor core. As a corrective measure, the fuel elements and control rod drive mechanisms were removed and the reactor vessel was cleaned and inspected.

On December 13, 1967, the AEC announced the termination of its contract for the operation of the Piqua facility. Recurring development difficulties and the engineering and design cost in preparing the the plant for restart, the lack of programmatic justification to gain further organic technology in view of the phase-out of the HWOCR concept, and the short time remaining, once the reactor was restarted, the February 1969 contract expiration, were major factors in the decision by the AEC to terminate its contract for operation of the Piqua Nuclear Power Facility.

LIGHT WATER REACTORS

With the exception of the Peach Bottom and Fort St. Vrain gas cooled reactors, all of the central station nuclear powerplants ordered by utilities since 1958 are light water reactors. Those being sold today are either pressurized water reactors (PWR) which are being mar-

keted by Westinghouse, Combustion Engineering, or Babcock & Wilcox, or boiling water reactors (BWR) which are being marketed by General Electric (see Appendix 5).

The AEC has assisted in the development of light water reactors through specific programs in support of these systems, and further assistance—*e.g.*, research and development, waiver of use charges for special nuclear materials (fuel)—provided to specific projects under the AEC's Power Reactor Demonstration Program (PRDP). Because of the widespread acceptance of light water reactors, no additional PRDP projects are deemed necessary to enable utilities to build and operate uranium dioxide-fueled PWR's and BWR's.

The AEC's research and development on large light water reactors is now confined to reactor safety, resolving particular technical problems on AEC-owned reactors, the Joint U.S.-Euratom research and development program, and developing the technology associated with improved fuel utilization.

San Onofre and Connecticut Yankee Reactors

Late in 1967, the startup experiments on the San Onofre and Connecticut Yankee reactors were completed, and commercial operation of these plants began on January 1, 1968.

The San Onofre Nuclear Generating Station reactor was first connected to its electric grid on July 16, 1967. Power testing and electric power generation was delayed over a month because of turbine difficulties. This 430-Mwe. PWR plant, owned by the Southern California Edison Co. and San Diego Gas and Electric Co., is located at San Clemente, Calif.

The Connecticut Yankee Atomic Power Plant at Haddam Neck, Conn., is owned by the Connecticut Yankee Atomic Power Co. It first produced electricity for distribution outside the plant on August 7, with an electric power output of about 50 megawatts. The gross capacity of this pressurized water reactor is 485 Mwe.

The AEC provided research and development support for San Onofre, and design assistance for Connecticut Yankee under the Power Reactor Demonstration Program. Use charges on the special nuclear materials are being waived for 5 years of operation on each plant.

LaCrosse Boiling Water Reactor

On July 11, 1967, the LaCrosse Boiling Water Reactor first achieved sustained nuclear operation. It was used for operator training and

power testing before the first generation of electricity. The startup program was in progress at the end of the year. The 50-Mwe. reactor was built for the AEC by Allis-Chalmers Manufacturing Co. The Dairyland Power Cooperative will operate the plant under the AEC's Power Reactor Demonstration Program.

Elk River Reactor

The 22-Mwe. Elk River Reactor at Elk River, Minn., which first attained full power operation early in 1964, continued to operate satisfactorily through 1967. The plant was shut down during May and June for refueling and installation of new control rods in the Allis-Chalmers-built boiling water reactor.

BONUS Reactor

In 1960, the AEC entered into a contract with the Puerto Rico Water Resources Authority (PRWRA) under which the AEC would build the Boiling Nuclear Superheat Power Station (BONUS) on and leased from PRWRA, pay for the operation of the nuclear plant, and sell the steam to the PRWRA. The plant's operation since 1964 has provided technology on the use of a nuclear superheater even though there have been continuing technical difficulties; *e.g.*, superheater fuel leaks, control rod drive malfunctions, preheater-dryer piping cracks, core flow reductions caused by corrosion-product deposits, and cracked boron-stainless steel control rods.

Technical Support Contractor

In October of 1967, the AEC announced the selection of United Nuclear Corp., Elmsford, N.Y., to provide technical services required to support the LaCrosse, Elk River, and BONUS facilities.

The Experimental Boiling Water Reactor

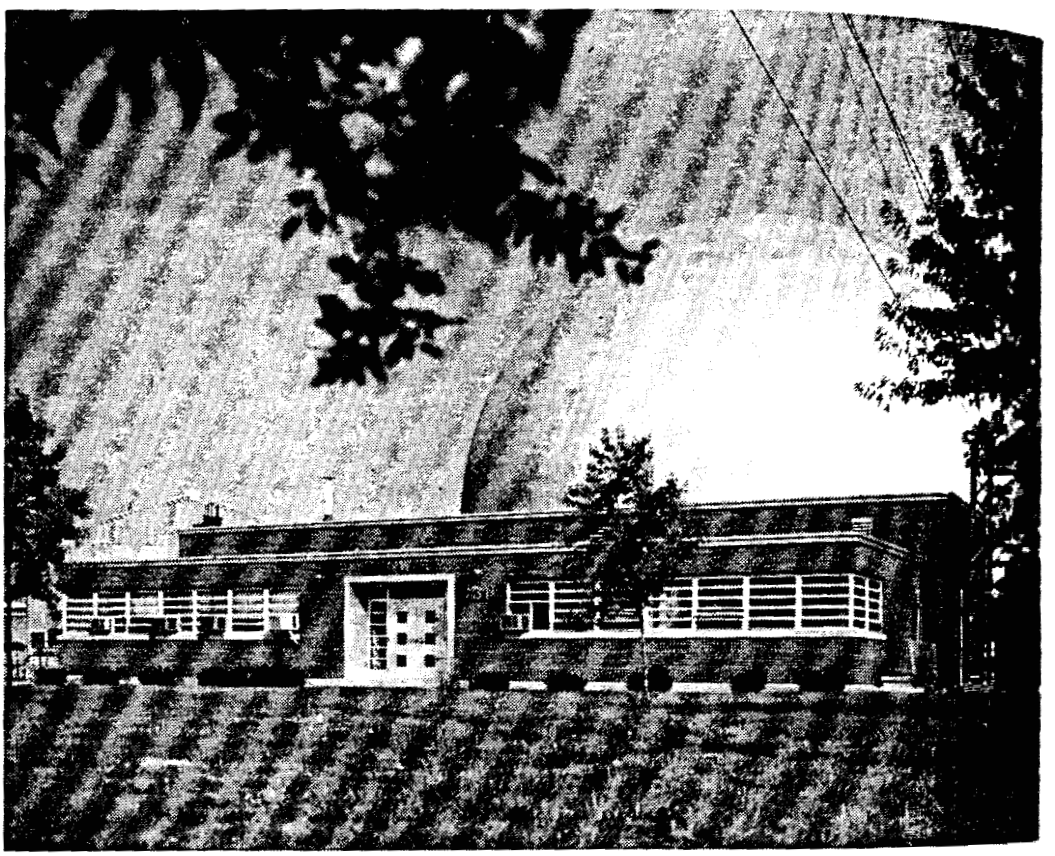
The Experimental Boiling Water Reactor (EBWR) at the Argonne National Laboratory (ANL) was shut down in June 1967 at the end of its planned program of experiments. Built in 1955–56, the EBWR began operation with plutonium fuel on October 11, 1966, thus becoming the first boiling water reactor to use plutonium fuel in significant quantities. Routine operations were conducted with plutonium at 42.5 Mwt. and in March 1967, reached a high of 70 Mwt.

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Terrestrial Low-Power Reactor Program

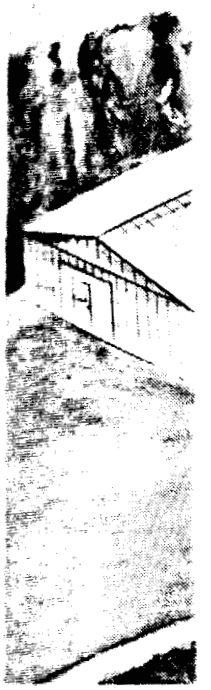
The terrestrial low-power reactor (TLPR) program is directed a exploiting the technology of small nuclear reactor power systems i order to provide a strong base from which advanced systems could b developed.

A preliminary design and technology program plan are being pre pared at the TLPR program office at Oak Ridge National Laboratory. Effort is concentrated on a pressurized water reactor plant for produc tion of 1.5 megawatts of electric power and additional heat for poten tial application at a remote military or commercial installation. Th technology can also be used for stationary oceanographic installations Reactor fuel lifetime would be extended significantly beyond that being experienced in existing small reactors such as the SM-1 and PM-type plans. (For information on other small nuclear power units, see Chapter 9—"Specialized Nuclear Power Units.")



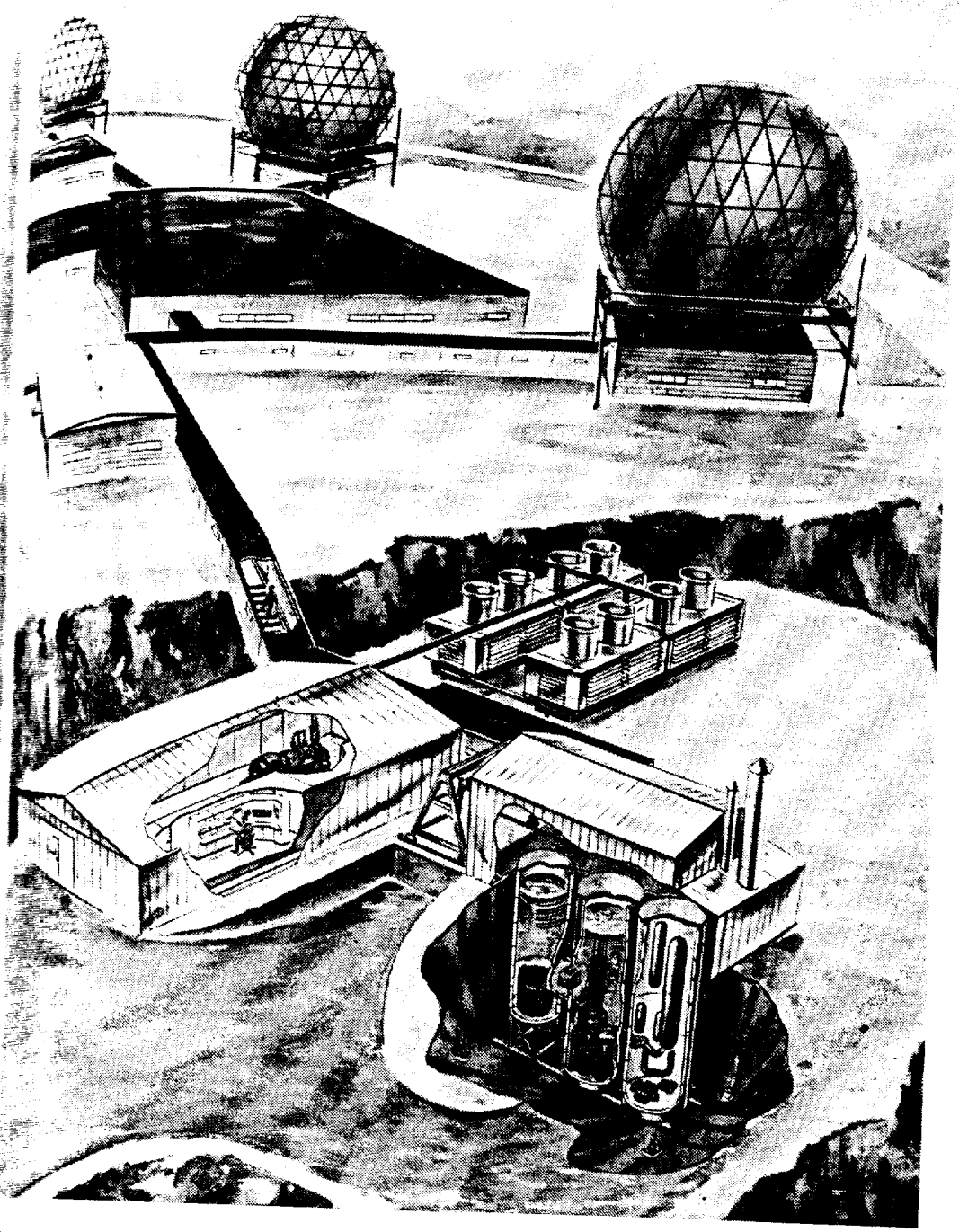
EBWR Retired. The historic Experimental Boiling Water Reactor (EBWR) at Argonne National Laboratory was retired in June of 1967 after 11 years of service. EBWR was the first plant of significant size to generate electricity di rectly from steam produced in the reactor. It was the first boiling water reactor to use plutonium fuel in significant quantities. The 4-Mwe.-EBWR was the first of the AEC power demonstration reactors to be completed and the direct forerunner of many of today's nuclear powerplants.





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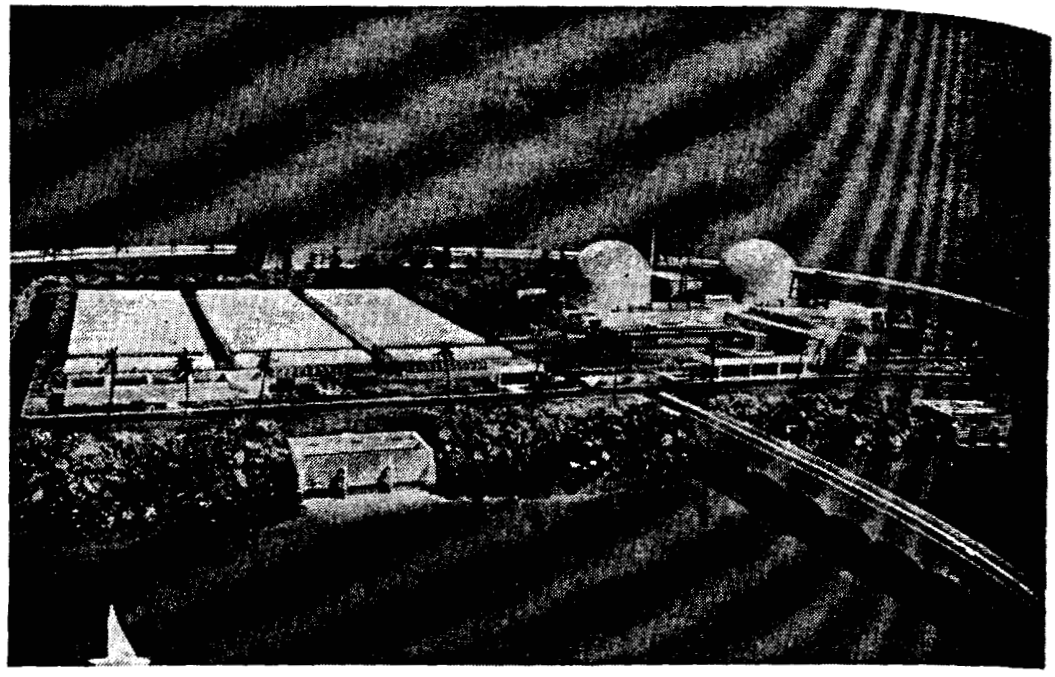
Portable Medium Powerplant-1 (PM–1). Increasingly longer periods of reliable power operation of nuclear powerplants such as PM–1 has led to increased interest in reactor systems in the 100 to 200 kwe. range which could be suitable for oceanographic and terrestrial operation. On February 27, 1967, the PM–1 reactor at Sundance, Wyo., recorded 4,101 hours of continuous power operation—a new record for this type of military land-based powerplants. During 1966, the PM–1 was available for power operation 97.5 percent of the time, a new record for availability for military land-based powerplants; power availability through November 1967 was approximately 91.2 percent.

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DESALTING AND PROCESSING USES

As part of its overall reactor program, the AEC is developing nuclear energy systems that can be economically applied to the desalting of sea water or used as energy sources for other industrial processes. In most applications, reactors to be used for these purposes will also produce electric power. In situations where power and process applications are combined, substantial savings in energy cost appear possible. In these, prime steam is used for power generation and exhaust steam from back-pressure turbines [13] is used for industrial processes.

[13] Turbines which exhaust steam at pressures above atmospheric conditions.



Bolsa Island Model. The Bolsa Island Nuclear Power and Desalting Plant will be located on a 43-acre island to be constructed offshore of the Bolsa Chica Beach State Park at Huntington Beach. The proposed facility's two nuclear powerplants (at *right*) will generate about 1,800 megawatts of electricity and supply steam for a distillation plant (at *left*) that will have an initial capacity to produce 50 million gallons of distilled water per day and ultimately to produce 150 million gallons of distilled water per day. One nuclear steam supply system and turbine generator will be owned by the Los Angeles Department of Water and Power, and the other will be owned jointly by the Southern California Edison Co. and the San Diego Gas and Electric Co. The Metropolitan Water District (MWD) will build and own a back-pressure turbine and the desalting plant, as well as the island, and a trestle causeway connecting it to the mainland. The AEC and the Office of Saline Water of the Department of Interior will provide financial and technical assistance to the MWD and will obtain new technological data and information for use in the Interior's saline water programs and the AEC's civilian nuclear power program. Contracts for the project were signed on November 20, 1967.

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various engineering studies have been undertaken which provide valuable data as a guide for further development activities.

The AEC's nuclear desalting efforts are coordinated closely with the programs of the U.S. Department of the Interior's Office of Saline Water (OSW).

A base program designed to advance the technology of desalting and the coupling of nuclear powerplants to large desalting plants is sponsored at the ORNL by the AEC and the Office of Saline Water. During 1967, the AEC also cooperated with the U.S. Bureau of Reclamation in a preliminary study of the potential of nuclear desalting for the Santa Barbara Channel coastal area of California.

Bolsa Island Power and Desalting Project

A large nuclear desalting project, the Bolsa Island Nuclear Power and Desalting Plant, has been initiated. The project participants include the AEC, OSW, the Metropolitan Water District of Southern California (MWD), and the electric utilities serving the southern California area—the City of Los Angeles Department of Water and Power, Southern California Edison Co. and the San Diego Gas & Electric Co. The plant is proposed to be built on a 43-acre man-made island located near Huntington Beach, Calif. Island construction will begin as soon as a permit to construct the nuclear power facilities is granted by the AEC.

Contracts were signed by the participants on November 20, 1967, in a ceremony at Newport Beach, Calif., culminating some 3 years of efforts toward establishing the project and developing the complex organizational and contractual arrangements for its conduct. On the basis of the preliminary design, the facility will produce about 1,800 Mwe. (gross) and 50 million gallons of fresh water a day in its initial operation. The plant will incorporate features so that the water plant capacity can be enlarged ultimately to 150 million gallons per day. The electric utilities will own and operate the two nuclear powerplants and furnish steam to the Metropolitan Water District for the back pressure turbine-generator and the desalting operation.

Contracts are expected to be awarded in early 1968 for the utilities' two large light water nuclear steam supply systems of about 3,000 megawatts thermal capacity each, and for MWD's large back-pressure turbine generator system which will deliver the steam to the water desalting plant. The English Electric Co., a British turbine manufacturer, will supply the electric utilities for the two 800-megawatt condensing turbine generator systems.

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Applications for construction permits for the two reactors proposed for the project were submitted to the AEC by the utilities in September, and were under review at year's end.

Desalting Study With Utah

During 1967, the State of Utah requested OSW and the AEC to participate in a cooperative study of large multi-purpose nuclear plants. These would provide electric power and desalting in the Great Salt Lake area, and also steam for the chemical industry currently predicted for the area. The preliminary phase of this study was initiated in 1967 and is to be completed in 1968.

Agricultural-Industrial Complexes

The future availability of low-cost nuclear-generated electric power and process heat from a centrally-located power complex could have a decided effect on the electrochemical and metallurgical industries, possibly for the processing of nitrogen fertilizer, minerals from the sea, phosphate rock products, iron, steel, and aluminum, and low-grain and high-value agricultural products. Also, very low-cost electric power is expected to make possible the application of some industrial processes not presently economically feasible.

During the summer of 1967, a preliminary study was initiated at the Oak Ridge National Laboratory (ORNL) to assess the technical and economical feasibility of large nuclear energy centers which would be the basis for new industrial and agro-industrial complexes. This study was a result of previous nuclear desalting studies which drew attention to the fact that large-size reactors could have economical advantage for combining fresh water and power production in a single plant.

Two types of installations considered were: (*a*) an industrial complex using current technology or technology which would be available within 10 years; and (*b*) an agricultural-industrial complex using longer-term technology. Under this plan, large nuclear powerplants would be considered together with various types of power-consuming industries to determine what combinations would have the greatest promise. Of particular interest were industrial processes which would assist in increased food supplies.

The first phase of this study is to be completed early in 1968.

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Dow-Consumers Dual Purpose Plant

In November, the Dow Chemical Co. and the Consumers Power Co. of Michigan reported that they were developing plans for the construction of a nuclear plant with two reactors to supply process steam and electricity to Dow's facility near Midland, Mich. The nuclear installation would supply steam and electricity currently being provided by three fossil-fuel plants now being used by Dow and, in addition, would supply electricity to Consumers for use in its electrical system. The first reactor unit is scheduled for 1974 operation and the second for 1975.

REACTOR SAFETY

The AEC's reactor safety program continues to receive high priority consideration. The growing number and size of planned power reactors, the economic advantages to industry for locating nuclear powerplants closer to load centers and more highly populated areas, increases in power density and the projected evolution of advanced systems, particularly the liquid-metal fast breeder reactor, emphasize the need for continued safety research and development.

The reactor safety program, through a broad research, development and test program, is directed at the establishment of a technical basis for the development of criteria, codes, standards, and specifications to enable the safe siting, design, construction, operation, and maintenance of nuclear reactors. This disciplined approach is required to assure the possibility of dangerous failure of reactors to a very low and acceptable limit from the standpoint of public safety.

In addition, through engineered safety system and related technology, the program provides a basis for the design and application of systems and devices which can safely interrupt the course of an accident, or limit its consequences to tolerable levels. The program also helps to provide a basis for the uniform assessment of reactors from a safety point of view in the safety review and licensing process and permits the assessment of safety margins.

PROGRAM ELEMENTS

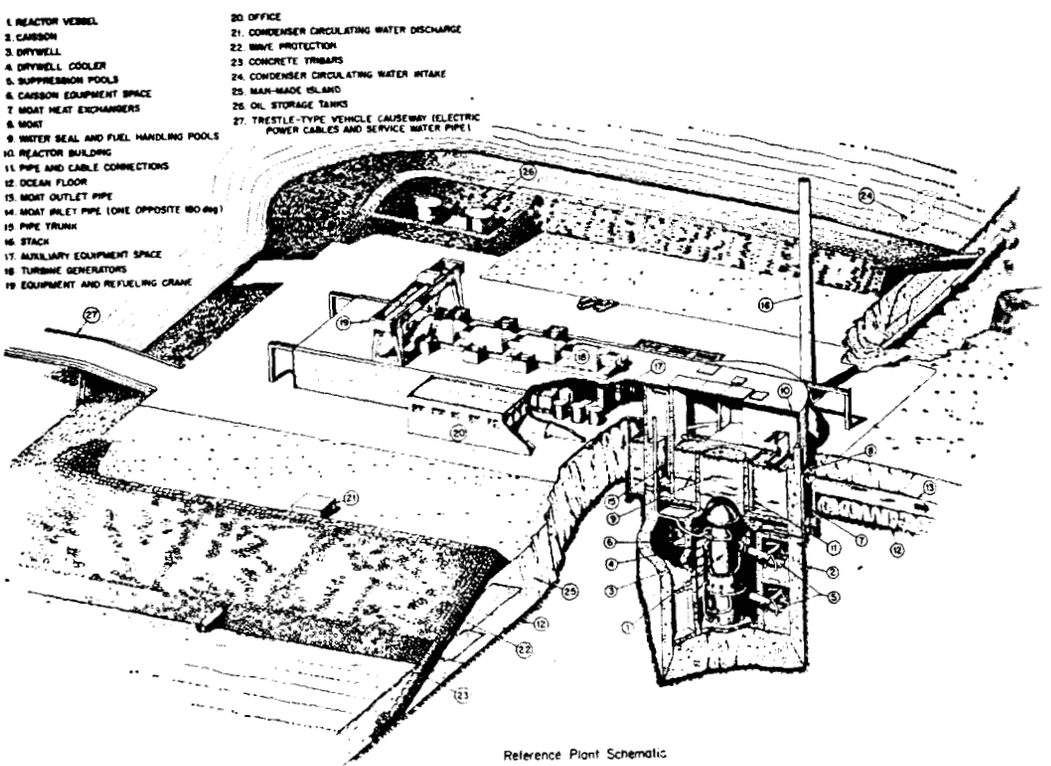
The reactor safety program includes laboratory research and development, engineering scale tests, studies, evaluations, and development of analytical methods. The program is concerned with phenomena and processes related to primary system integrity, reactor kinetics, fuel

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failure mechanisms, fuel-coolant interactions, fission product rele and behavior, containment systems, engineered safety systems, effluen control, and waste management and seismic, geologic, hydrologic an meterological aspects of nuclear power reactors and their sites.

The program work is performed by national laboratories, such a Oak Ridge National Laboratory (ORNL), and by industrial and un versity contractors both in their own and in Government facilities suc as those located at the National Reactor Testing Station (NRTS) an Pacific Northwest Laboratories (PNL). Specialized AEC facilities in clude the Loss of Fluid Test (LOFT) and the Power Burst Facility (PBF) under construction at NRTS, and the Waste Solidification Engineering Prototype (WSEP) and the Containment Systems Experiment (CSE) in operation at PNL.

High priority projects specially include those related to primary systems integrity, emergency core cooling systems, and the development of standards, codes, and criteria for reactor plants.



Reference Plant Schematic

Theoretical Study. In addition to experiments, the AEC's nuclear safety progra includes theoretical studies. In a design study at Oak Ridge National Laboratory, the caisson containing a Dresden Unit 2 boiling water reactor was "sunk" in an artificial island, approximately ½ mile offshore in about 30 feet of water. If, dur ing operation, the hydrostatic head should fall below a prescribed minimum, rupture disks would fail, allowing the ingress of seawater. It is estimated that this type of containment would have leak rates between $\frac{1}{10}$ and $\frac{1}{100}$ of those for a Dresden Unit 2 with conventional containment.

Primary System

Clearly, if th maintained inta fission product r reactors—under related to assur in the program steel technology assurance of pr



Heavy Section S Lukens Steel Co. ing's Chattanooga nology (HSST) p tinually record th the plate will be r be taken from it before and after i the structural int central station po and operation of l

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Primary System Integrity

Clearly, if the primary coolant system of a nuclear reactor can be maintained intact at all desired times, despite any other malfunctions, fission product release to the environment—the main hazard of nuclear reactors—under control and safety has been achieved. Thus, projects related to assuring primary system integrity have the highest priority in the program. During 1967, work was started on the heavy section steel technology (HSST) program in an effort to provide additional assurance of primary vessel integrity and to provide a basis for the



Heavy Section Steel Technology. A 12-inch-thick steel plate purchased from Lukens Steel Co. is shown undergoing heat treatment at Combustion Engineering's Chattanooga, Tenn., plant as a part of the AEC's heavy section steel technology (HSST) program. The wires lead to embedded thermocouples which continually record the temperature of the steel during processing. When completed the plate will be rechecked ultrasonically for hidden flaws and test specimens will be taken from it to determine its mechanical and metallurgical properties, both before and after irradiation. The HSST program will extend the knowledge about the structural integrity of the heavy steel vessels now being designed for large, central station power reactors and provides a basis for the design, construction, and operation of larger reactors in the future.

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construction of future larger reactor plants. This project, which ha
been planned and undertaken in cooperation with industry, is con
cerned with the study of properties of thick sections of steel plate an
the propagation of flaws. Also, work on flaw detection, both in plat
and in the form of reactor vessels in service, is being performed.

Emergency Core Cooling Systems

Should the primary coolant system boundary of a nuclear reacto
fail, the capability to cool the reactor fuel could be lost, resulting i
melting of the fuel and release of the fission products to the contain
ment vessel. As a backup to protect against the substantial release o
fission products in such an event, emergency core cooling system
(ECCS) are used in reactors to supply emergency coolant to preven
significant fuel melting.

An important component of the reactor safety program is the de
velopment of technology related to ECCS to assure their capability
and reliability in their function and their testability over the life of
the plant. This work has been started in 1967 with scoping tests a
NRTS and is planned to be further extended in an AEC-industry co
operative program in 1968.

LOFT has been redirected to emphasize tests of this important engi
neered safety system.

Program Planning Activities

Reactor safety program offices for water cooled reactors and ga
cooled reactors and a safety section of the Liquid Metal Cooled Fas
Breeder Reactor Program Office are functioning and have provided the
AEC with assistance in program planning, including the identifica
tion of new needed program, and the overall program priorities. Long
range program plans developed by these groups have been submitted
to industry for comment, and these comments are being analyzed an
used appropriately in arriving at final planning decisions.

Industrial Participation

Industrial nuclear capability has been enhanced by direct and in
direct involvement of industrial organizations in the AEC's reacto
safety programs. The AEC has requested program guidance fro
the commercial segment of the nuclear community through direc

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...itation and through contacts and discussions with the safety re-...rch subcommittee of the Atomic Industrial Forum. Industrial ...nizations participate directly in specific projects through the ...gnment of technical personnel to on-the-job activities at national ...oratories and with contractors at specialized AEC facilities such as ...FT and CSE. Industry has undertaken to assist in the support of ...ial projects, both in their direction and in their financing as de-...ibed in connection with the HSST program. Additional cooperative ...orts are planned.

The AEC also has extensive contact with the nuclear industry ...ough mutual participation in national standards groups which are ...stantially industry efforts.



...ject *Salt Vault.* In a high-level radioisotope waste storage project (Project ...t Vault) at Lyons, Kans., the objectives were to determine the heat and radia-... effects on salt from high-level solidified wastes, and to demonstrate radioac-...wastes handling techniques in this type of environment. Canned irradiated ...elements, augmented by heaters, were buried in the floor of a mined-out salt ...mation, and the behavior of the salt, including plastic flow, was observed and ...asured. Radiolytic damage to salt also was evaluated. As a result of this test, ...ich was completed in 1967, it appears that this type of storage may provide ...e and efficient ultimate storage for high-level radioactive wastes. Photo shows ... of seven canisters containing over 1,000,000 curies of fission products being ...ered into the floor of the salt mine from a mobile shielded transporter.

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SUPPLEMENTAL RESEARCH REPORT

The AEC's "Fundamental Nuclear Energy Research—1967" report [14] supplements this "Annual Report to Congress" and summarizes some of the more noteworthy advancements being made in the area of basic research and exploratory development under AEC-sponsored studies in nuclear technology and the life and physical sciences.

REACTOR TECHNOLOGY PROGRAMS

A feature section of the supplemental report concerns the AEC's nuclear reactor safety activities in much more detail than as presented in this report. In addition, the report summarizes recent advancements in reactor technology that can be applied in various ways to the broad reactor development program. The following are a few brief "highlights" on the work mentioned in the reactor technology and development portion of the supplemental report.

Nuclear Safety Research

- Brittle-fracture tests on the highly irradiated pressure vessel of the PM-2A reactor demonstrated that the degree of design conservatism in establishing a margin of safety for the vessel was much more than adequate. The vessel did not rupture until subjected to conditions that were much more severe than those predicted by prior analysis.
- Blowdown of water and steam from small pressurized vessels in the LOFT and CSE projects is providing confirmation of the analytical methods for determining the pressure transient resulting from stored heat energy in the water coolant. Likewise, experiments conducted at laboratories on small samples of metal-clad fuel are providing basic data on the amount of additional energy to be expected from metal-water reactions.
- A study of four separate reactor designs is being made to develop improved antiseismic designs. These designs describe reactors that can withstand a range of severe vibration and displacement loads from earthquakes combined with loans which may be caused by reactor accidents.

Reactor Fuels and Materials

- A mathematical model relating irradiation performance of carbon-coated fuel particles for high-temperature gas-cooled reactors

[14] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $2.50.

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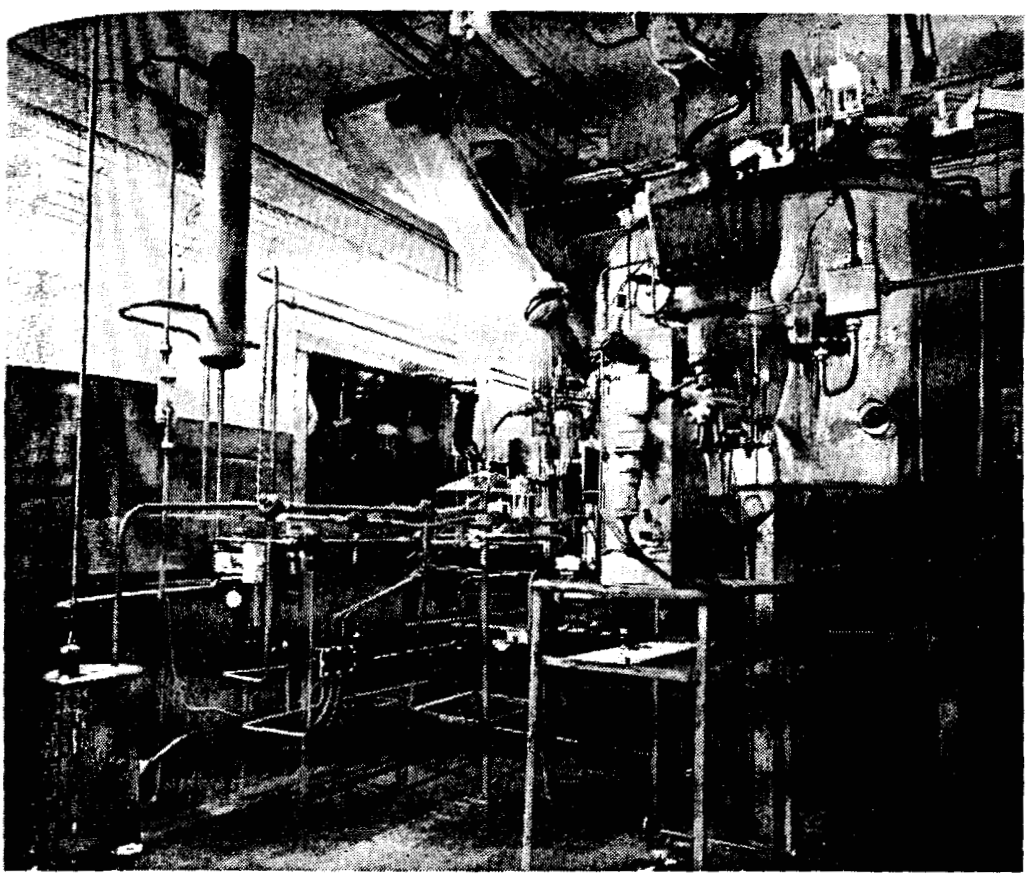


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their physical characteristics has successfully predicted particle ability. In addition, the substitution of propylene for methane s coating gas in the carbon coating process has markedly reduced e required coating time and temperature.

• In a series of in-reactor creep tests on type AISI 304 stainless el, over the temperature range 400–760° C., it has been discovered at neutron flux has little effect on dynamic creep rate but does consently shorten the time to failure. Careful electron microscope exination discloses that this loss of ductility is caused by the formation metallic carbides promoted by neutron irradiation and possibly by diation-induced gas atoms.



ion Product Release Study. The Contamination-Decontamination Experiment F, pictured above, is installed in a manipulator-equipped shielded cell at the Chemical Processing Plant. It permits study of fission product release from ted reactor fuel under conditions simulating those expected in the forthcom- LOFT tests. The 5-foot-diameter by 5-foot-high containment vessel permits ng of actual fission product sampling and plateout devices to be used in the FT experiment, and contains protective coating and decontamination systems developed for the LOFT experiment. Five meltdowns of irradiated fuel taining from 7,000 to 35,000 curies of radioactivity have been conducted in the E, each followed by successful decontamination and recovery of test devices, helping assure operability of the systems finally selected and installed in the -of-fluid-tests (LOFT) experiment which will be conducted, starting in 1970, the Phillips Petroleum Co. as a part of the AEC's nuclear safety program.

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● Studies of the sublimation of structural graphite from a high temperature gas-cooled reactor by the corrosive action of oxident impurities in the helium coolant have determined the factors controlling the rate of loss. If the coolant flow rate, geometry of the system, and pressure are maintained constant, the reaction rate of loss is a function of the temperature and oxidant concentration.

● A significant new development in eddy current testing of reactor tubing has been the demonstration of a technique for simultaneously displaying the location and size of a flaw on an oscilloscope. This display, similar to a radar display of a cross section of the tube, indicates the relative magnitude and positions of the flaws, whereas previous eddy current displays had been in the form of blips on an oscilloscope.

Reactor Physics Research

● A plutonium-fueled critical experiment of special interest to fast reactor physicists was constructed in the ZPR–3. The "Assembly 4" reactor core was designed to be similar to that of a very large power reactor in its neutron energy spectrum, yet simple enough in the arrangement of its constituents to permit detailed analysis.

● Irradiations of the fissile isotopes uranium-233 and 235, and plutonium-239 and 241, together with measurements of the resulting changes in reactivity caused by depletion of the fissile isotope, have disclosed a depletion pattern which indicates that, on the average, the cross sections of daughter products do not differ appreciably from the cross sections of their parent fission products 500 hours or more after the termination of their irradiation.

● An experiment in which the neutron capture and fission cross sections of uranium-233 were measured simultaneously over the neutron energy range of 0.5 to 100 electron volts was performed successfully, yielding the first direct measurements of the uranium-233 capture cross section in this energy range.

● In studies of concepts for high-performance, pulsed fast research reactors, a peak power of some 20,000 megawatts for about 60 microseconds appear to be feasible. The neutrons generated during these power bursts would provide an intense source for neutron physics research.

Reactor Instrumentation

● A fluidic temperature sensor, specifically designed for operation in a high radiation and high temperature environment, has been developed and successfully demonstrated. This instrument senses the

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perature of the fluid and generates an output pressure signal pro-tional to the fluid temperature.

• An instrument to provide a continuous measure of carbon activity flowing sodium, for use in liquid metal-cooled reactors has been der development. This meter will be particularly important, since dium can change the carbon content of the structural materials it tacts enough to seriously impair their mechanical properties.

• A digital computer, programmed to perform a variety of record-checking, calculating, and operating functions, has been incorpo-ed in the high-temperature gas-cooled graphite reactor, UHTREX. is computer checks over 600 temperatures and pressures every 15 onds and checks the position of all valves in the system each second, ording the data and sounding an alarm if any changes take place ich endanger the system. The computer also handles the fuel loading ess, opening and closing valves in the prescribed sequence to load when "requested" to do so by the operator.

eat Transfer and Fluid Dynamics

• It has been concluded that for the flow rates normally en-ntered in liquid-metal heat exchangers, heat transfer coefficients tained experimentally with only one test rod may be applied directly commercial exchangers, where all rods in the bundle are transfer-ng heat.

• Investigations of the conditions under which a liquid-metal re-tor coolant might inadvertently boil, should there be a flow stoppage sudden insertion of reactivity, have shown that alkali metals must ch very high superheats before initiation of boiling, which then ds to occur "explosively" with rapid oscillation in fluid temperature d pressure. There is a slight, but noticeable increase in this boiling iation superheat with repetition in a series of runs.

• By using a novel technique for high-speed impingement of liquid tassium droplets of known size against a wedge of pre-chosen ma-ial, information has been obtained which pertains to the rate of sion of high-speed turbine blades. Likewise, by running a super-ic turbine for a stated time period in wet potassium vapor, it has n determined that while damage does occur to the turbine blades, s not sufficient to cause serious deterioration of the turbine per-mance.

el Processing Development

• Centrifugal extractors of a new design are now separating plu-ium and uranium from radioactive fission products. The new

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extractors have replaced conventional mixer settlers, in which the two phases are separated by gravity. Because the centrifugal separation is much faster, the holdup time of the process solutions is 50 times shorter than in the mixer-settler equipment.

● Ion exchange membranes have been developed to continuously concentrate and purify aqueous solutions of metal ions. Several small concentrating units have been built and successfully tested to concentrate uranium solutions.

● A more accurate method for measuring the percentage of uranium and plutonium which has fissioned in a spent fuel element has been developed by measuring the amount of a specific nonvolatile, stable low neutron cross section fission product produced within the fuel. Neodymium-148 has been found to meet these requirements for a burnup indicator.

Direct Energy Conversion

● A new high-temperature adsorption cesium reservoir has been developed for operation within thermionic converters. Consisting of a multiplicity of small elements to which cesium adheres, the reservoir contains a relatively large amount of cesium in a small volume.

Chapter 6

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Chapter 6

LICENSING AND REGULATING THE ATOM

The Nation's electric utilities turned increasingly to nuclear power in 1967. Applications were filed with the AEC to construct and operate 29 civilian nuclear powerplants, nearly double the record volume of 1966. A trend toward multi-unit stations continued. Proposals for several plants in the 1,000-megawatt range pushed the average size of nuclear power reactors in the planning stage to more than 800 net electrical megawatts (Mwe.).

During the year, the AEC continued to seek improvements in its procedures for licensing the expanding use of atomic energy and carrying out its regulatory responsibilities for the protection of public health and safety. The AEC had the benefit of advice from special review panels which had been appointed by the Commissioners to study various phases of the regulatory program. Also, the AEC regulatory staff was realigned and expanded to streamline reactor licensing functions and emphasize development of design and siting criteria. The permanent chairman and vice-chairman of the Atomic Safety and Licensing Board Panel assumed their duties early in the year.

The status of the AEC program for licensing and regulating nuclear reactors and current problems faced by industry and the Government were reviewed in detail in hearings before the Congressional Joint Committee on Atomic Energy.

In the regulation of atomic energy materials, two more States—Arizona and Louisiana—assumed certain of the Commission's regulatory authority and transfer to a third State—Colorado—was scheduled for year's end. Also, the AEC put into effect certain recommendations of a review panel for improving its procedures for licensing radioisotopes. The AEC also strengthened its program of safeguarding special nuclear materials from the standpoint of the common defense and security (see Chapter 2—Safeguards and Materials Management).

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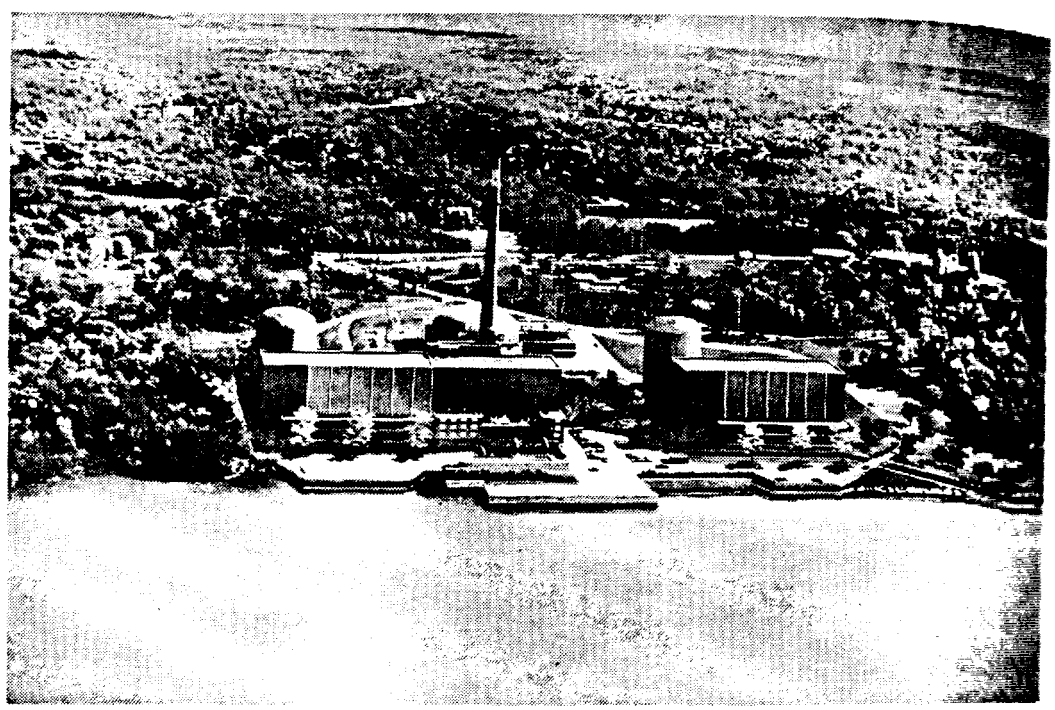
NUCLEAR POWER GROWTH

Nearly two-thirds of the 29 new power units for which applications were received in 1967 are projected for completion by 1972, with the latest scheduled for operation in 1974 (see Table 1). A new peak was reached during August when the AEC received applications for seven nuclear plants.

The continued stepping up of industry's schedules for commercial atomic power operations in the early 1970's, combined with proposals for larger reactors and siting closer to metropolitan centers, highlighted the task of the AEC's regulatory organization.

Larger Reactors Predominate

Proposals for larger reactors and multi-unit stations dominated the 1967 applications. The total designed electrical output of the 29 plants



Indian Point Complex. Consolidated Edison's proposed third nuclear electric generating unit is shown to the *right* (south) on this artist's rendering of the company's nuclear power complex at Indian Point, Buchanan, N.Y., as it will look on completion in 1971. The rendition, on an actual aerial view, shows the 275-Mwe. Indian Point No. 1 unit which has been operating since 1962, in *center* (with stack); the 873-Mwe. Indian Point No. 2 (now under construction) is to the left and the proposed 965-Mwe. Indian Point No. 3 to the *right*. The Indian Point station will have a capacity of 2.2 million kilowatts, when all three units are in operation by 1972. Included in site development plans is a visitors' information building, where exhibits and guided tours will be offered to the public.

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24,287 Mwe., more than twice the 11,626 Mwe. capacity represented by the 16 units applied for in 1966.

Nine large reactors designed to produce more than 1,000 Mwe. each, were proposed for construction in six States: Alabama, California, Illinois, Michigan, New Jersey, and Pennsylvania. Six utilities or utility groups applied for twin units in single applications. Of particular interest were the applications in the fall of 1967 for construction of two 900-Mwe. power reactors for the first dual-purpose desalting and electric power project yet proposed.

TABLE 1.—NUCLEAR POWERPLANT CONSTRUCTION APPLICATIONS RECEIVED—1967

(Further details on these units will be found in Appendix 5.)

Applicant	Plant	Month	Unit size (Net Mwe.)	Projected operation
Pacific Gas & Electric Co. (Calif.)	Diablo Canyon 1	January	1,060	1971
Philadelphia Electric Co. (Pa.)	Peach Bottom 2	February	1,065	1971
	Peach Bottom 3	February	1,065	1973
Virginia Electric & Power Co	Surry Station 1	March	783	1971
	Surry Station 2	March	783	1972
Northern States Power Co. (Minn.)	Prairie Island 1	April	550	1972
	Prairie Island 2	August	550	1974
Consolidated Edison Co. of N.Y.	Indian Point 3	April	965	1971
Omaha Public Power District (Nebr.)	Fort Calhoun 1	April	450	1971
Duke Power Co. (S.C.)	Oconee Unit 3	April	839	1973
Metropolitan Edison Co. (Pa.)	Three Mile Island	May	831	1971
Boston Edison Co. (Mass.)	Pilgrim Station 1	June	625	1971
Consumers Public Power District (Nebr.).	Cooper Station	July	778	1972
Tennessee Valley Authority (Ala.)	Browns Ferry 3	July	1,065	1972
Commonwealth Edison Co. (Ill.)	Zion 1	July	1,050	1972
	Zion 2	August	1,050	1973
Niagara Mohawk Power Corp. (N.Y.)	Easton Station	August	766	1971
Wisconsin Electric Power Co. and Wisconsin Michigan Power Co. (Wis.)	Point Beach 2	August	457	1971
Florida Power Corp	Crystal River 3	August	825	1972
	Crystal River 4	August	825	1974
Wisconsin Public Service Corp	Kewaunee 1	August	527	1972
Southern California Edison Co. and San Diego Gas & Electric Co.	Bolsa Island (Edison-San Diego Unit).	September	900	1973
Los Angeles Department of Water & Power (Calif.)	Bolsa Island (Dept-Unit).	September	900	1974
Maine Yankee Atomic Power Co	Maine Yankee Atomic Power Station.	September	790	1972
Public Service Electric & Gas Co. (N.J.)	—— Unit 2 (formerly Burlington).	October	1,050	1973
Sacramento Municipal Utilities District (Calif.).	Rancho Seco 1	November	800	1973
Kansas Power & Light Co	Russellville Nuclear Unit.	November	825	1972
Indiana & Michigan Electric Co. (Mich.)	Donald C. Cook Unit 1	December	1,054	1972
	Donald C. Cook Unit 2	December	1,054	1973

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Status of Civilian Nuclear Power

At the end of 1967, central station nuclear powerplants in operation, under construction, or for which applications were under review by the AEC represented a total of 42,750 net Mwe. as follows:

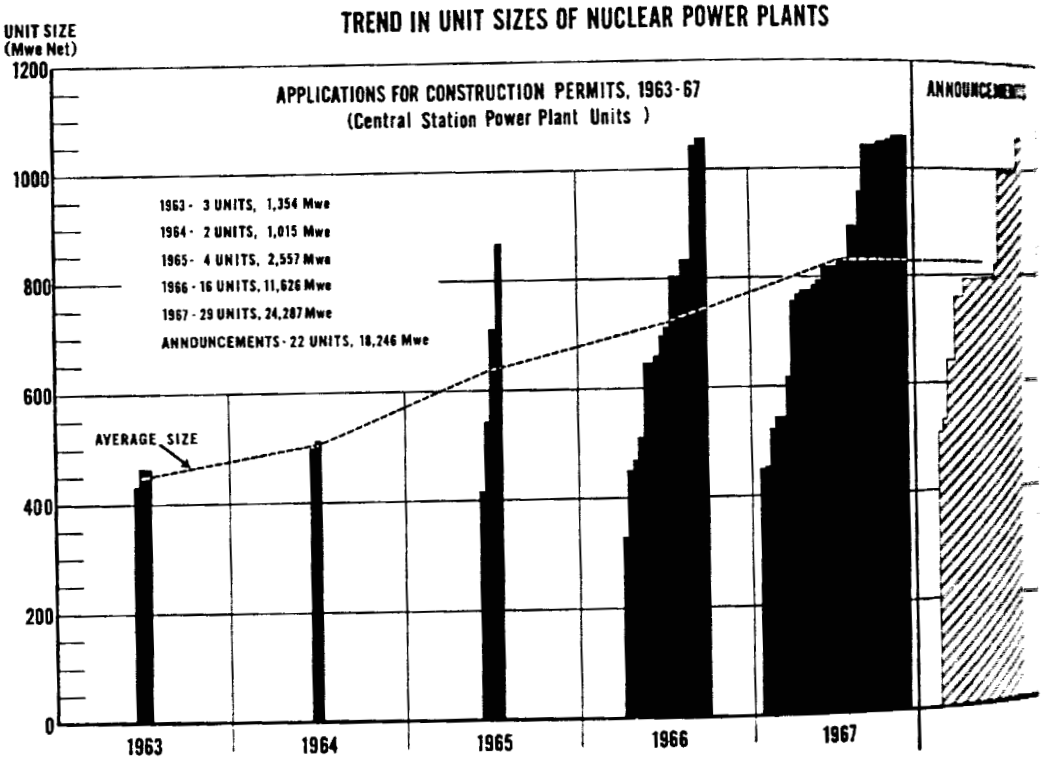
- Fifteen operational, with an installed capacity of almost 2,5[illegible] net Mwe.[1]
- Twenty-one under construction, with a total capacity of 14,6[illegible] net Mwe.
- Thirty-one (including 3 prior to 1967) under review or awaiting decisions of atomic safety and licensing boards, with a combined design capacity of 25,290 net Mwe.

In addition, utilities had placed orders for 11 reactor units, totaling 8,746 net Mwe., but for which construction applications had not been received by the AEC.

Appendix 5 lists the central station nuclear powerplants in operation, under construction, under review, or planned, and AEC licensing actions during 1967.

[1] Includes the Shippingport Atomic Power Station in Pennsylvania which was initiated as a cooperative project of the AEC and Duquesne Light Co. prior to the Power Reactor Demonstration Program, and the AEC's "N" reactor at Hanford, Wash., which produces steam for the Washington Public Power Supply System's 790 Mwe. generating station. Does not include the Hallam (Nebr.) Nuclear Power Facility which is being dismantled, the Carolinas-Virginia Tube Reactor (Parr, S.C.) which was shut down in 1967, and the Piqua Nuclear Power Facility, Piqua, Ohio, for which the operational arrangement is being terminated.

TREND IN UNIT SIZES OF NUCLEAR POWER PLANTS



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JCAE Hearings on Reactor Regulation

The first comprehensive review of AEC reactor licensing and regulation since 1962 was afforded by public hearings before the Congressional Joint Committee on Atomic Energy (JCAE) in April, May, and September. Commissioners, representatives from the AEC staff, Advisory Committee on Reactor Safeguards, Atomic Safety and Licensing Board Panel, AEC hearing examiners, electric utilities, the nuclear industry, and others appeared before the Committee.[2]

The hearings served to focus on the problems faced by the industry in scheduling, and the AEC in approving, nuclear facility projects. These included, in particular, the safety requirements for reactors, safety research needs, the siting of nuclear reactors nearer to population centers and in earthquake zones, technical manpower requirements, and the time involved in the licensing process.

REACTOR LICENSING IMPROVEMENT

As the nationwide move toward nuclear power gained momentum during the year, the AEC expanded and realigned its reactor regulatory staff to streamline licensing functions and intensify the development of reactor safety criteria, standards and codes.[3] Improvements put into effect included a number of recommendations made by the first Regulatory Review Panel which had been appointed by the Commission to study the reactor licensing process in 1965.[4]

Review Panel on Contested Facility Cases

In June, the Commissioners received a report from a three-member panel that had been appointed from outside the Government in the spring of 1966 to study AEC procedures for handling contested cases involving applications to construct and operate nuclear facilities.[5]

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[1] Committee prints of the 1967 JCAE hearings, "Licensing and Regulation of Nuclear Reactors," are available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, in two volumes, Part 1 at $1.75 each. Part 2 will be printed in early 1968.

[2] Details in AEC public announcement No. K–42, available from Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

[3] The first Regulatory Review Panel, also known as the "Mitchell Panel," focused primarily on procedures for handling uncontested licensing cases. Consisting of seven members, it was chaired by William Mitchell, Washington, D.C., an attorney and former General Counsel for the AEC. (See pp. 297–299, 305–307, "Annual Report to Congress for 1965.")

[4] Copies of the "Report to the Atomic Energy Commission by the Second Regulatory Review Panel, June 1967," may be obtained by writing to the Secretary, U.S. Atomic Energy Commission, Washington, D.C. 20545. This panel, which made a follow-up study of that conducted by the first (1965) Regulatory Review Panel, also was chaired by Mr. Mitchell. Other members were Gerald Charnoff, Washington attorney, formerly legal projects manager of the Atomic Industrial Forum; and Roger Coe, Vice President, Yankee Atomic Electric Co., Boston, Mass.

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Contested proceedings are those in which there is a controversy between the AEC regulatory staff and the applicant concerning the issuance of the license or any of its terms or conditions, or in which a petition to intervene in opposition to an application has been granted or is pending.

The panel's review endorsed a number of practices in contested proceedings which the AEC had recently put into effect. Recommendations for improvements, which are being considered by the AEC, include: (*a*) changes in time schedules for the various steps leading up to the prehearing conference; (*b*) changes in the time schedule for interventions; (*c*) clarification of the rights of intervenors and persons making limited appearances; and (*d*) the establishment of additional guidelines for atomic safety and licensing boards concerning technical issues and reliance on decisions in previous cases.

Reactor Criteria and Codes

More specific regulatory criteria [6] have been established in the light-water power reactor area. Progress was made in this direction by the AEC in 1967 with the cooperation of industry and professional groups.

Design Criteria for Reactors

On July 11, 1967, the AEC published in the *Federal Register*, for public comment, a revised and expanded set of general requirements expected to be satisfied in the design of power reactor systems and components. The "General Design Criteria for Nuclear Powerplant Construction Permits," first published on November 22, 1965, were further developed in view of experience with their use and as a result of new developments in reactor design since that time. These general design criteria would not add any new requirements, but are intended to describe more clearly the present AEC requirements to assist applicants in preparing applications. Many of the general design criteria, while particularly applicable to light water power reactors, also are generally applicable to other power reactors. As the basic requirements in safety performance goals and objectives, they form the framework upon which supplementary regulatory criteria or standards for reactors will be developed.

Supplementary Criteria

In March 1966, the AEC regulatory staff initiated, with industry cooperation, two programs to develop separate specific design per-

[6] As used here, the criteria are requirements which must be met.

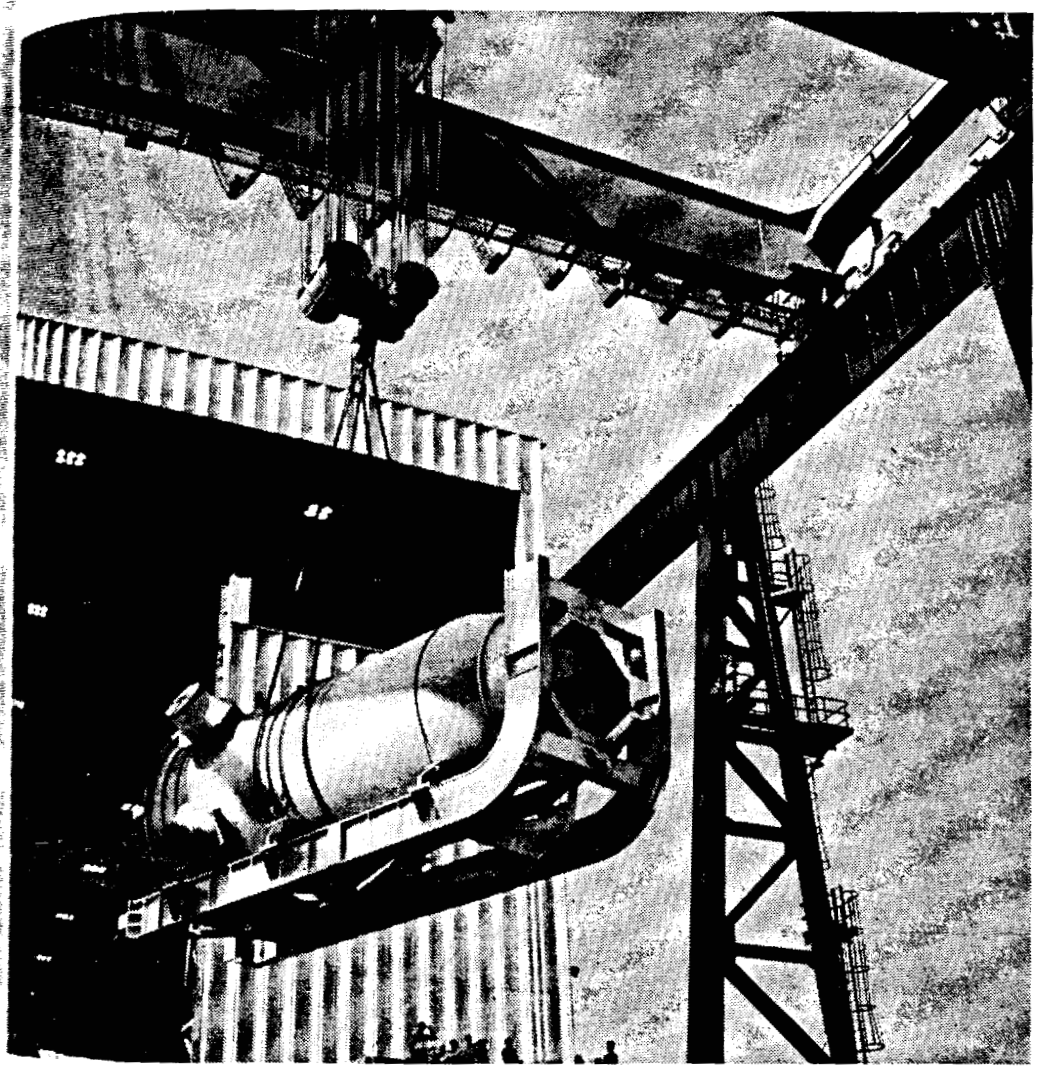
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...mance criteria for pressurized water reactors and boiling water ...ctors.[1] The development of pressurized water reactor criteria is ...ng carried out under the auspices of the United States of America ...andards Institute (USASI) with AEC encouragement and support. ...parallel effort for boiling water reactors is underway by the AEC ...cooperation with General Electric, the principal manufacturer of ...s type of reactor.

Supplementary Criteria for Pressure Vessels

In addition to joint cooperative efforts with industry, the AEC has ...dertaken to supplement its "general design criteria" with more

[1] See p. 36, "Annual Report to Congress for 1966."



First Shipment. The first nuclear pressure vessel to be shipped from Babcock & ...cox's Mt. Vernon, Indiana facility, is shown being lifted out of the fabrica... shop after completion of final quality control test in October. The vessel is for ...chester Gas & Electric's 420-Mwe. Robert Emmett Ginna (formerly called ...ookwood") nuclear station in Ontario, New York.

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detailed design, fabrication, and inspection criteria for reactor coolant system components. A joint AEC-Advisory Committee on Reactor Safeguards review group, assisted by the AEC's developmental and national laboratories, developed tentative "Supplementary Regulatory Criteria for ASME Code-Constructed Nuclear Pressure Vessels," which were issued by the AEC on August 25, 1967.[8] These criteria specify AEC requirements for the design, construction, and inspection of reactor pressure vessels to help assure that they are built to the highest quality standards practicable. More specific criteria for other reactor coolant system components are being developed by this group.

Industry Code Development

The AEC cooperates with the code activities of the industry and with the technical societies. These efforts have been broadened as a result of additional committees created in response to AEC recommendations for accelerated effort in the areas of reactor pressure vessels, piping, valves, pumps, electrical systems, and materials. These code groups, with active AEC participation, have made considerable progress in assuring that the rapidly advancing technology is being reflected both in existing codes and in newly proposed codes and standards.

Power Reactor Emergency Core Cooling Study

An advisory task force, appointed in October 1966, to review emergency core cooling systems for power reactors, submitted a report of its study in the fall of 1967.[9]

The task force reported that although much has already been done to assure an acceptable level of primary system integrity, it would be

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[8] The tentative criteria are available for inspection in the Commission's Public Document Room, 1717 H Street NW., Washington, D.C. A copy may be obtained by writing to the Director, Division of Reactor Standards, U.S. Atomic Energy Commission, Washington, D.C. 20545.

[9] The report is available for inspection in the AEC's Public Document Room, 1717 H Street NW., Washington, D.C. A copy may be obtained by writing to the Director of Regulation, U.S. Atomic Energy Commission, Washington, D.C. 20545. Members of the task force were: Dr. William Krasny Ergen, Oak Ridge National Laboratory, Oak Ridge, Tenn., *Chairman*; Dr. Louis Baker, Jr., Argonne National Laboratory, Argonne, Ill.; Eric Stephen Beckjord, Westinghouse Electric Corp., Pittsburgh, Pa.; A. Philip Ross and Dr. Salomon Levy, General Electric Co., San Jose, Calif., Joseph R. Dietrich, Combustion Engineering, Inc., Windsor, Conn.; I. Harry Mandil, MPR Associates, Inc., Washington, D.C.; David L. Morrison, Battelle Memorial Institute, Columbus, Ohio; John M. Ware and T. R. Wilson, Phillips Petroleum Co., Idaho Falls, Idaho; Warren E. Nyer, Aerojet General Corp., Idaho Falls (formerly with Phillips Petroleum Co.); and Robert E. Wascher, Babcock and Wilcox Co., Lynchburg, Va. In addition, J. J. DiNunno and Dr. J. A. Lieberman of the AEC staff participated, and R. J. Impara, AEC staff, served as technical secretary.

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...dent to upgrade the integrity of all components of primary sys-
...s of reactors to a reliability comparable to that presently planned
...reactor pressure vessels.

The task force concluded that the basic approach taken in the ...gn of current emergency core cooling systems is satisfactory and ...l the analysis of safety factors related to such systems is within ...e capability of current technology. In this context, the task force ...commended a systematic approach to core cooling system design ...d evaluation, including more tests to verify current concepts and ...e use of reliability analyses in evaluating system design.

The task force considered the problem of handling the meltdown of ...reactor core in the unlikely event that no emergency cooling were ...ilable following the loss of all normal cooling. It concluded that ...may be desirable as a long-term solution to seek measures other ...an emergency core cooling to prevent a possible breach of the ...ctor containment, but for the near future it recommended a small-...ale, tempered effort on these problems. It also suggested that meas-...es to collect fission products could be effective in reducing hazards ...ring the period prior to breaching of the containment.

MAJOR FACILITY LICENSING

The goal of the AEC's reactor regulatory program is assurance that ...actors and other nuclear facilities are constructed and operated ...a manner consistent with public health and safety and the common ...fense and security. It encompasses both the licensing of new facili-...s and surveillance of the operations of existing facilities throughout ...eir lifetimes. In addition to the regulation of licensed facilities, the ...EC regulatory staff reviews the safety of reactors owned by the ...EC and the Department of Defense and provides advice on siting, ...sign and operation of reactors, and on porting operations for nu-...ar ships.

THE REGULATORY PROCESS

An application for a permit to construct a power or test reactor or ...er major facility undergoes a comprehensive safety review by the ...gulatory staff, and an independent review by the AEC's Advisory ...mmittee on Reactor Safeguards (ACRS) as required by law. A ...blic hearing on the application then must be conducted by an atomic ...fety and licensing board (ASLB). An application for an operating ...ense for the completed facility also is reviewed by the AEC regula-...y staff and the ACRS, but a public hearing is not mandatory.

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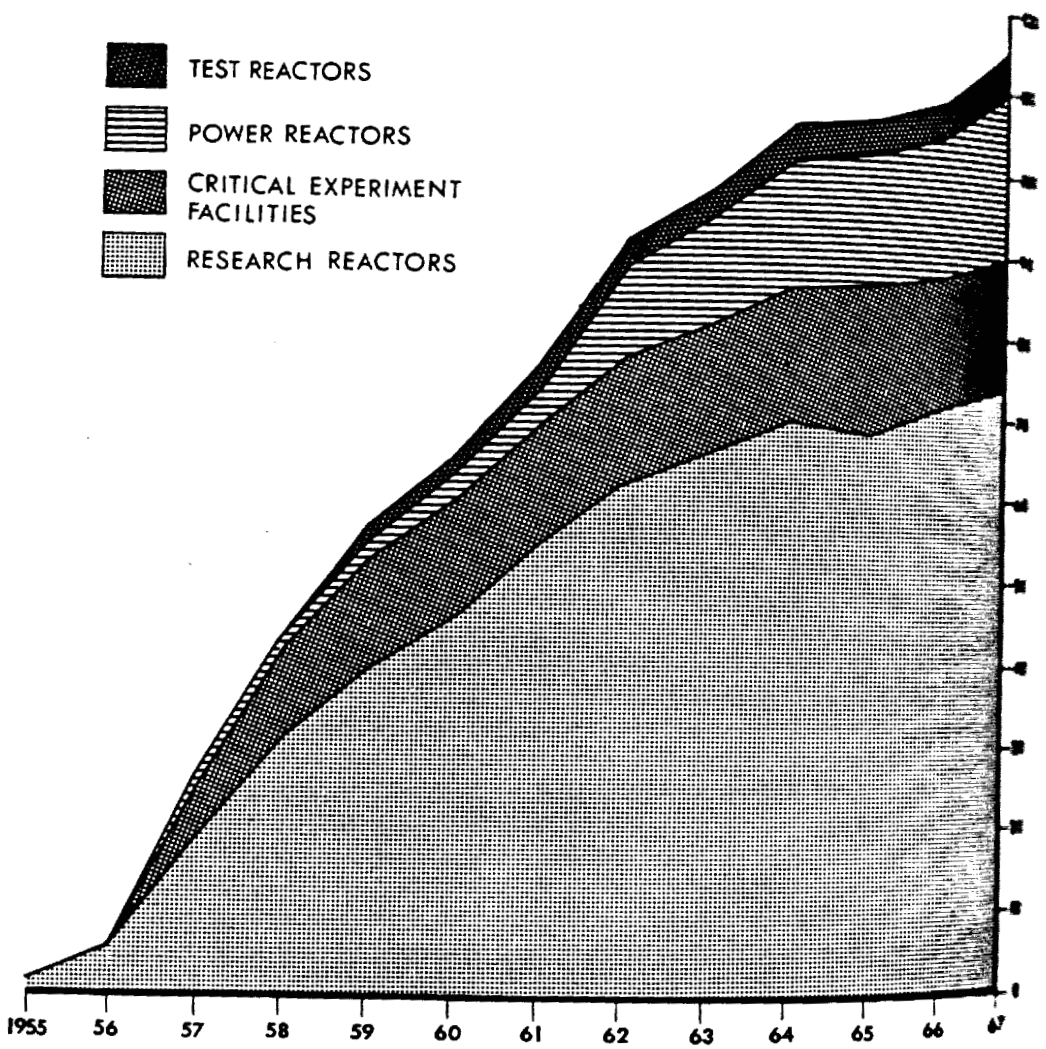
ACRS Activities

The ACRS was established as a statutory committee in 1957 to a
vise the AEC on the safety aspects of proposed and existing nuc
facilities and the adequacy of proposed reactor safety standards. (S
Appendix 2 for ACRS membership.) In addition to its indepen
reviews of proposals for construction and operation of nuclear fac
ties, the ACRS participates in the evaluation of substantive chan
in design, or mode of operation for nuclear facilities. The commit
also reviews reactor facilities owned by the AEC and proposed b
other government agencies as requested by the Commission. The AC
also participates actively in the development of applicable saf
standards and criteria and in a continuing review of the AE
safety research program.

GROWTH OF LICENSED NUCLEAR REACTORS AND FACILITIES

DECEMBER 31, 1955 - DECEMBER 31, 1967

Licenses in Effect for Operation or Possession of Reactors and Other Facilities



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In 1967, the committee met on 13 occasions, and 72 meetings of ACRS subcommittees were held to consider specific nuclear project proposals, safety research activities and development of criteria related to the design, construction, inspection, and testing of nuclear facilities. Members of the ACRS also participated in several conferences and symposiums and on task groups sponsored by the AEC and other regulatory agencies on nuclear safety matters.

The ACRS is a 15-man committee composed of members with extensive experience in nuclear and other phases of American industry, research and development organizations, and academic institutions, who are experts in the various disciplines required for safety evaluation of nuclear facilities.

During the year, the ACRS provided reports to the AEC on 18 licensed reactor and chemical processing facilities, 4 reports on AEC reactor facilities, and 1 report on a non-licensed facility owned by another government agency. The committee also provided four reports dealing with reactor safety research and criteria for nuclear plant design.

ASLB Hearings

A three-man atomic safety and licensing board (ASLB) is appointed by the Commission to conduct a public hearing on each application for a permit to construct power or test reactors or certain other major nuclear facilities. The board conducts the hearing in the vicinity of the proposed site. After considering the record of the hearing, the board issues an initial decision as to whether a construction permit is to be granted. Before becoming final, this decision is subject to appeal by the parties in the proceeding and to review by the Commission. Members of each board—composed of two technically qualified members and a chairman qualified in the conduct of administrative proceedings—are drawn from the Atomic Safety and Licensing Board Panel. This panel is made up of technically qualified experts and persons experienced in administrative procedures. (See Appendix 2 for ASLB Panel membership.) During the year, three permanent officers—a chairman, vice chairman, and an executive secretary—were assigned to coordinate the panel's activities.

During the year, 11 individual boards were constituted from the panel to consider applications for construction permits involving 16 power reactors and a reactor fuel recovery plant. Seven of the cases were not contested, and nine provisional construction permits were granted to the Commonwealth Edison Co., Consumers Power Co. of Michigan, Carolina Power & Light Co., Tennessee Valley Authority,

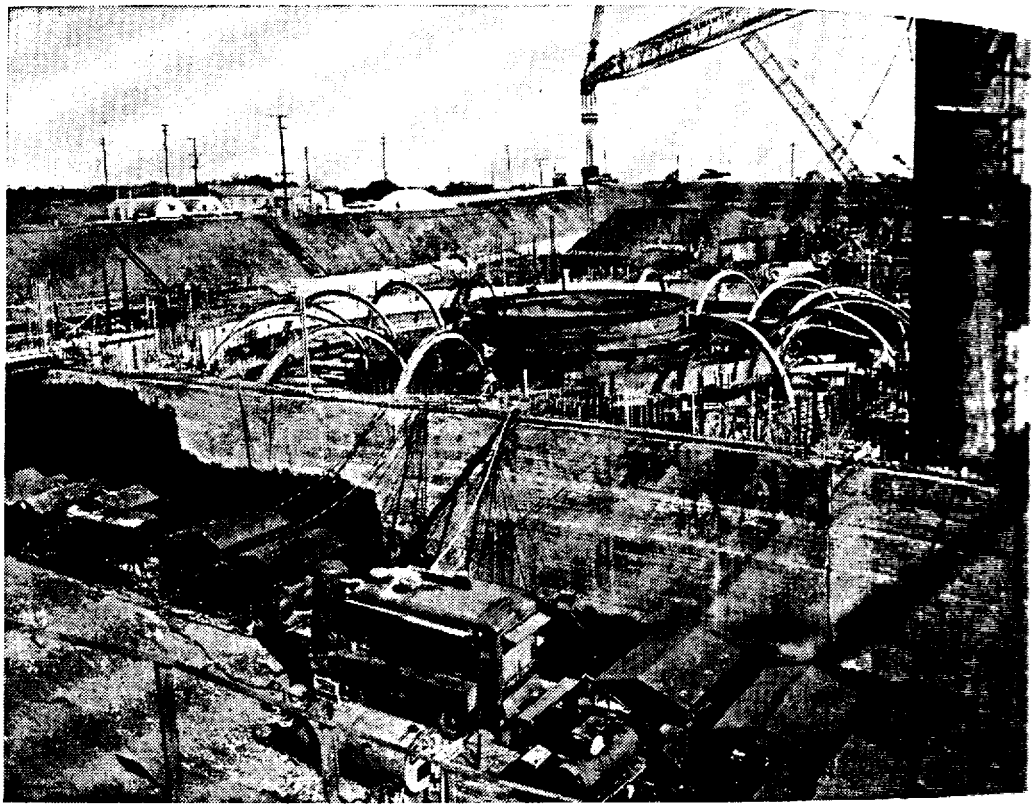
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Northern States Power Co., Wisconsin Michigan Power Co., and General Electric Co.

Initial decisions were issued in three of the four contested cases granting provisional construction permits for two power reactors for the Florida Power & Light Co., three power reactors for the Power Co., and one for the Vermont Yankee Nuclear Power Corp. The initial decisions in these cases, were appealed to the five-man Commission for formal review (see "Commission Adjudication" section). The fourth case, involving an application from the Philadelphia Electric Co., for provisional construction permits, was awaiting the initial decision of an ASLB at year's end.

CONSTRUCTION PERMIT APPLICATIONS

As applications from the electric power industry mounted, the AEC issued construction permits for 14 large nuclear powerplants in 196[illegible]



Construction Underway. The first multi-unit nuclear power station to be authorized by the AEC is the Tennessee Valley Authority's (TVA) Browns Ferry complex on the north shore of the Wheeler Dam Reservoir near Decatur, Ala. Construction of the first two 1,065 Mwe. units was authorized in May 1967; in Jan. the TVA applied for a permit for a third 1,065 Mwe. unit at the site. When all three units are operating in 1972, the combined electrical output will be 3½ million kilowatts—nearly twice the capacity of any powerplant now operating in the U.S. This October photo shows the erection work progress for the Unit 1 suppression chamber and drywell skirt.

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nearly triple the number approved in 1966 (see Table 2). Among these were the largest yet to be proposed—twin 1,065-Mwe. reactors which were placed under construction during the year by the Tennessee Valley Authority (TVA) at its Browns Ferry Nuclear Power Plant near Decatur, Ala.

In August, the Public Service Electric & Gas Co. of New Jersey withdrew its proposed Burlington site, between Trenton and Philadelphia, for a single 993-Mwe. pressurized water reactor. The utility's application, originally received in December 1966, was amended on October 24, 1967, to include two 1,050-Mwe. pressurized water reactors at a site yet to be selected.

Competing Application Rejected

On September 12, Piedmont Cities Power Supply, Inc., filed with the AEC a competing application for commercial licenses under section 103 of the Atomic Energy Act "to acquire, own and use a 4 percent undivided interest" in the three pressurized water reactors which had been proposed by the Duke Power Co. for construction at its Oconee Nuclear Station in South Carolina.

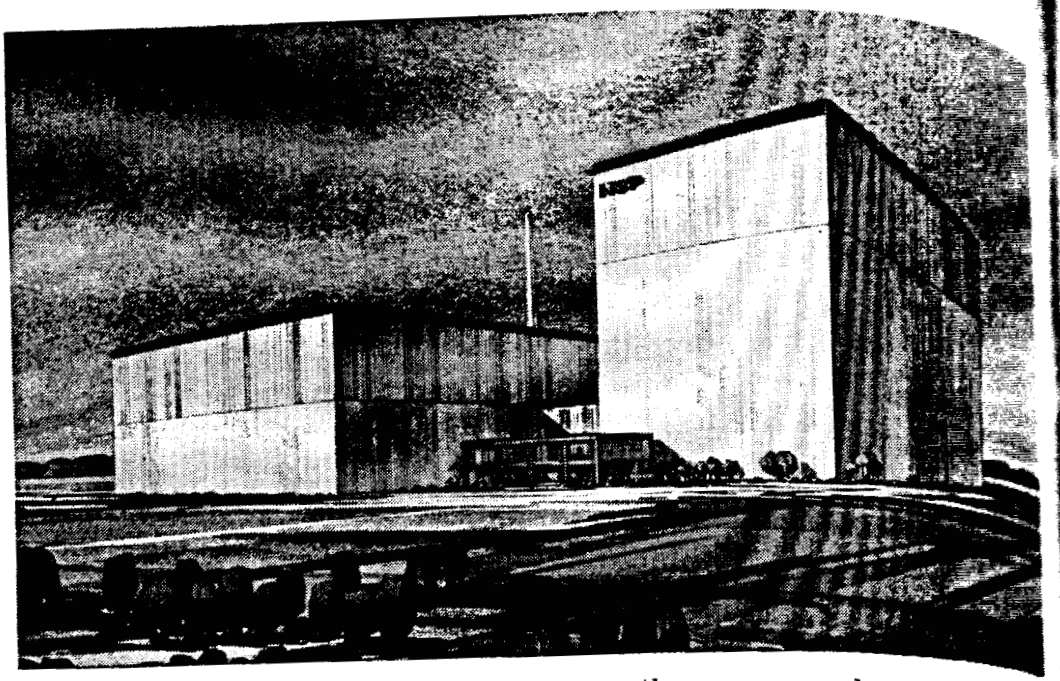
This application was rejected by the Director of Regulation for the reasons that: (*a*) the Commission has no authority to grant a license to acquire, own, or use an undivided interest in the property of another person without the consent of that person; (*b*) since no finding of practical value [10] has been made concerning pressurized water utilization facilities pursuant to section 102 of the Act, such facilities are not

[10] See pp. 16–18, "Annual Report to Congress for 1965," and p. 433, "Annual Report to Congress for 1966."

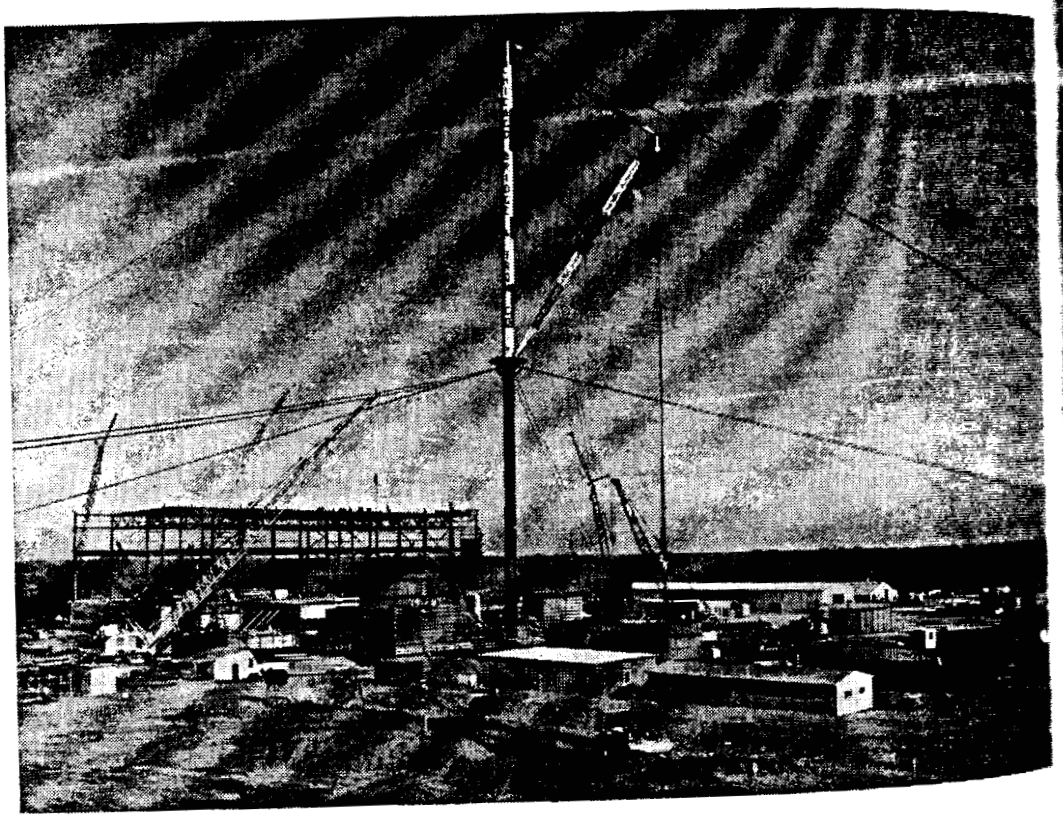
TABLE 2.—CONSTRUCTION PERMITS ISSUED—1967

Applicant	Plant	Month	Unit size (Net Mwe.)	Projected operation
Commonwealth Edison Co. (Ill.)	Quad-Cities 1	February	715	1970
	Quad-Cities 2	February	715	1971
Consumers Power Co. (Mich.)	Palisades Plant	March	700	1970
Carolina Power & Light Co. (S.C.)	H. B. Robinson 2	March	663	1970
Florida Power & Light Co	Turkey Point 3	April	652	1970
	Turkey Point 4	April	652	1971
Tennessee Valley Authority	Browns Ferry 1	May	1,065	1970
	Browns Ferry 2	May	1,065	1971
Northern States Power Co. (Minn.)	Monticello	June	472	1970
Consumers Michigan Power Co	Point Beach 1	July	455	1970
Duke Power Co. (S.C.)	Oconee 1	November	839	1971
	Oconee 2	November	839	1972
	Oconee 3	November	839	1973
Vermont Yankee Nuclear Power Corp.	Vermont Yankee	December	514	1970

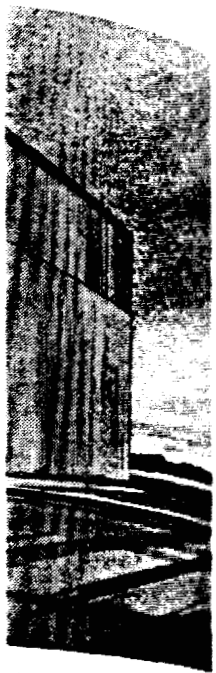
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Monticello Plant. Of especial interest among the new powerplants placed under construction during 1967 is the Monticello Nuclear Generating Plant in Minnesota which will have the first large reactor pressure vessel to be fabricated at the site. The Northern States Power Co. (NSP) received a construction permit for the 472–Mwe. plant in June. *Above* is a General Electric concept of the finished plant. In the NSP photo, *below*, the Chicago Bridge & Iron Co. has work well underway on the containment vessel and is preparing for field fabrication of the pressure vessel. About three-fourths of the major pieces of the reactor vessel are shop assembled, and sections are fitted and welded together, tested and treated in shelters at the site. Some of the round, domed metal shelters in which the work will be done are shown to the right of the base of the derrick tower.



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nsable under section 103; and (*c*) the application did not provide sufficient information to meet requirements of AEC regulations.

Construction permits for Oconee Units 1, 2, and 3 were issued to Duke Power Co. on November 6 following a favorable decision of an atomic safety and licensing board.

At year's end, the AEC regulatory staff had under initial review, construction applications for 30 nuclear powerplants representing a total design output of 24,828 Mwe.[11]

NEW REACTORS IN OPERATION

Provisional operating licenses for the first two large central station power reactors with generating capacities in excess of 400 Mwe., and one major test reactor were issued in 1967.

Two New Power Facilities

The Southern California Edison Co. and San Diego Gas & Electric Co. were licensed on March 27 to operate the San Onofre Nuclear Generating Station Unit 1 at San Clemente, Calif., at power levels up to 1,347 megawatts, thermal (Mwt.) producing about 430 net Mwe. The pressurized water reactor achieved a nuclear reaction on June 14.

The Connecticut Yankee Atomic Power Co. was authorized on June 30 to operate the Connecticut Yankee Power Plant at Haddam Neck, Conn., at levels up to 1,473 Mwt. The pressurized water plant, which is designed to produce about 462 net Mwe. for the 11 New England utilities sponsoring Connecticut Yankee, achieved an initial chain reaction on July 24.

In addition, Allis-Chalmers Manufacturing Co. was issued a provisional operating authorization on July 3 for the LaCrosse Boiling Water Reactor (LACBWR) at Genoa, Wis. This reactor, which attained a nuclear chain reaction on July 11, was constructed by Allis-Chalmers for the AEC and Dairyland Power Cooperative under the Power Reactor Demonstration Program. It will be operated at power levels up to 165 Mwt., with an electrical output of about 50 Mw.

New Test Reactor

The National Bureau of Standards was authorized on November 13 to operate its 10 Mwt. enriched uranium-fueled, heavy water-

[11] Does not include Malibu Nuclear Plant Unit 1 (462 Mwe.) proposed by Los Angeles Department of Water and Power, which is not currently under review, pending amendment of the application.

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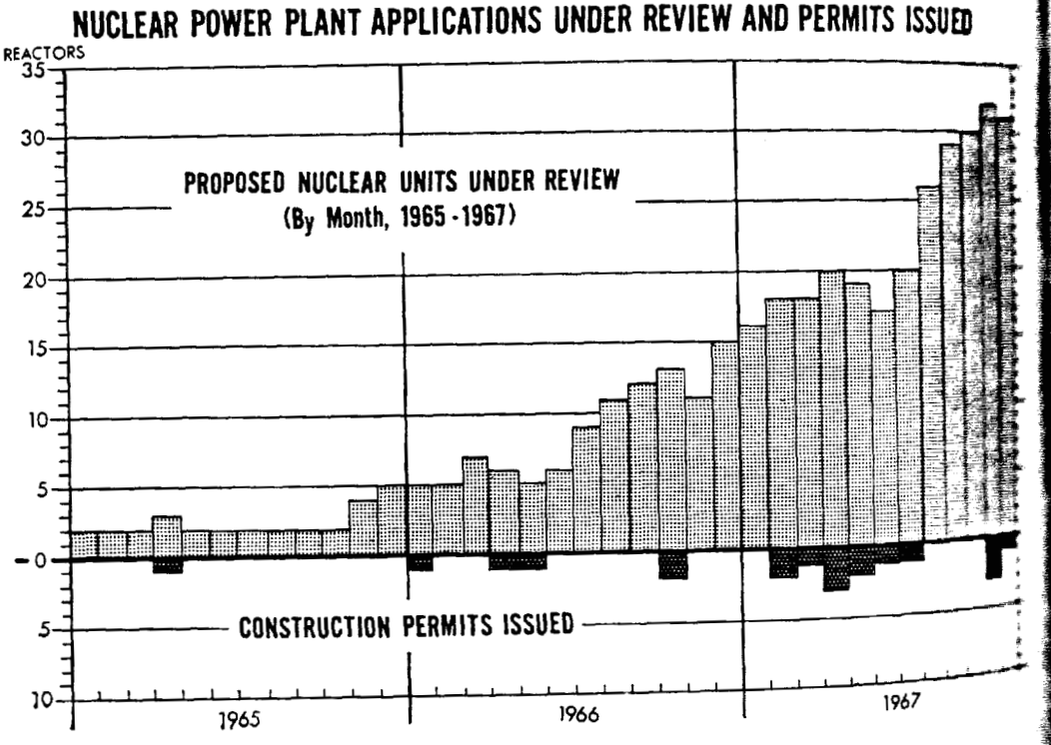
moderated and cooled test reactor near Gaithersburg, Md. The provisional license was issued following an informal review by an atomic safety and licensing board which concurred with the safety findings and recommendations of the ACRS and the AEC regulatory staff. The NBS tank-type reactor, which sustained a nuclear reaction on December 7, will be used in research to develop standards on materials and nuclear processes.

Reactors Planning Operation

On January 25, Jersey Central Power and Light Co. applied for a provisional license to operate the Oyster Creek Nuclear Power Plant in Lacey Township, Ocean County, N.J. This boiling water reactor, which was authorized for construction in December 1964, is scheduled to be placed in operation in early 1968. It is designed to operate at 1,600 Mwt., with a net electrical output of 515 megawatts.

An application was received on June 1 from Niagara Mohawk Power Corp., requesting authority to operate its Nine Mile Point Nuclear Station at a power level of 1,583 Mwt. with a 500-Mwe. net output. The facility is located in Oswego County, N.Y., about 36 miles from Syracuse.

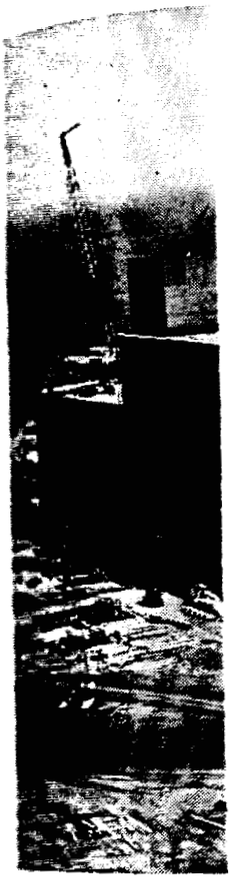
Commonwealth Edison Co. on November 17 requested authority to operate each of its Dresden Units 2 and 3 in Grundy County, Ill., at power levels up to 2,527 Mwt. (producing 809 net Mwe. each), the



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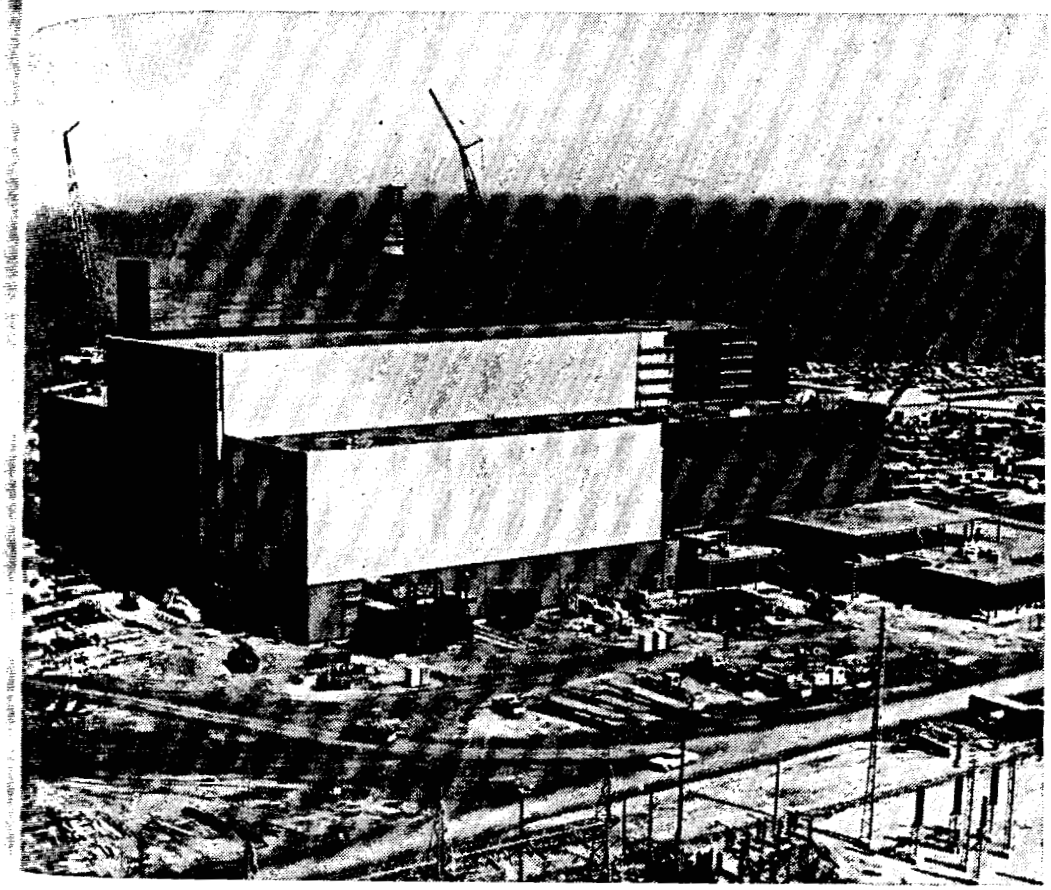
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timate design capacity of the reactors. In filing its safety analysis eport for review by the AEC, the utility also requested appropriate mendment of its construction permits for the two units. Common-ealth Edison, which originally had scheduled these plants for initial eration at 715 Mwe., plans commercial operation for Dresden 2 in ebruary 1969, and for Dresden 3, a year later.

General Electric Co. applied for a license on July 24 to operate the outhwest Experimental Fast Oxide Reactor (SEFOR) located at ove Creek Township, Ark., at 20 Mwt. Operation of this sodium-ooled reactor, which will be used for research on fast breeder reactors, planned in the spring of 1968.

ther Major Licensing Actions

Philadelphia Electric Co.'s operating license for its 40 Mwe. gas-ooled Peach Bottom Unit No. 1 was amended on January 12 to



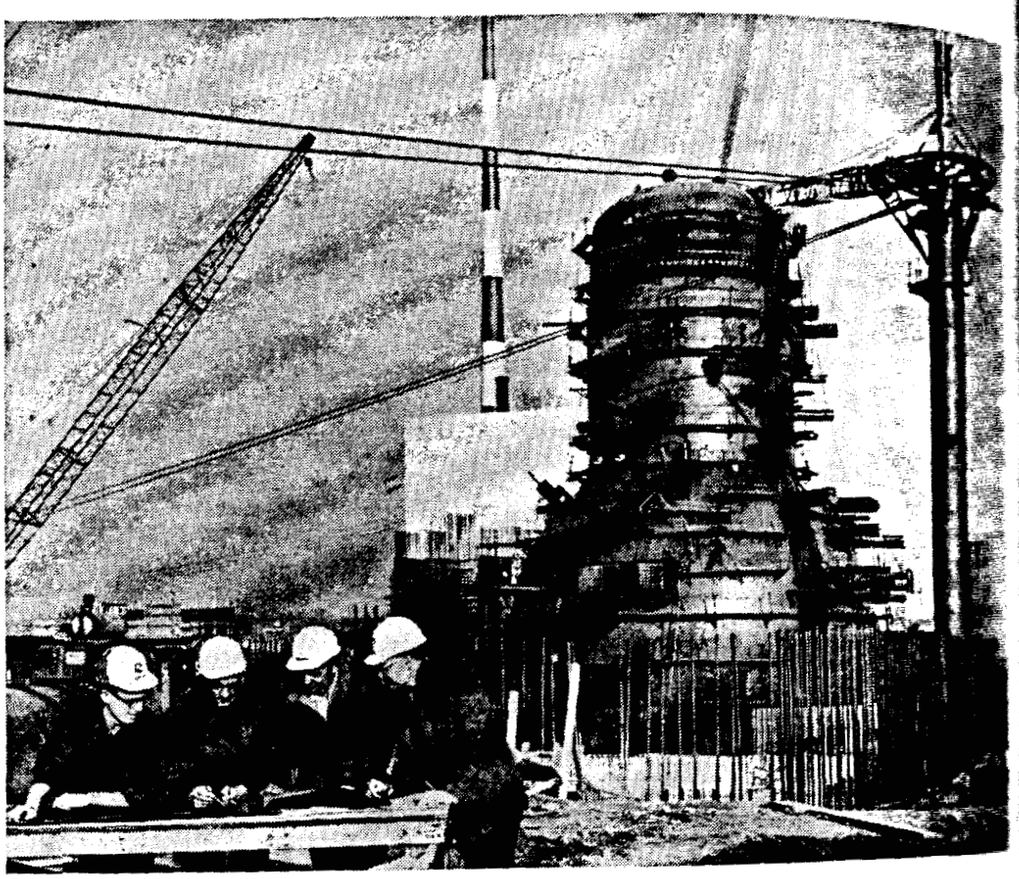
Operation Planned. The Niagara Mohawk Power Corp. will own and operate Nine Mile Point Nuclear Power Plant now under construction by General ectric on the shore of Lake Ontario in the State of New York. The plant will a rating of 500 Mwe. and is scheduled for start of operation in late 1968.

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increase the authorized power level to 115 Mwt. following the succe
ful completion of operating tests at one megawatt.

The Carolinas-Virginia Tube Reactor (CVTR) located at Par
S.C., having served its purpose, has been closed down following
Commission order dated June 12, 1967. The 17-Mwe. heavy wate
prototype powerplant had been operated as a training and resear
facility since March 1963, by the four utilities comprising the Car
linas-Virginia Nuclear Power Associates, Inc.

An AEC order for dismantling and decontaminating the Hallam
Nuclear Power Facility, Hallam, Nebr., was issued on November
to Consumers Public Power District of Nebraska. The sodium-cooled
graphite-moderated reactor which was operated for the AEC ha
been shut down since September 27, 1964. Removal of the fuel and
sodium coolant were initiated during the year. The retirement plan
calls for enclosure of the radioactive material in sealed spaces in the
below-grade structure.



Dresden 1, 2, and 3. The Commonwealth Edison Co.'s Dresden 1 unit (shown in *background*) has been producing 200 Mwe. since mid-1960. It was the first pri
vately built nuclear plant to go into operation. Two more units, each with
Mwe. capacity, are under construction at the Illinois site by the General Electric
Co. Unit 2 is scheduled to be in service in 1969, and Unit 3 in 1970.

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FUEL REPROCESSING PLANTS

On December 28, following an initial decision by an atomic safety and licensing board (ASLB), a provisional construction permit was issued to General Electric Co. for a plant to process irradiated reactor fuel.[1] The ASLB conducted a public hearing on the application near the site location in Morris, Ill., on November 28, and issued its decision on December 27.

The facility, to be known as the Midwest Fuel Recovery Plant (MFRP), will be located on a 1,300-acre site south of the Dresden Nuclear Power Station. All operations will take place within a heavily shielded process building, the major components of which will be a receiving and storage basin, a processing area, and a solid waste retention area.

[1] Spent (used) fuel elements are chemically processed to recover unused and newly created fissionable material and, to a limited extent, to recover certain useful byproduct radioactive materials.



Quad-Cities, Units 1 and 2. Commonwealth Edison Co. and Iowa-Illinois Gas & Electric expect to have their Quad-Cities Unit 1 in service in 1970, and Unit 2 in service in 1971. Aerial view shows the twin 715-Mwe. reactor plant construction progress during October. Construction, by General Electric, was authorized in February 1967.

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The second privately owned plant of its type to be built, the MFR is designed to process 300 metric tons per year of irradiated uranium in the form of uranium dioxide clad in stainless steel or zirconium alloy. General Electric Co. expects the plant to be ready for commercial operation by mid-1970.

Nuclear Fuel Services, Inc.

On November 15, 1967, Nuclear Fuel Services, Inc. (NFS) and the New York State Atomic and Space Development Authority applied for a construction permit to build a facility for the extraction of neptunium. The new plant which would be located at the site of the present irradiated fuel processing plant operated by NFS at West Valley, N.Y., is scheduled for startup in 1970. The application was under AEC staff review at year's end.

Operator Licensing

During the 12-month period ending November 30, the AEC issued 346 operator licenses and 311 senior operator licenses. These were for 345 new licenses, 13 amended licenses, and 299 renewed licenses for persons manipulating the controls at reactor or processing plants. During the same period, 76 license applications were denied. Including previously issued licenses, 952 operator licenses and 699 senior operator licenses were in effect on November 30.

COMMISSION ADJUDICATION

During the year, the Commissioners completed or undertook formal reviews of the following facility licensing matters upon appeals from initial decisions of atomic safety and licensing boards (ASLB's):

Malibu Nuclear Plant Unit 1

The Commission completed its review, pursuant to exceptions filed by the AEC regulatory staff and three intervenors, of an ASLB's initial decision on the application by the Los Angeles Department of Water and Power to construct a power reactor at Corral Canyon, near Malibu, Calif. The Commission's decision, issued on March 27, 1967, upheld the ASLB's determination that the probability of permanent ground displacement at the proposed site was sufficiently high to require that the design criteria for the plant be modified and supple-

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...ected to include provision for ground displacement from earthquake ...rity. The Commission set aside the board's order authorizing ...ance of a provisional construction permit and sent the matter back ...the ASLB for further proceedings after submission by the appli...nt of an appropriate amendment to its application and review by the ...ulatory staff and the ACRS.[13]

...key Point Units 3 and 4

A hearing on the Florida Power & Light Co. application for pro...sional construction permits for two reactors at its Turkey Point ...e in Dade County, Fla., was held February 28–March 3, 1967, in ...ami before an ASLB, with two intervenors participating.

[13] See p. 59, "Annual Report to Congress for 1966."



In response to a question certified to the Commissioners by the ASLB prior to the hearing, the Commissioners directed the ASLB not to consider in the proceeding the effects of possible attacks and destructive acts by enemies of the United States, or of accidents which might result from use or deployment of weapons in U.S. defense activities. The ASLB's April 26 initial decision directed issuance of provisional construction permits subject to the condition that further data related to establishment of an "exclusion area" under AEC criteria be filed with AEC and made available for public hearing review and evaluation. The two intervenors and the AEC regulatory staff filed exceptions to the initial decision. One intervenor, an owner of property adjoining the site, excepted on the ground that construction permits should not have been issued until sufficient evidence was submitted to demonstrate compliance with the Commission's site criteria. Both intervenors took exception to the ASLB's exclusion of evidence concerning intentional efforts to damage the facility. The AEC regulatory staff contended that sufficient information on the exclusion area had been supplied to support the issuance of construction permits, and that the condition in the permits requiring a further hearing should not have been imposed.

On August 4, the Commission directed the ASLB to obtain further information on alternative safety features, site meteorology, and control of persons and property within the exclusion area. The Commission also ordered that the provisional construction permits remain in effect pending completion of the further proceedings. The Commission, in addition, stated that ASLBs do not have authority to direct the holding of hearings following the issuance of a construction permit. All other exceptions to the initial decision were denied.

Judicial Review. On October 2, one of the intervenors filed a petition in the U.S. Court of Appeals for the District of Columbia Circuit for review of the Commission's action in refusing to consider the effects of attacks and destructive acts by enemies of the United States. On October 4, the same intervenor also filed an appeal in that court seeking review of the Commission's action in promulgating a conformatory rule [14] on this subject.

Vermont Yankee Nuclear Power Station

A hearing to consider the application of Vermont Yankee Nuclear Power Corp. for a permit to construct a nuclear powerplant on the Connecticut River near Vernon, Vt., was held before an ASLB on August 1–2 and September 6–7, 1967, in Brattleboro, Vt. Petitions to intervene in the hearing were granted by the ASLB to the State

[14] All rulemaking actions of the Commission pertaining to licensing and regulation during 1967 are described in Appendix 6.

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Vermont, New Hampshire, and Massachusetts but denied to an association of municipal power systems and three individual municipal power systems located in Massachusetts, and to the local chapter of the Anti-Pollution League. On September 15, the Commission denied without prejudice, as interlocutory, an appeal from the ASLB's order denying intervention to the municipal power systems group.

The intervening States of Massachusetts and New Hampshire opposed the granting of a construction permit on the basis of thermal effects of the proposed plant on the Connecticut River. The State of Vermont was similarly concerned with the problem of thermal effects but did not oppose the issuance of a permit.

On December 8, the ASLB issued its initial decision which authorized the issuance of a construction permit. The permit was issued on December 11. Subsequently the State of New Hampshire filed exceptions to the initial decision and requested that an order be issued staying the provisional construction permit, pending further hearings. Also, the Massachusetts municipal electric systems group filed exceptions to the decision of the ASLB and its action in denying intervention.

Judicial Review. On November 13, the municipal power systems group filed a petition for review of the action denying them intervention in the United States Court of Appeals for the District of Columbia Circuit.

Oconee Nuclear Station Units 1, 2, and 3

An ASLB hearing on Duke Power Co.'s application for provisional construction permits for three nuclear power reactors in South Carolina was held August 29–30 and September 12 in Walhalla, S.C. Intervention was granted to 11 North Carolina cities and towns. They raised the jurisdictional question of whether the AEC had the authority to issue the permits under section 104b of the Atomic Energy Act. The ASLB's initial decision, issued on November 3, confirmed its previous order that the first two reactors were subject to licensing under section 104b and found that the third unit was also licensable under that section. In addition, the ASLB authorized the immediate issuance of construction permits for all three units. The intervenors filed exceptions to the initial decision and to the ASLB's action in denying intervention to a petitioning corporation. The matter was under review by the Commission at year's end.

FINANCIAL INDEMNIFICATION

In 1967, the indemnification program established by the Price-Anderson legislation of 1957 completed its first decade of operation. The program affords financial indemnity to the public and to AEC

licensees and contractors against public liability risks associated with atomic energy. It provides for private insurance and governmental indemnity amounting to a maximum of $560 million to cover public liability claims, that might conceivably arise from a nuclear incident. To date, no claims have been made under the licensee indemnity agreements.

Refund of Nuclear Liability Insurance Premiums

As a further reflection of the excellent safety record of the nuclear industry, refunds were paid to policy holders by the two nuclear energy liability insurance pools. These are Nuclear Energy Liability Insurance Agency (NELIA) and Mutual Atomic Energy Liability Underwriters (MAELU). They refunded, during 1967, a substantial portion of the first premiums which had been paid in 1957, for nuclear liability insurance. The refunds of premium reserves were made under the pools' retrospective rating plan, which is one of the provisions of the policy form approved by the AEC as proof of financial protection under the Price-Anderson indemnity.

Under the rating plan, a portion of the annual premium (65 to 75%) for the nuclear liability insurance policies is set aside as a reserve for either payment of losses or return to the policyholders after 10 years. The amount of reserve available for refund is determined by the loss experience over the 10-year period. Total refunds of $46,436 represented about 66 percent of the 1957 premiums paid on 44 policies, totaling $70,142, and 97 percent of the loss reserve established from the premiums.

Small Reactor Financial Protection Increased

When the amount of available private nuclear energy liability insurance was increased in 1965 from a maximum of $60 million to $74 million, the AEC amended its regulations to require the larger amount as financial protection for power reactors with a rated capacity of 100 or more electrical megawatts. At the same time, as required by the 1965 amendments to the Price-Anderson legislation,[15] Government indemnity for such reactors was reduced proportionately from $560 million to $486 million per nuclear incident.

In view of the increased availability of private insurance, the AEC, on August 7, 1967, proportionately increased the financial protection requirements for power and test reactors of less than 100 Mwe but more than one thermal megawatt (Mwt.). Amendment of the formula in 10 CFR Part 140 of the AEC's regulations increased by about 2

[15] Public Law 89–210 ; see p. 300, "Annual Report to Congress for 1965."

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percent the financial protection requirements for licensees who operate these smaller reactors and also raised the minimum level of required protection for this class of reactors from $3.5 million to $4.5 million. Requirements for small research reactors were unchanged.

Indemnity Agreements in Effect

There were 89 indemnity agreements in effect with AEC licensees at the end of 1967 covering the licensed operation of 13 power reactors, 16 research reactors, 5 testing reactors, 17 critical facilities, 1 chemical processing facility; and the N.S. *Savannah;* the storage of nuclear fuel prior to operation of a reactor at 7 sites; and 3 construction permits. Indemnity fees[16] paid to AEC for the 12 months ending November 30, 1967, totaled $204,146.

CONTROL OF MATERIALS

Despite the substantial transfer of regulatory authority for materials to 17 States since 1962—two of which in 1967 assumed responsibility for 332 licenses that had been previously issued by the AEC—the number of AEC licenses has remained at a relatively stable level, reflecting the constant increase in uses of atomic energy materials.

During the 12-month period ending November 30, 1967, nearly 3,000 applications for materials licenses, amendments, and renewals were filed with the AEC regulatory staff. At the end of this period, 8,351 AEC licenses were in effect, consisting of 8,351 for by product materials (radioisotopes), 414 for source materials, and 586 for special nuclear materials.

IMPROVING MATERIALS LICENSING

The AEC took several actions during the year to simplify materials licensing procedures and began a systematic revamping of its regulatory program for radioisotopes with the assistance of recommendations from an independent review panel.

Radioisotopes Licensing Reviewed

Results of a 6-month study—the first comprehensive review of materials licensing by a group from outside government—were reported

[16] The AEC charges, as required by statute, an annual indemnity fee of $30 per thermal kilowatt for licensed reactors, subject to a minimum annual charge of $100.

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to the AEC in September and made public.[17] The detailed study of the AEC's regulatory program for byproduct materials (radioisotopes) was undertaken during the first half of 1967 by the Radioisotopes Licensing Review Panel. The 11-member panel was appointed by the AEC in late 1966. Its membership was drawn from experts outside the Government and represented nuclear medicine, nuclear industry, higher education, State regulation, health physics, and organized labor.[18] Appointment of the panel followed an earlier AEC examination of its radioisotope program aimed at simplifying the licensing process without prejudicing public health and safety. The panel was asked to give special attention to the changes contemplated by the AEC and also to appraise the effectiveness of AEC policies and procedures for protecting public health and safety.

The panel's report concluded that the AEC radioisotopes regulatory program had been "well conceived and well administered and the panel has no doubt of its contribution to an excellent health and safety record . . . this safety record along with the generally increasing competence of licensees has enabled the panel to make recommendations aimed at simplifying AEC regulations."

Among highlights of the panel's report were:

(*1*) A general conclusion that licensees are competent to develop sound radiation safety programs without detailed regulatory requirements, and that the AEC should place more emphasis on performance objectives than on specific procedures and techniques for meeting those objectives;

(*2*) A recommendation that the AEC safety standards (10 CFR Part 20) be simplified and supplemented with a series of "manuals of good practice" which would provide guidance and operations standards for diverse types of isotope use;

(*3*) A recommendation that the AEC develop exemptions for certain classes of consumer products together with specific criteria by which the staff could determine whether individual items meet the conditions of exemption;

(*4*) A recommendation that small quantities of radioisotopes presently used under general license be increased and exempted:

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[17] A copy of the report submitted by the Radioisotopes Licensing Review Panel, September 5, 1967, may be obtained by writing to the Director, Division of Materials Licensing, U.S. Atomic Energy Commission, Washington, D.C. 20545.

[18] George F. Trowbridge, *Chairman* of the panel, is a Washington attorney; other members were: Dr. Merrill A. Bender, Roswell Park Memorial Institute, Buffalo, N.Y.; Dr. Lauchlin M. Currie, Mamaroneck, N.Y.; Donald T. Green, Picker X-Ray Corp., Cleveland, Ohio; Dr. John M. Heslep, Department of Public Health, Berkeley, Calif.; Dr. Wilfred E. Konneker, Mallinckrodt Chemical Works, St. Louis, Mo.; Herbert M. Parker, Consultant, Pacific Northwest Laboratory, Richland, Wash.; Dr. Seymour Rothchild, New England Nuclear Corp., Boston, Mass.; Dr. John P. Ryan, Minnesota Mining & Manufacturing Co., St. Paul, Minn.; George H. R. Taylor, Department of Research, AFL–CIO, Washington, D.C.; and Dr. G. Hoyt Whipple, University of Michigan, Ann Arbor, Mich.

A recommendation that the AEC study the feasibility of licensing individual radiographers and require improved standards for radiographic equipment;

A recommendation that evaluation of sealed sources and devices using byproduct material which manufacturers propose to distribute be performed centrally by the AEC rather than by individual agreement States; and

A proposal for future regulation of nuclear medicine in which many of AEC's present functions would be carried out by the Food and Drug Administration and by the medical profession itself.

The panel expressed its belief that simplification of AEC regulations would encourage increased use of radioisotopes and at the same time improve regulatory effectiveness and increase acceptance of the program by licensees. It endorsed a number of steps contemplated by the AEC, such as extension of the broad licensing concept to a greater number of licensees.

At year's end, action either had been taken or was underway on several of the recommendations. Some, such as those concerning exempt consumer products, medical licensing, and development of manuals of good practice, will require further consideration.

Materials License Period Extended

In May, the AEC revised its regulations to permit 5-year effective periods for its licenses for source, byproduct, and special nuclear materials, which in effect lengthens the time most materials licenses will be in force.

Previously, licenses for the source materials thorium and uranium had been issued for 3-year terms and licenses for special nuclear materials had also usually been issued for 3 years. Byproduct material (radioisotopes) licenses had been issued for terms of 1 to 5 years, depending on the nature and form of the material and its intended use. All materials licenses are now issued for 5-year terms except in cases where the nature of the applicant's proposed activities shows the need for a shorter period. The longer license periods will significantly reduce the volume of renewal applications, thereby easing the regulatory burden on licensees.

Simplified Licensing for Diagnostic Uses

In October, the AEC amended its regulations to simplify licensing procedures for physicians who use radioisotopes for diagnostic purposes. The change will allow the issuance of a license for an entire

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group of related diagnostic procedures—even if only one is applied for—if the AEC finds the applicant is qualified.

The most common diagnostic uses of radioisotopes are divided into scanning procedures and nonscanning (uptake, dilution, and excretion) studies. An applicant for a use within one of the groups will be issued a license for all of the diagnostic procedures in the group if his application demonstrates that he meets the necessary licensing criteria. Previously, medical radioisotope licenses had been limited to the specific procedures and isotopes requested by the applicant.

New Pharmaceutical Compounds

Radiopharmaceuticals under investigation are evaluated with the assistance of the AEC's Advisory Committee on the Medical Uses of Isotopes (see Appendix 2 for list of members). When their safety and efficacy are sufficiently established the products may be used for routine diagnosis or therapy.

Eight radioactive pharmaceutical products were approved in 1967 for the routine diagnostic uses specified: iron-59 as sulfate for iron metabolism studies; iodine-131 as sodium iothalamate for kidney function studies; potassium-42 as chloride for potassium space determinations;[19] chromium-51 labeled human serum albumin, and chromium-51 labeled red blood cells for placenta localization; xenon-133 and krypton-85, both as gas, for diagnosis of cardiac abnormalities; and selenium-75 as labeled methionine for pancreas scans.

Radioactive Waste Disposal

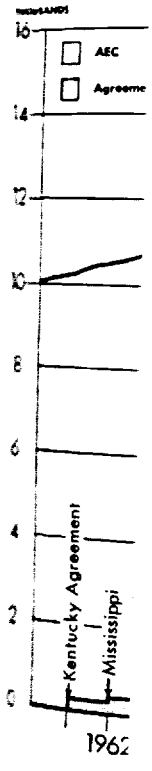
California Nuclear Inc., of Lafayette, Ind., was licensed in August to operate a radioactive waste burial site near Sheffield, Ill. The new facility increases the number of commercial land burial sites to five, the others being in Kentucky, Nevada, New York, and Washington.

General License for Exports to Soviet Bloc

On June 29, the AEC amended its regulations to permit AEC licensees to export certain radioisotopes to several Soviet bloc destinations under a general license.

The new general license, which requires no application to AEC, permits exports of radioisotopes (byproduct material) having atomic numbers of 3 to 83, inclusive, in labeled organic and inorganic compounds in quantities not to exceed 1 curie a shipment; and tritium

[19] A measure of that volume of the body which contains readily exchangeable potassium



Hydrogen-3) with a specific activity of not more than 10 curies per gram of hydrogen in quantities not to exceed 10 curies a shipment, as labeled organic compounds. This general license applies to Albania, Bulgaria, Czechoslovakia, Estonia, Hungary, Latvia, Lithuania, Outer Mongolia, and the Soviet Union (and also to Poland and Rumania with regard to tritium).

Exports of byproduct material having an atomic number of 3 to 83, inclusive, may continue to be made to Poland and Rumania under an earlier general license.

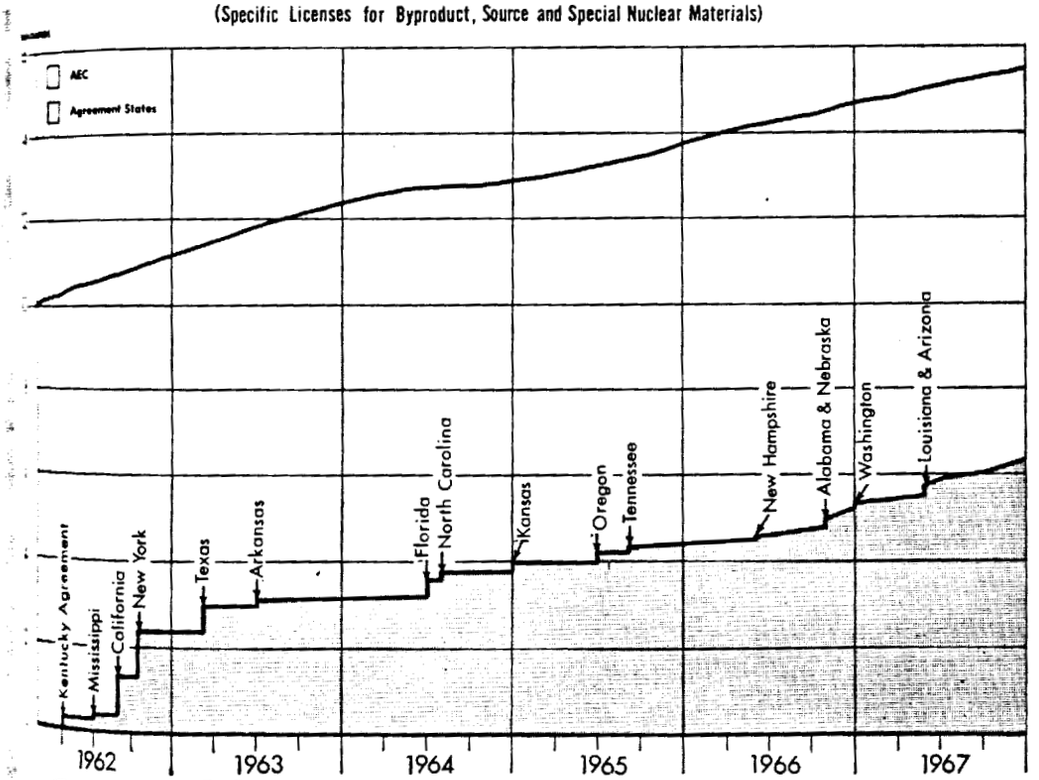
The new general license, covering material used principally in physical, biological, biochemical, and life science research, was issued as a further step to encourage the peaceful and beneficial uses of atomic energy and to facilitate export sales by simplifying administrative licensing procedures. The AEC determined that export of these labeled compounds in the limited amounts specified would not be inimical to the interests of the United States.

STATE REGULATORY AGREEMENTS

Increasing State interest in the AEC's Agreement States Program was evident throughout 1967 as two new States entered the program and a third State was scheduled to do so in early 1968. Several other States were actively preparing for assumption of regulatory

AEC AND AGREEMENT STATES' MATERIAL LICENSES IN EFFECT, 1962 - 1967

(Specific Licenses for Byproduct, Source and Special Nuclear Materials)



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authority. In addition, seven more States enacted enabling legisla-
tion for such agreements with the AEC.

The AEC's Federal-State program, authorized by Section 274 of the Atomic Energy Act,[20] provides for agreements for the transfer of certain of the AEC's regulatory authority over byproduct, source, and small quantities of special nuclear materials. Before entering into such agreements, the AEC must determine that the State's proposed regulatory program is adequate to protect the public health and safety, and is compatible with the AEC's program for like materials.

New Agreements

The addition of Arizona and Louisiana in 1967 brought to 17 the number of States entering into such agreements since the first was signed in 1962. A similar agreement with Colorado is scheduled to be signed in mid-January 1968. Others are Alabama, Arkansas, California, Florida, Kansas, Kentucky, Mississippi, Nebraska, New Hampshire, New York, North Carolina, Oregon, Tennessee, Texas, and Washington. At the end of the year, these States had regulatory jurisdiction over more than 39 percent of the estimated 15,500 materials licenses in effect in the United States.

The agreement with Louisiana became effective May 1, 1967, at which time 234 AEC materials licenses were transferred to the State. Arizona became an agreement State effective May 15, assuming regulatory authority over 98 former AEC licenses.

States Preparing for Agreements

Before entering into an agreement with the AEC for assumption of regulatory controls, most States must enact new legislation to enable the Governor to sign such an agreement. During 1967, enabling legislation was passed by Connecticut, Hawaii, Montana, South Carolina, South Dakota, Utah, and Vermont. This brought the total of States with enabling legislation (not including those with agreements) to 2[illegible]

Post-Agreement Cooperation

To assure the continued adequacy of the State regulatory programs as required by law, and the continued compatibility of AEC and agree-

[20] 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 1[illegible]" pp. 375–376, "Annual Report to Congress for 1961."

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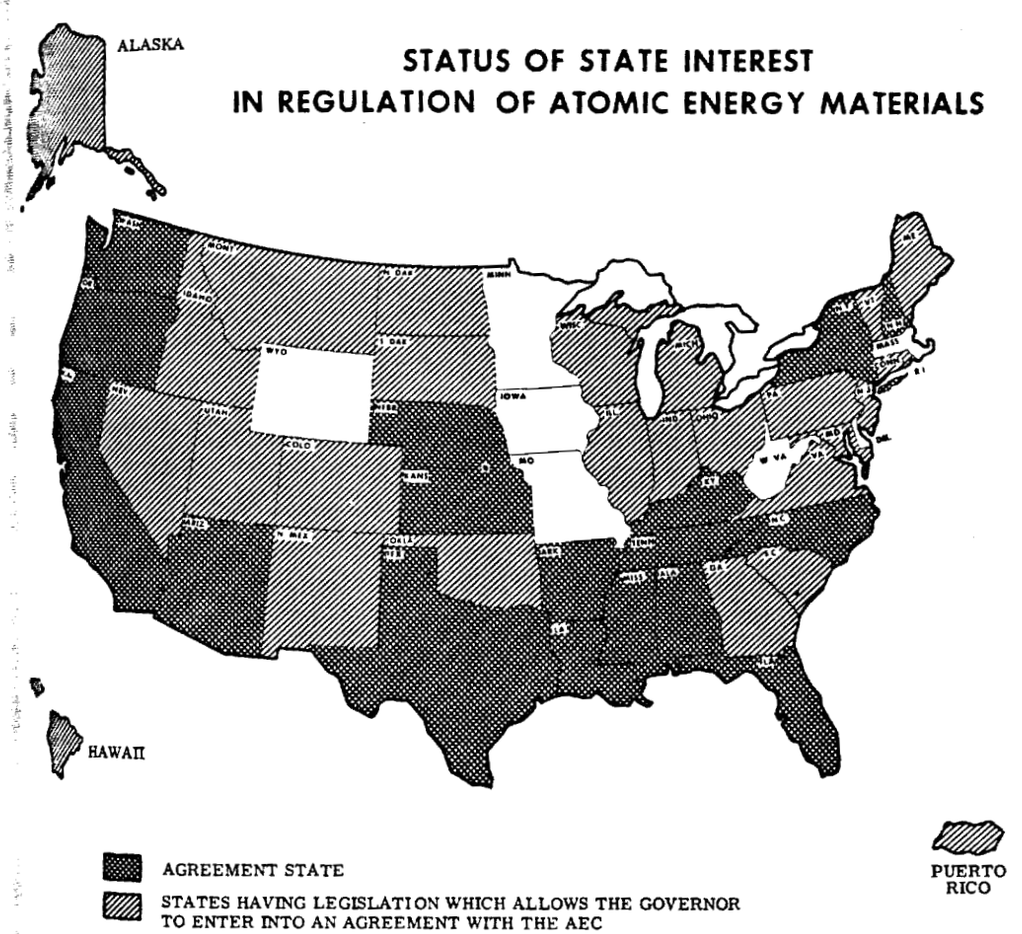
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ent State programs—a commitment contained in each of the regula-
ry agreements—the AEC maintains a continuing exchange of in-
rmation with the States. This exchange covers licensing and inspec-
n procedures and criteria, new or unusual licensed uses and license
nditions, enforcement actions and procedures, and changes or pro-
sed changes in regulations.

Review meetings with State regulatory officials are held semi-
nually during the first few years of each State's program, and at
st annually thereafter.

ntinued Compatibility

In 1965, the Commission announced a policy of conducting a formal
nual redetermination of the compatibility of State programs with
t of the AEC. The second such redetermination of compatibility
s made in March 1967 when the AEC found the programs of the then
agreement States to be both adequate to protect health and safety
d compatible with the AEC's regulatory program for like materials.



Training for State Personnel

Adequate numbers of well-trained and experienced personnel are one of the most important factors in a State radiation program. The AEC, therefore, provides State personnel with technical training in radiation protection and orientation in the AEC's regulatory practices and procedures.

Twelve people from nine States participated in the annual 10-week course in health physics and radiation protection given by Oak Ridge Associated Universities (ORAU). In addition, a 3-week course in applied health physics was presented by ORAU in the spring for 15 other persons from nine States. This course provides practical experience for students with theoretical training but limited experience in health physics.

Two orientation courses in AEC regulatory practices and procedures were attended by 22 persons from 16 States.

A special 1-week course in the regulatory and health physics aspects of nuclear medicine was given at the University of Florida, Gainesville, for State personnel in the southeastern United States, with 19 persons from seven States participating.

SAFETY AND COMPLIANCE

During 1967, the AEC obtained new measures of the degree of safety in the atomic energy field outside its own sphere of operations. These included results of the first surveys of the work-injury experience of the private sector of the growing atomic energy industry. Also, leading film badge processors reported to AEC the distribution of radiation exposure to employees of nuclear energy licensees.

INDUSTRIAL SAFETY

The AEC has long-established methods of determining the safety performance of operational activities involving AEC and AEC contractor employees (see Chapter 7—Operational Safety). It also maintains a systematic radiation safety inspection and enforcement program with respect to the operations of AEC licensees. However, comprehensive indicators of safety in the atomic energy industry have not been developed. In view of the need for industrial safety statistics that could be compared directly with those of other industries, the AEC requested the Bureau of Labor Statistics (BLS) to conduct a special survey of private companies having employees in atomic energy work. The BLS survey included statistics on 175 establishments

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with 183,617 employees for the year 1965, and 176 companies with 45,494 employees in 1966.[21]

Industry Injury Frequency and Severity

The BLS report, which covered all types of industrial accidents, showed the work-injury experience of the private atomic energy industry to be better than that of most industries reported to BLS in its nationwide survey.

It indicated that a frequency rate of 4.3 disabling injuries for each million man-hours worked was achieved by the atomic energy industry in 1965 and a rate of 4.7 in 1966. The 1965 frequency rate was considerably below the comparable rate of 12.8 for all manufacturing industries as reported to BLS in its national survey.[22] (For AEC and AEC-contractor rates see Chapter 7—Operational Safety.)

The severity rates of the private atomic energy industry—the total days "lost or charged" because of injuries for each million man-hours worked—were 514 and 539, respectively, for 1965 and 1966. The 1965 severity rate also compared favorably with the BLS average of 900 for all manufacturing industries for the same period.[22]

The BLS survey covered industrial accidents of all types. None of the injuries recorded in the survey in 1965 was attributed to exposure to radiation. In 1966, one injury occurred involving X-radiation burns to the fingertips of one hand of an employee.[23]

Radiation Exposure Statistics

To obtain information on the general levels of radiation exposure of employees of AEC licensees below that which is required to be reported under its regulations, the AEC contracted with four leading film badge processing companies to supply a summary of film badge readings for all AEC licensees who subscribed to their services during the calendar year 1966.

The four film badge processors whose data covered 61,000 persons employed by licensees, reported that badges of 96.2 percent of the employees indicated annual doses in the range of 0 to 1 *rem* [24] and 99.8

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[21] Establishments in the commercial sector were identified from a list reporting to BLS in a survey of professional and technical manpower. Government-owned facilities operated by private companies under contract, and firms with less than 25 employees working in the atomic energy field were eliminated from the list for purposes of the survey.

[22] Work-injury statistics for 1966 for all manufacturing industries were not yet available at year's end.

[23] The AEC does not regulate or license the use of X-ray generating devices.

[24] Rem stands for roentgen equivalent man—A measure of the dose of ionizing radiation to body tissues in terms of its estimated biological effect relative to a dose of 1 roentgen with high voltage X-rays.

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percent showed doses in the range from 0 to 5 *rems*. These results are comparable to those indicated in statistics maintained by the AEC for its employees and those of AEC contractors.

The 61,000 individuals covered by the statistics included the employees of approximately 2,900 or 41 percent of all AEC licensees, and thus are considered to be representative of all AEC licensees.

COMPLIANCE AND ENFORCEMENT

During the 12-month period ending November 30, 1967, 1,43[illegible] inspections were made of operations conducted under specific AEC licenses to possess, use, or transfer byproduct (reactor-produced) source, or special nuclear materials. In addition, a total of 385 inspections of licensed facilities were performed during the 12-month period, representing a 9 percent increase over the corresponding period ending November 30, 1966. Facility inspection efforts were concentrated on nuclear powerplants both under construction and in operation, with 215 inspections being made at 39 such plants. Approximately 90 percent of the cases in which inspection disclosed noncompliance were handled by the regional offices. The remainder, which involved more serious or complex cases of noncompliance, were referred to AEC headquarters for action. Compliance inspections during 1967 showed that reactor and other facility licensees experienced occasional equipment malfunctions and other operating problems, as is normally experienced with the operation of complex facilities. None of these occurrences presented any hazard to licensee employees or to the general public.

Four Orders Issued During Year

During the year, orders were issued to four materials licensees by the Director of Regulation because of violations of AEC requirements. The license of a radiography firm was suspended because of the use of unqualified radiographers and their helpers. A cease and desist order was issued to another radiography concern because of alleged falsification of its calibration records for radiation survey instruments. The license of a laundry was suspended because the firm processed clothing contaminated with radioactivity at an unlicensed location. The license was reinstated later when proper facilities became available for use. A uranium mill operator was ordered to stop using any liquid waste retention system not described in its license application after the embankment of an unauthorized storage pond ruptured and discharged radioactive material to the Colorado River.

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...diation Incidents

...icensees are required by AEC regulations to report all significant ...iation incidents.[25] Each incident is investigated by AEC personnel ...determine its cause, extent of exposure to personnel, adequacy of ...see efforts to prevent recurrence, and need for licensing or enforce... action. Eighteen such incidents were reported from among the ...roximately 7,000 AEC materials licensees in the 12-month period ...ing November 30, 1967.

Fourteen of the 18 incidents involved radiation exposures to a total ... persons. One of the incidents disclosed an estimated exposure of ... *rems* to the hands of two men engaged in the encapsulation of ...ntium-90 sources. The exposure apparently had occurred in 1962. ...earlier investigation by the licensee did not reveal that a skin condi... suffered by the two men was attributable to radiation. One man ...fered a recurrence of the skin condition and the licensee reported ... matter to the AEC in 1967. An AEC compliance investigation, in ...ich a medical consultant participated, concluded that the condition ... caused by an earlier radiation exposure of at least 1,000 *rems* to ... hands.

The highest 1967 exposure reported in the remaining 13 incidents ...lving exposures to personnel was a dose of 750 *rems* to the left ... of a radiographer, causing reddening of the hand. Apparently, ...out making the required radiation survey, he had handled the ...ce cable of the radiography camera briefly while the source was ...in its unshielded position. No harmful effects were observed in ...12 other incidents involving radiation exposure. The maximum ...e-body exposure was 39 *rems* and exposures to hands ranged from ...200 *rems*. In one of these incidents, two employees received lung ...sures of 45 *rems* and 14 *rems*, respectively, from deposition of ...um-192 when an abrasive wheel accidently cut into a capsule.

The four remaining incidents did not involve significant radiation ...sure but were reported pursuant to regulations because of facility ...down for more than one day, releases of 50 cc. and 10 cc. of tritium ... to the atmosphere, and damage of $18,000 to a plant as the result ...chemical explosion.

...Radioactive Materials

...ensees reported 31 losses of radioactive material for the 12-month ...d ending November 30. In 10 cases the materials were later

[25] ...es of incidents required to be reported by AEC licensees are listed in a footnote ... "Annual Report to Congress for 1965." Licensee reports on all such incidents ... for public inspection in the AEC's Public Document Room, 1717 H Street NW., ...ton, D.C.

recovered. In the 21 other cases, a careful review and evaluation of the individual circumstances surrounding the loss was made by the AEC. It was determined, based on the circumstances involved, that it was unlikely that any of these reported losses would constitute a hazard to the public health and safety.

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Chapter 7

OPERATIONAL SAFETY

During its history, the AEC has maintained an outstanding safety record, not by chance, but by careful planning. Accident prevention measures, experience gained from the few accidents that do occur, and the cooperation of AEC and AEC-contractor management and employees have all contributed to AEC's leading position in industrial safety. The year 1967, in fact, was a record year for the AEC and its contractors. It was the safest year in the AEC's 20-year history. The injury frequency rate (the number of disabling injuries for each one million man-hours worked) was 1.45 in 1967, compared to 1.54 in 1966 and an overall industry average for that year of 6.91. Early in 1967, the AEC and its contractors were presented with the National Safety Council's 1966 "Award of Honor" for the fifth consecutive year and for the seventh time in the history of the AEC.

PUBLIC SAFETY ASPECTS

Control of nuclear and nonnuclear contaminants continued to be emphasized during 1967 in all AEC activities, from the simplest to the most complex. Control of air pollution was further intensified and water pollution controls were maintained at a rigid high level.[1]

POLLUTION CONTROL

Review of progress on the water pollution abatement plan developed in response to Executive Order 11288 (of 1965) showed that all but one proposed abatement project would be completed by January 1968. The remaining project, a treatment plant for the removal of chromium from anticipated increases in the discharge of cooling water from Argonne National Laboratory, is under further study. More effective chromium removal is also under study at the Paducah Gaseous Diffusion Plant.

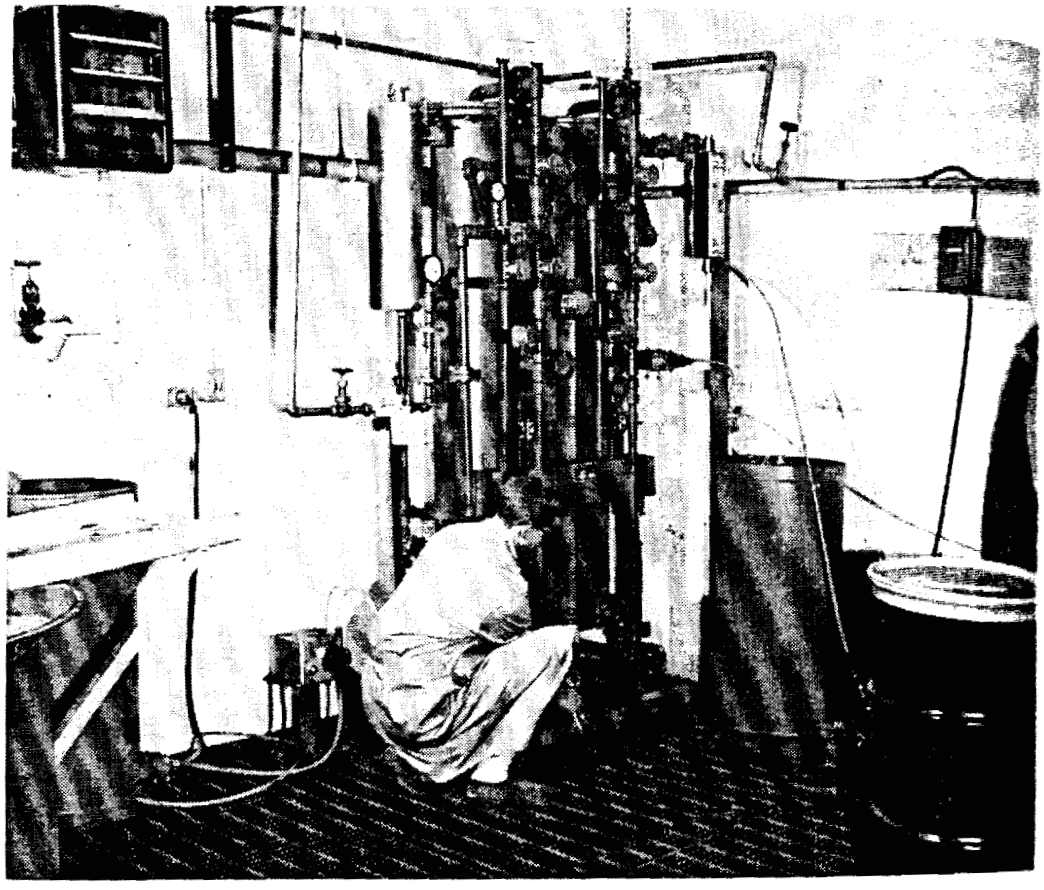
[1] See pp. 337–340, "Annual Report to Congress for 1966."

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Included in the plan are 24 proposed actions at 20 AEC plant locations to meet newly established standards for nonradioactive pollutants. Specifically, major portions of the plan are directed toward compliance at fossil fuel-fired heating and powerplants with the particulate and sulfur dioxide emission standards promulgated by the U.S. Public Health Service (USPHS), and meeting similar USPHS standards concerning open-pit burning and incineration of refuse.

Uranium Mill Tailings

In July, the AEC and the USPHS began a joint sampling program to evaluate the public health aspects of radon, a gas produced by radioactive decay of radium, at and near uranium mill tailings in the



Pollution Abatement by Waste Chromate Recovery. The feasibility of recovering and reusing chromates from the discharge of recirculating cooling water systems has been demonstrated by the operation of this ion exchange pilot plant for the past year. Testing of the chromate recovery system was a joint effort between Nalco Chemical Co. and Union Carbide Corp., operator of the AEC's Paducah Gaseous Diffusion Plant. The recovery of chromate by ion exchange is based on a process patented by Nalco. Determination of the best solution to the chromate problem is being studied further as part of the AEC's pollution abatement program.

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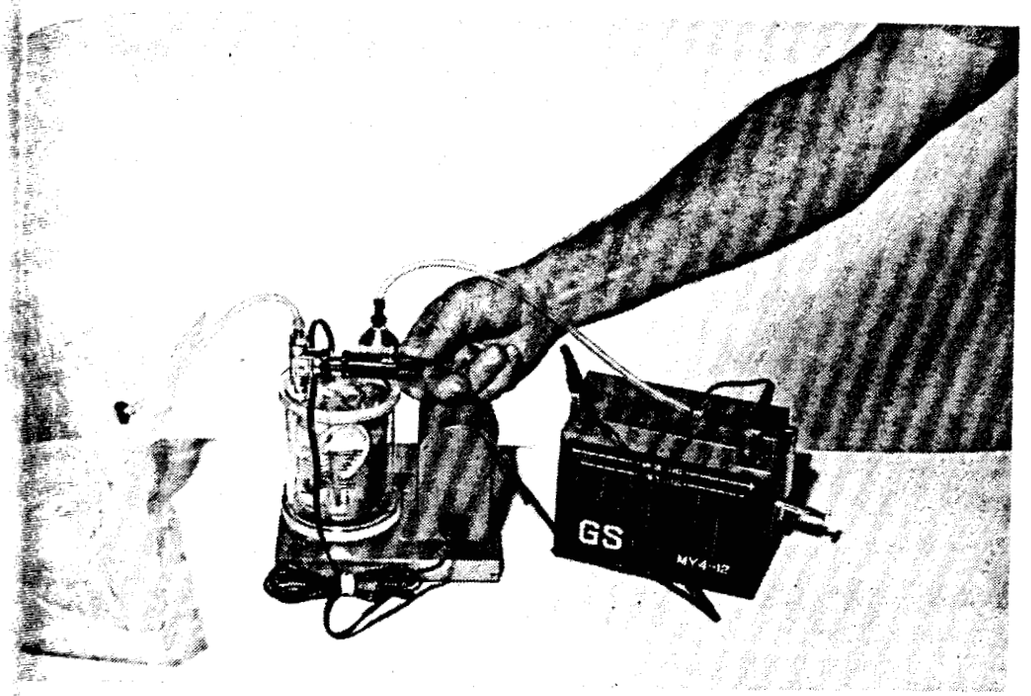
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olorado River Basin states. The piles at Monticello, Utah, Grand unction and Durango, Colo., and Salt Lake City, Utah, will be udied.

Work to be performed includes: (*a*) the development of techniques sampling air for radon content in the vicinity of uranium tailings; determination of the effect upon radon emissions when tailings covered with earth or paving material; (*c*) evaluation of atmospheric concentrations near tailing piles as a first step to develop an dex of population exposure; and (*d*) the preparation, if necessary, recommendations for the control of radon exposure.

The Monticello pile is covered, and the others are considered representative of uncovered piles. Samples (covering 48-hour periods) will collected every 3 weeks at each site for about 1 year, to eliminate subjective extrapolation and extensive weather data required to timate an annual average radon level from one or two samples. A



Gas Sampler. Because of the marked differences in the release rate of gas from the ground (occurring as a function of time), the actual radiodose potential from mill tailings piles has been difficult to assess with the sampling techniques presently used. The AEC's Health Services Laboratory National Reactor Testing Station, Idaho, has developed an integrating pler to permit air to be collected continuously for periods up to 48 hours to out the fluctuations and permit a more realistic evaluation of the dose relatively few samples. A small aquarium aerator pumps air at about 10 iters per minute through a filter and a precision needle valve with a digital ator handle into a collapsible 40-liter Mylar bag. The pump can be used directly from an AC line or from a 12-volt storage battery through the power inverter, as shown, when sampling at locations remote from a source ctric power.

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new sampling technique was developed by the AEC's Idaho Health Services Laboratory to accomplish the sampling of the amount of radon gas emanating from a tailings pile in a 48-hour period.

OFF-SITE MONITORING ACTIVITIES

The AEC has an established system of environmental monitoring as a part of the radiation safety program for each major installation. The safety staff for each major facility continues to submit reports semiannually on measurements of nuclear radiation and radioactivity in the off-site area. These data are summarized in Radiological Health Data and Reports,[2] a monthly publication of the U.S. Public Health Service. Similar data are provided periodically for the Nevada Test Site (NTS), and the Nuclear Rocket Development Station (NRDS) located within the NTS reservation.

Nevada Test Site

There are programs and staff at NTS, NRDS, and the AEC Nevada Operations Office to cope with day-to-day radiological situations and to assure the safety of off-site residents. A safety evaluation is made before conducting any nuclear test. The AEC obtains the advice of other Federal agencies and contractors who also have technical staffs with detailed knowledge of these potential hazards.[3] The AEC supports a program of long-range safety studies to develop data for a better understanding of the radiological and physical effects that may have a controlling or limiting influence upon testing programs. The off-site radiological monitoring around NTS, and also at other (Central Nevada, Amchitka Island, and Plowshare program) test sites, is conducted for the AEC by USPHS.[4]

During 1967, there were 25 announced underground weapons development or Department of Defense (DOD) tests, three underground Plowshare experiments (see Chapter 11—The Plowshare Program

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[2] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Subscription Price—$5.00 per year; $1.50 additional for foreign mailing; single copy, 50¢.

[3] These agencies and contractors are: The U.S. Public Health Service; the U.S. Environmental Science Services Administration (which includes the Air Resources Field Research Office and the U.S. Coast and Geodetic Survey); the U.S. Geological Survey; the U.S. Bureau of Mines; the Environment Research Corp., 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, Calif.; Holmes & Narver, Inc., Los Angeles, Calif.; EG&G, Inc., Las Vegas, Nev.; Eberline Instrument Corp., Santa Fe, N. Mex.; Battelle Memorial Institute, Columbus, Ohio; and Desert Research Institute, University of Nevada, Reno, Nev.

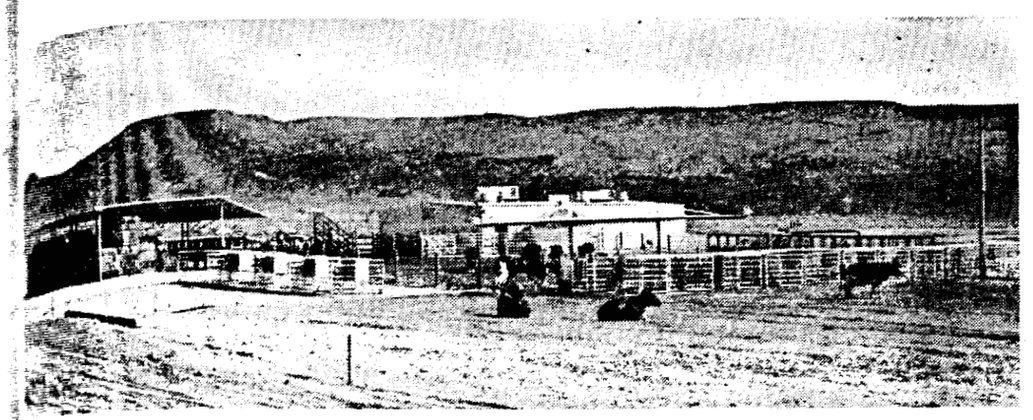
[4] See p. 63, "Annual Report to Congress for 1965," for a map of station locations

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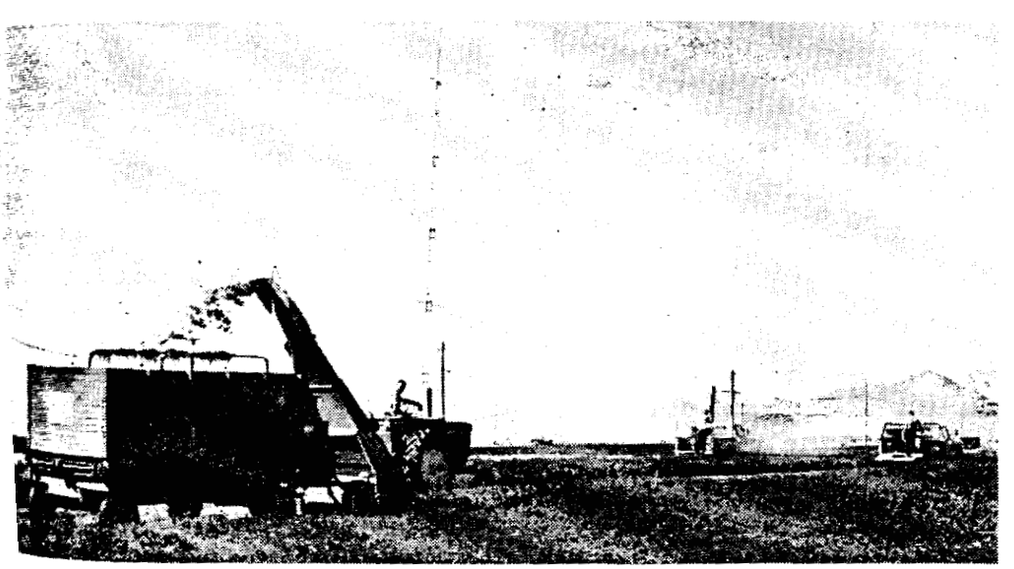
three NRDS full-power space reactor tests at the Nevada Test Site (see Chapter 8—Nuclear Rocket Propulsion).

The NRDS full-power space reactor test conducted on December 15, 1967, released some radioactivity to the off-site area. From preliminary data, it appears that the levels of radioactivity in air, milk, and water did not exceed those levels listed below following earlier tests conducted during the year. The time required for collecting and analyzing the samples collected in the off-site area preclude inclusion of the data in this report.

Detectable levels of radioactivity were measured off-site, by ground monitoring, from three of the 1967 underground nuclear detonations: Hush, January 19, Umber, June 29, and Door Mist of August 31 (see Appendix 4). Only from the Umber event could external gamma



...w at NTS. Green crops and a modern dairy farm appear out of place in the ...c dry, hot desert environment of the AEC's Nevada Test Site (NTS). Photo ... shows part of the U.S. Public Health Service-operated farm at the NTS; ... the photo *below* shows green feed for the animals being harvested. The crops ...cattle are a part of the AEC's continuing health and safety program to develop ...rmation on the environmental effects of nuclear testing.



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radiation levels above background be positively detected at a popula... off-site location. The highest dose rate measured in a populated ar... for this event was at Death Valley Junction, on the California bo... and 25 miles south of the controlled area (NTS plus the adjacent N... Air Force Range). The peak dose rate measured in the morning ... June 29 was 0.1 milliroentgen [5] per hour; it returned to backgro... level by noon that day. The total estimated dose was about 0.4 mi... roentgen and could have been received only by a person who had r... mained out-of-doors during the entire period of cloud passage. T... is a small fraction of the average annual exposure in that area (1... 200 milliroentgens) from all naturally occurring radioactivity an... from cosmic radiation.

Film Badges. Approximately 1,905 film badges were issued to t... off-site population in areas surrounding NTS during the year. Thes... badges, each worn for approximately 1 month, are used to relate... off-site exposures associated with NTS events. None of the badge... showed exposures above the lowest limit of detectability for these film... (20 milliroentgens).

Milk Monitoring. About 342 routine samples were collected a... approximately 43 different milk sampling stations during 1967. I... addition to the routine milk samples, 350 special samples were co... lected for NRDS activities and 82 special samples for weapons events... Among these milk samples, the two highest iodine-131 values for the... year (each 0.09 nanocurie [6] per liter) were correlated with foreign... atmospheric weapons tests. These values may be compared with the... computations of the Federal Radiation Council (FRC) for a single... deposition of iodine-131 on pasturage. A peak value of 4.2 nanocuries... of iodine-131 in a liter of milk, using the FRC assumptions for intake... may be equated to the guide for a suitable sample of an exposed... population group for normal peacetime operations.

Water Monitoring. Water supplies are routinely monitored for gross... beta radiation in the off-site area around NTS. During the year, sam... ples were collected at 90 different locations. Of the more than 7... samples collected, there were no positive results for fresh fission... products, including radioiodine.

Gross Beta Radioactivity in Air. There were 105 air sampling stations... operating continuously in the area surrounding the NTS. In addition... up to 65 supplementary samplying units were employed during specia... events. The peak gross beta concentration in air in a populated area...

[5] A milliroentgen is one thousandth of a roentgen.

[6] A nanocurie is a quantity of radiation in which there is the same number of disintegra... tions per minute as in one-thousandth of a millionth of a gram of radium.

...during 1967 ... at Lathrop ... NRDS on F... passage of a ... (gross beta ... Plowshare te... The measu... determining ... by air sample... rate the prese... determine the... be collected f...

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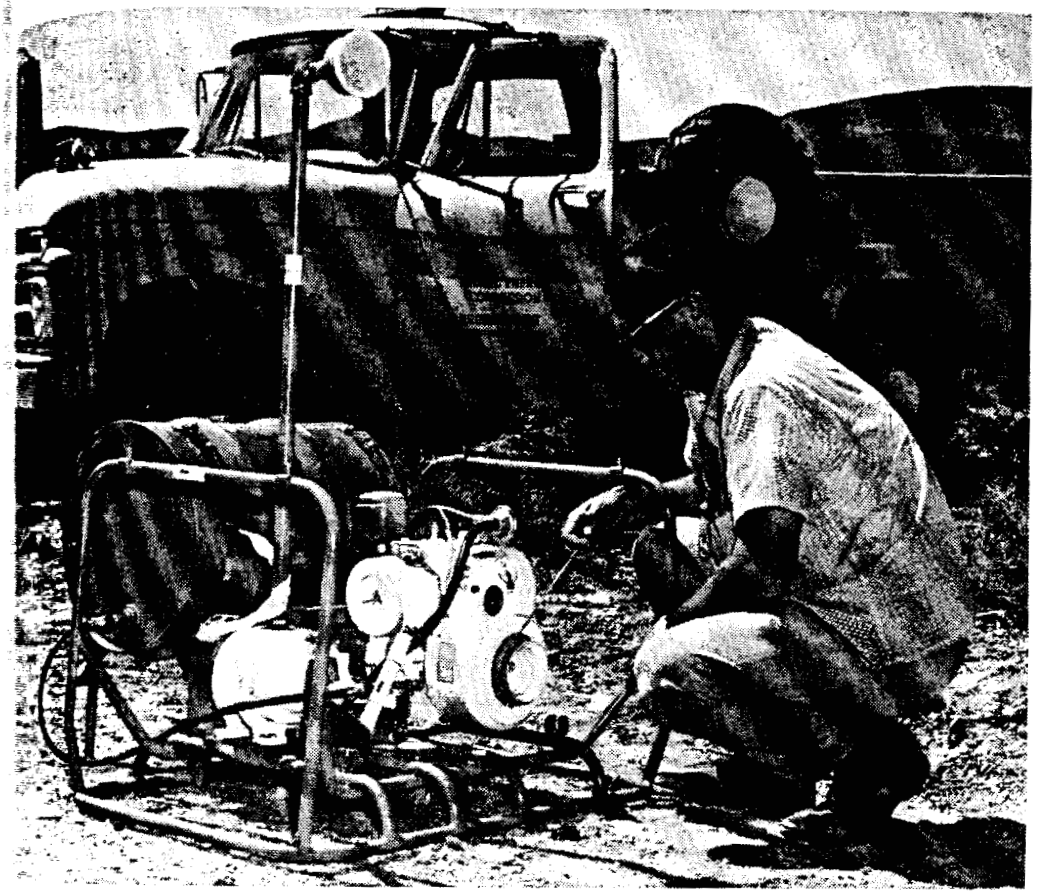
New Air Sampl... Engineering Co... testing operatio... and the cost o... tional advantag... the use of a limi... The units are se... a positive-displa...

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during 1967 was 228 picocuries[7] per cubic meter of air. This occurred at Lathrop Wells, Nev., following a space propulsion reactor test at NRDS on February 24. This was a transient increase caused by passage of airborne radioactivity.

Gross beta results on air filters collected following weapons or Plowshare tests at NTS did not exceed 2 picocuries per cubic meter. The measurements of gross beta activity in air have little value in determining radiation doses to persons. However, the data obtained by air samplers are used by the off-site monitoring group to: (*a*) indicate the presence of airborne radioactivity in a specific area, and (*b*) determine the areas where milk, water, and vegetation samples should be collected for analysis.

[7] A picocurie is a quantity of radiation in which there is the same number of disintegrations per minute as in one-millionth of one-millionth of a gram of radium.



Air Sampler. For use at the Nevada Test Site, the Reynolds Electrical and Engineering Co. has developed a compact air sampler for use in the field during testing operations. The new unit is smaller, more efficient, and operates at one-half the cost of the previous air sampling trailers. The model also has the additional advantage in that samples are obtained in a more predictable manner by use of a limited orifice technique which results in more reliable documentation. The units are self-contained and can operate for long periods of time and feature a positive-displacement pump directly coupled to a gasoline engine.

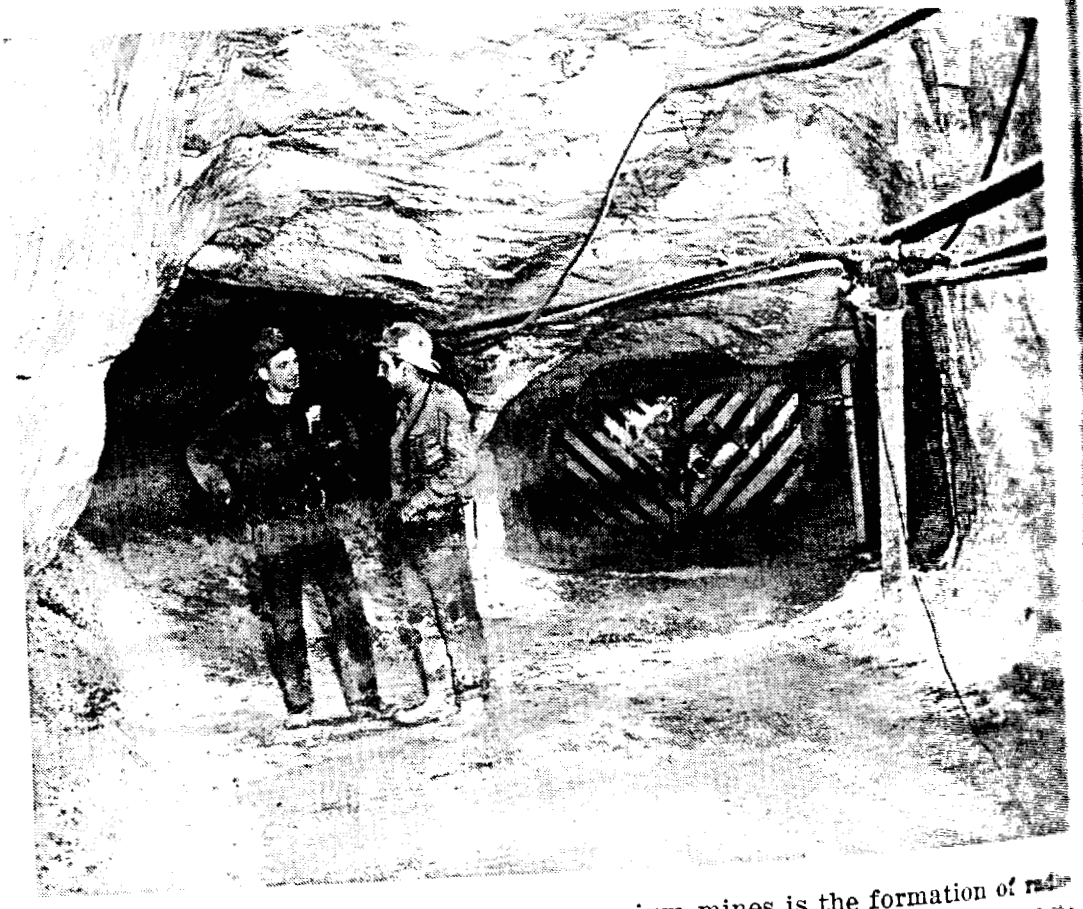
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OPERATIONS SAFETY ASPECTS

New guidelines for certain atomic energy program activities were prepared during 1967 and steps were taken to improve emergency radiological assistance procedures.

Uranium Miners' Health

During the spring and summer of 1967, the Congressional Joint Committee on Atomic Energy (JCAE) held extensive public hearings on radiation exposure of uranium miners. These exposures are attributable to daughter (decay) products of radon which is itself a gaseous decay product of uranium. The higher concentrations of daughter products are found in underground mines having poorer ventilation. Miners working in such areas have been observed to have a higher incidence of lung cancer than that found in the general population. Testimony by authoritative witnesses indicated that the



Uranium Mine. One of the hazards in uranium mines is the formation of radon active radon gas, a decay product of the ever-present radium, and one of the heaviest gases known. During the year, the Government took steps to reduce uranium miners' exposure to radon. United Nuclear Corp. photo shows pair of ventilation doors installed to reduce radon concentration at a drift intersection

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assumption of uncertainties. The AEC ha eral agencies t underlined the eral jurisdicti ators—had int underground n in Denver in 1 have been imp lung cancer—1 crease despite t the 1960's. Exp have started w 1930's.

Other factor are: (*a*) the di dividual miner (*c*) lack of a of adequate ex or across occu posure to oth practices.

In response t research and d terior's Bureau the Departmen vision of respo has been agre can best be acc

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New Uranium

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sumption of a direct cause-and-effect relationship is fraught with certainties.

The AEC has, over the years, cooperated with State and other Federal agencies to improve conditions in uranium mines. The hearings underlined the difficulties presented by overlapping State and Federal jurisdictions. The States—traditionally the mine safety regulators—had intensified their efforts to bring about better ventilation in underground uranium mines following a Conference of Governors in Denver in 1960. Over the years, working conditions in the mines have been improved. Because of the long period for development of lung cancer—10 to 20 years—the total number of cases is likely to increase despite the corrective actions taken in the late 1950's and during the 1960's. Exposures related to current lung cancer mortalities may have started with the mining of vanadium-uranium ores in the late 40's.

Other factors complicating the analysis and solution of the problem are: (*a*) the difficulties of measuring and estimating exposures for individual miners; (*b*) controlling radon concentrations in mine air; (*c*) lack of adequate surveillance-monitoring equipment; (*d*) lack of adequate exposure records; (*e*) shifting of miners between mines and across occupational lines; (*f*) strong evidence of a history of exposure to other lung irritants; and (*g*) variation in ventilation practices.

In response to these problems, the AEC has joined in a cooperative research and development effort with the U.S. Department of the Interior's Bureau of Mines and with the U.S. Public Health Service of the Department of Health, Education, and Welfare (DHEW). A division of responsibility for various research and development activities has been agreed upon. Each agency is conducting programs which can best be accommodated by its staff and facilities as follows:

AEC: Improved surveillance-monitoring equipment, characterization of mine air, and basic research supporting development of improved instrumentation.

Interior: Improvement of mine air and personal protection.

DHEW: Epidemiological studies, medical aspects, bio-effects of alpha radiation, and evaluation of control methods.

It is anticipated that as the program continues, many projects will be expanded and new ones will be initiated.

New Uranium Mine Safety Guidelines

During 1967, the AEC worked closely with the Federal Radiation Council (FRC), an advisory body to the President on radiation matters, in the preparation of FRC Report No. 8, "Guidance for the Con-

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trol of Radiation Hazards in Uranium Mining." The report and associated memorandum to the President was approved in July. They contain recommendations for both immediate and near-future steps to improve the working environment for uranium miners and establish guides for controlling exposure of miners.

Accelerator Safety Report

The AEC has issued a publication, "Safety Guidelines for High Energy Accelerator Facilities,"[8] which was prepared by a national committee established by the AEC to evaluate and recommend safety guidelines. The committee's report presents guidelines that may be considered by management for development of policies and standards and review of safety programs in accelerator laboratories and represents much of the knowledge and experience currently available in the area of accelerator safety. Included are considerations of problems having special significance to the safe conduct of research at high energy accelerator laboratories.

Emergency Assistance and Information Systems

Implementation of the Interagency Radiological Assistance Plan at the regional level has been accelerated in an effort to establish liaison and regional coordination between AEC regional coordinating offices and the offices of other Federal agencies. AEC regional radiological assistance plans were revised to include procedures by which the appropriate personnel and other resources of several Federal agencies would be organized at once in the event they are needed to protect health and safety after an accident involving radioactive materials.

AEC Accidents and Property Damage

Ten deaths occurred in AEC operations during the year, none from radiation. Nine resulted from industrial-type accidents and one from a motor vehicle accident—as compared with two in 1966. The AEC property damage ratio of a little more than 1 cent was well below the AEC 20-year average of slightly over 2 cents loss per $100 of AEC owned property and compares with a rate of one-half cent for 1966. Of the total property damage of $2,394,126, three operating incidents each resulted in a loss of $100,000 or more.

[8] Available (TID–23992) from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $0.30 per copy.



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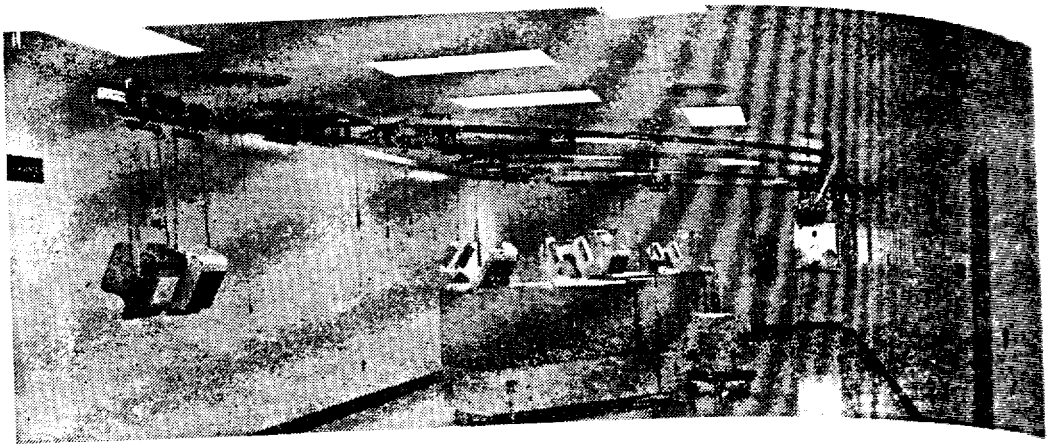


New Dosimeter System. Conventional dosimeter film packets have been replaced with lithium fluoride (LiF)-Teflon disc thermoluminescent dosimeters (TLD) in the badges of approximately 3,000 regular employees at the National Reactor Testing Station (NRTS) in Idaho. Substituting the TLD system required no modification of the NRTS dosimetry badge holder. The badges, shown *at left*, use two LiF-Teflon disc dosimeters, one positioned in the open-window area and the other in the cadmium filter area. The discs are held in a plastic dosimeter retainer the same size and ...pe as a standard dosimeter film packet. An insert in this plastic retainer ...ides a punched binary code number for identification. NRTS personnel using ...Teflon disc dosimeters are those who normally receive less than 500 *mrad* per ... total exposure. Except in case of accident or a known exposure the dosim... are read on a quarterly basis. In the routine processing of the badges a data ...isition system is utilized. This system, shown *below*, composed of a mechani... contact-closure sensing device and electronic punch-drive circuitry, records ... badge number and the digital thermoluminescence value on punched paper ... at the time of the readout. This paper tape serves as input to a computerized ...ation and record-keeping system from which all reports and information ...eral are accomplished.

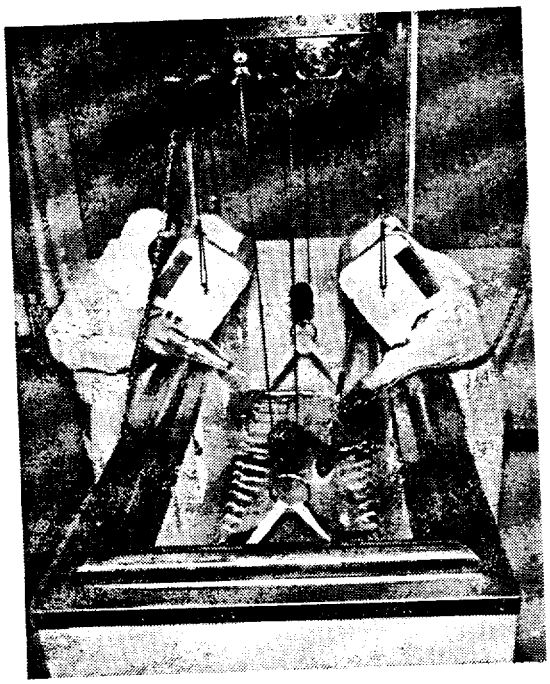


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On September 3, 1967, a severe wind and hail storm, with wind[illegible] the range of 80 to 100 miles per hour, and hailstones the size of orang[illegible] caused extensive roof and window damage, disrupted utilities, dem[illegible] ished a warehouse wall, leveled security fencing, and caused se[illegible]



Operating Room. Special facilities for treating persons with impregnated ra[illegible] active materials have been designed and built at the Hanford Works by the AEC, Vitro Engineering Co., Battelle-Northwest, and the Hanford Environmental Health Foundation. Special hoods with lead glass and shielding around the operating "cells" shown *above*, permit surgeons and others to work with no radiation danger and operations can be observed by closed-circuit tele[illegible] The facility is believed to be the only one of its type in the world. The equipment includes a shielded ambulance, a special electric hoist litter, overhead tr[illegible] system, "car wash" type whole-body spray, and two shielded cells. It will be used by all AEC medical departments to test various surgical decontamination con[illegible] cepts. Experience with it will contribute to the design of future units of this kind. In photo *below left*, the "patient" is placed in a heavily shielded body wash where a spray is used to remove surface contamination. In photo *below right*, the "patient" is being checked for injuries and monitored for radioactivity





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...icle damage at the Pantex Plant, Amarillo, Tex. The estimated 1.5 ...ion damage does not include weapon and weapons component ... incurred.

... fire occurred in a heat exchanger cell of the "N" reactor at the ...ford Works, Wash. which was being restarted after a maintenance ...down. The apparent cause was the escape of oil from the system ...plying oil to the bearings of the primary circulating pumps, prob- ... involving accidental tripping of solenoid valves by electricians ...ing previous maintenance work. The source of ignition for the oil ... not been determined. This accident, which occurred on June 21, ..., resulted in a property damage loss of $220,000.

...iation Exposures

There were no Type A[9] radiation exposure incidents during 1967. The 22 Type B reportable exposures occurred as follows: a 370 ... exposure to the right wrist of an employee while screwing caps ... shielded sample carrier; 250 *rem* exposure to the hands of an ...loyee while handling a radioactive steel wire; 80 *rem* to a hand of ...search technician while using an X-ray machine; 75, 39.4 and 39.2 ... to the hands of three employees while processing a curium solu- ...; 10.5 *rem* to the skin of the whole body of a rigger; and cumula- ... whole body exposures were received over a period of from six ... to three months by employees in the amounts of 5.9; 3.8; 3.7; 3.4 ... (four employees), 3.3; 3.2 *rem* (three employees), and 3.1 *rem* ...r employees), respectively.

...portable Type A and Type B incidents are defined in TID–5360, supplement 6, "A ...mary of Industrial Accidents in USAEC Facilities, 1965–1966," available from Super- ...dent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for ... copy.

... *rem* is the quantity of any type of radiation that, for general purposes, produces ... the same biological effect as one roentgen of X-ray radiation.

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Chapter 8

NUCLEAR ROCKET PROPULSION

The nuclear rocket program is a joint effort of the AEC and NASA [1] ...ed at providing a significant increase in propulsion capability ...uired for high-payload missions after Apollo. The nuclear rocket ...ers substantial advantages over the best high-energy chemical ...kets for such missions. In a nuclear rocket engine, a reactor heats ...uid hydrogen (−420° F.) to thousands of degrees and the hydro-...'s tremendous expansion through the rocket nozzle produces the ...pulsive thrust.

Through the extensive research and development conducted over ... past 11 years, the performance of the nuclear rocket has been ...monstrated, and the technological basis has been established for ...ceeding with the development of a flight engine called NERVA ...Nuclear Engine for Rocket Vehicle Application).

The significant achievements in the joint AEC/NASA nuclear ...ket program during 1967 were the continued development of graph-... reactor and engine system technology and preliminary design and ...gram planning for a nuclear rocket flight engine development ...gram. Complementing this was an extensive program of supporting ...earch and technology to: (*a*) enhance the performance capabilities ... nozzles, turbopumps, and control systems used in reactor and ...ine system tests; (*b*) gain a better understanding of component ...avior in these systems; and (*c*) obtain basic radiation effects data ... materials. Work also continued on the basic problems of advanced ...lear rocket propulsion concepts.

The preliminary phases of engine design and preliminary planning ... preparation for the development of a 75,000-pound-thrust engine ...ight status were completed during the year. This work showed that ...pletion of preliminary flight rating tests for an engine based on ...rent NERVA technology could be accomplished in 7 to 8 years. This

[1] National Aeronautics and Space Administration.

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engine would provide high reliability and major performance gain for a wide variety of advanced manned and unmanned space missions.

REACTOR TECHNOLOGY

In the reactor portion of the technology program, the goals for 1967 were to: (*a*) scale-up the technology demonstrated in previous reactor tests to conditions consistent with reactor operations at 5,000 megawatts, thermal (Mwt.); (*b*) extend reactor lifetime to 60 minutes; and (*c*) increase power density (power per unit of volume).

At the Los Alamos Scientific Laboratory (LASL) under the project heading of Phoebus, efforts were directed toward increasing temperatures, power levels, power densities, and the endurance capabilities of graphite reactors.

Phoebus Tests

In February 1967, the Phoebus-1B reactor was tested at the Nuclear Rocket Development Station (NRDS), in Nevada. The full power test of the Phoebus-1B was conducted on February 23, with the reactor operating at power levels approaching the 1,500-Mwt. design rating. The total operating time was approximately 46 minutes, with 28 minutes above 1,250 Mwt. (Approximately 10 minutes of power operation had been accumulated 2 weeks earlier during a reactor and instrumentation calibration test.) The reactor performed as planned during startup and shutdown. An error introduced in the reactor control circuits caused the reactor power to decrease gradually during the full-power run, but this did not prevent achievement of the major test objectives. Technically, the tests proved that resistance to fuel element corrosion was greatly enhanced; structural design improvements to reduce the amount of structural bypass coolant flow provided a substantial increase in specific impulse; and experiments to reduce corrosion in the unfueled perimeter area, and other improved structural components were successful.

Concurrently with the Phoebus-1 reactor work, LASL began to design and fabricate two large-diameter test reactors. The first of these reactors, a cold-flow assembly [2] called the Phoebus-2CF, was tested during July and August. More than a dozen test runs were made, and good data were obtained depicting the behavior of the reactor and facility. The tests: (a) verified the structural and mechanical integrity of the reactor design under hydrogen flow conditions; (*b*) permitted

[2] A "cold-flow" assembly cannot become radioactive since there is no uranium in the core; a "hot" reactor becomes radioactive during operation since it is uranium-fueled.

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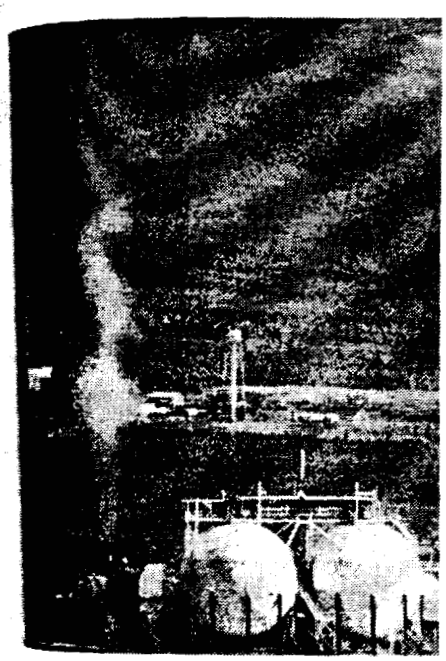
valuation of facility and reactor behavior under various reactor start-up conditions, such as those planned for the Phoebus-2A hot reactor; (*c*) verified instrumentation and control drum performance at the low temperature cold-flow conditions; and (*d*) confirmed design analyses through detailed measurement of reactor flow rates, temperatures, and pressures.

The second test reactor, called the Phoebus–2A, is now being assembled at NRDS. This reactor is a scale-up to approximately 5,000 mwt. of the 1,000 to 1,500 megawatt Kiwi [3]/NRX [4]/Phoebus–1 reactor designs. Reactor testing is currently scheduled to get underway in the second quarter of 1968.

NRX Experiments

On December 15, the sixth in the series of NRX reactors, the NRX–A6, was tested at NRDS. The primary purpose of the test was to obtain additional data on reactor fuel element characteristics under

[3] Kiwi—A series of nuclear rocket test reactors built by LASL, named for the tailless, stubby-feathered bird in New Zealand which cannot fly. The first Kiwi reactor test was conducted at NRDS in July 1959.
[4] NRX–NERVA Reactor Experiment.





Phoebus Reactors. The colorless hydrogen plume is barely visible in the *above* close-distance photo at *left* as the Phoebus-1B reactor operates at full power during February 1967. Dewar tanks at right hold the liquid hydrogen (—420° F.) supply for the nuclear propulsion reactor experiment. Photo at *right* was made with infrared film and gives a moonlight effect to a mid-day "cold flow" (non-reactive) test of the Phoebus-2CF reactor during July 1967 at the Nuclear Rocket Development Station in Nevada. The reactor has a coating of frost from the liquid hydrogen.

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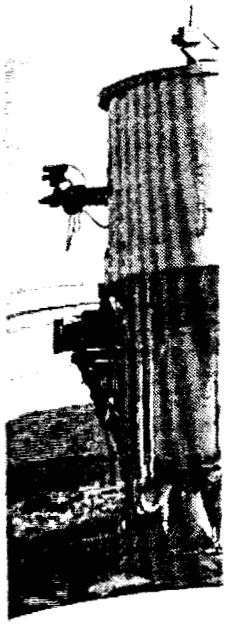
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extended running time of design power. In the experiment, the NRX-A6 was operated for approximately 70 minutes, of which 60 minutes was at the design power of approximately 1,100 Mwt. The duration at design power was twice that achieved in any previous space propulsion reactor test.

At year's end, the NRX–A6 was being disassembled at the NRDS prior to a post-mortem examination of the reactor core. These analyses will provide a good indication of the accuracy of electrically heated furnace corrosion experiments on single fuel elements for predicting fuel element performance in test reactors for extended durations.

Fuel Element Development

A major development effort in the reactor technology program is to extend both the duration and temperature capability of the reactor graphite components (fuel elements, etc.). Corrosion of components by the hydrogen propellant limits the duration of reactor operation at appreciable powers. Recent improvements in the coating of these components have provided gratifying results. For example, fuel elements coated by the most current process consistently have experienced less corrosion in 60 minutes of corrosion furnace testing than the average corrosion shown by the fuel elements in the NRX–A5 after 30 minutes at full power. The development of the process for producing these elements represents the culmination of years of effort by many program participants, the principal being the Westinghouse Astronuclear Laboratory, LASL, and the AEC's Y–12 Plant at Oak Ridge, Tenn., operated by the Nuclear Division of the Union Carbide Corp.



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ENGINE SYSTEM TECHNOLOGY

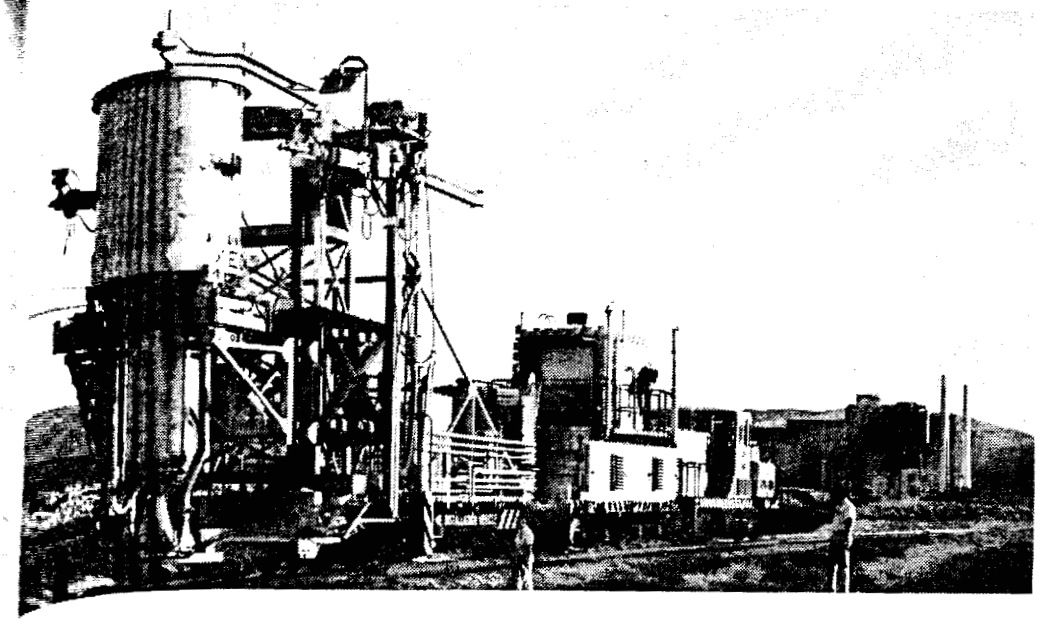
The remaining engine system technology goals will be accomplished through ground experimental engine (XE) investigations in the new Engine Test Stand No. 1 (ETS–1) at the NRDS. The Aerojet-General Corp., Sacramento, Calif., and Westinghouse Electric Corp. are responsible for this work. The goals are to: (*a*) operate to engine performance characteristics; (*b*) gain experience in operating nuclear engines in a down firing[5] test stand (ETS–1) under simulated altitude conditions; and (*c*) gain experience in the remote maintenance of a radioactive nuclear engine assembly.

Functionally, the design of the XE engine is similar to the "breadboard" engine system (NRX/EST) tested in 1966.[6] The primary

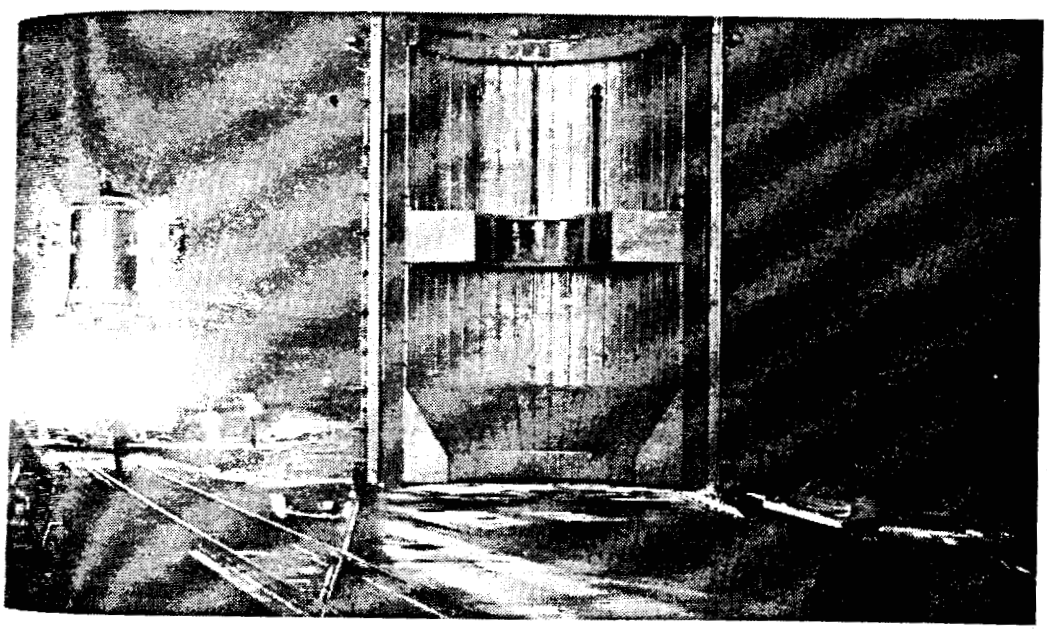
[5] Up to the present, all tests have been conducted with hydrogen gases being expelled skyward; in the ETS–1 the "down-firing" tests will be conducted in a normal thrust (downward) position and under conditions more closely simulating space flight.

[6] See p. 184, "Annual Report to Congress for 1966."

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XECF Transported to Test Stand. The first ground experimental nuclear rocket engine (XE) assembly is shown *above left*, in "cold flow" configuration (XECF) as it was being transported by the railroad-mounted "engine installation vehicle" to Engine Test Stand No. 1 (ETS–1) at the Nuclear Rocket Development Station in Nevada. The "cold flow" experimental engine is undergoing a series of tests designed to verify that the recently completed test stand is ready for "hot" engine testing; investigate engine start-up under simulated altitude conditions; and for checking of operating procedures not previously demonstrated. Photo *below* shows the XECF during its late evening arrival at ETS–1. The large object at the left of photo is one-half of an aluminum cylindrical shield that can be sealed around the engine, forming an air-tight compartment, to facilitate testing in a simulated space environment. (See also "Engine Test Stand No. 1" photo.)



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difference between the two is in the physical arrangement of components, which for the XE engine more closely approaches that of a flight configuration. Assembly of the major components of the first XE engine, a cold-flow assembly, has been completed. This engine, called the XECF, is to be used to verify that ETS–1 is ready for hot engine testing, and to investigate engine startup in the test stand under simulated altitude conditions. Other objectives include the checking of operating procedures that have not been demonstrated in previous tests, and the investigation of engine malfunctions under simulated conditions. Testing of the XECF is scheduled for the first quarter of 1968.

"Hot" Tests in ETS–1 Start in 1968

In addition to the work on the XE Cold-Flow engine, work also continued on the assembly of the first "hot" [7] ground experimental engine. The testing of this engine is currently scheduled for the second quarter of 1968.

All ground experimental engine tests will be conducted in the ETS–1. Each engine will be fired downward into an exhaust duct with which it will be possible to simulate high-altitude operation. The construction of ETS–1 has been completed and experimental plans are now in progress to check the various facility subsystems. The first hot XE engine is currently scheduled to be installed in the stand in March, 1968.

Removal of a radioactively "hot" engine from ETS–1 will be accomplished remotely through the use of a locomotive-driven "manned control car" and "engine installation vehicle." These vehicles were checked out at NRDS during 1967 and are ready for operation.

The maintenance, assembly, and disassembly of ground experimental engine will be accomplished in a building called E–MAD at NRDS. This building was partially activated on June 8, 1967, and will be ready to support engine testing in 1968.

COMPONENT DEVELOPMENT

Each reactor and engine system test that is conducted at NRDS is the culmination of many concerted component development activities. In addition, each test serves as a building block to advance the current state of the technology and to prepare the way for the next echelon of experiments.

[7] Containing uranium fuel.

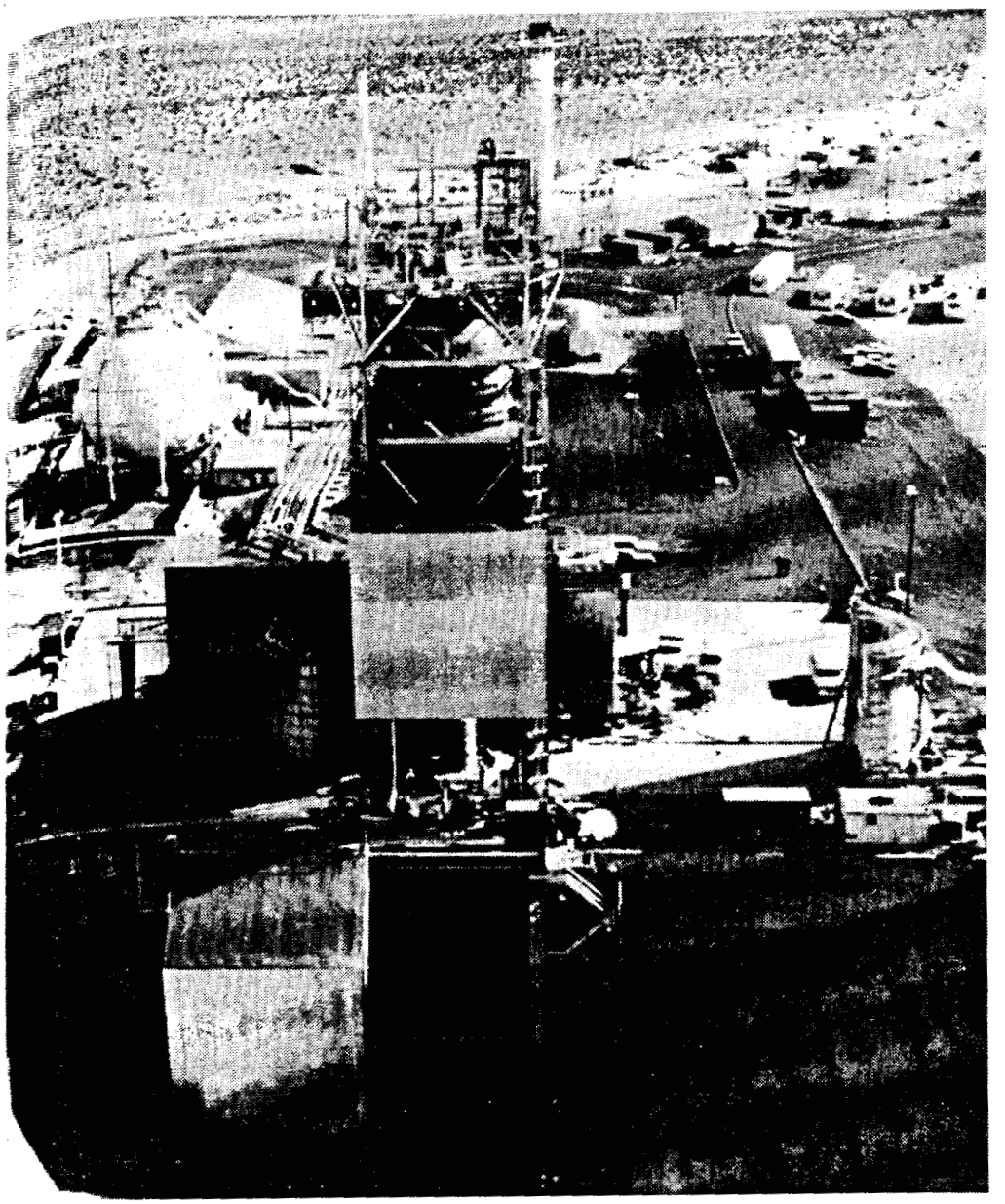
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The major component development work conducted during 1967 centered on the nonnuclear components required to conduct the Phoebus–2A hot tests. The two most important of these components



Test Stand No. 1. All ground experimental engine tests for the NASA nuclear rocket propulsion program will be conducted in the recently completed ETS–1. Each engine will be fired downward into an exhaust duct (*bottom* of photo) with which it will be possible to simulate high altitude operation. The conditions will be simulated by locking the two curved shields (*center right*) around the experimental engine system. All previous tests have been in an "upward firing" position. The first "hot" XE engine is currently scheduled to be installed in the stand in early 1968. Removal of a radioactively "hot" engine from ETS–1 will be accomplished through the use of a remote-controlled locomotive.

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were the Aerojet-General regeneratively-cooled [8] nozzle for the Phoebus–2 reactor and the Rocketdyne [9] liquid hydrogen feed system for the Test Cell "C" facility (see below).

Nozzle Development

The Phoebus-2 nozzle is similar in design to the U-tube nozzle used for NRX–A reactor testing, except that Hastelloy X is used as the principal structural material instead of stainless steel. Hastelloy X is more suitable for the higher operating temperatures and stresses of the Phoebus-2. The Phoebus nozzle also is larger and this required the development and application of new fabrication techniques. In 1967, Phoebus-2 development nozzles were successfully fabricated in time for use on the Phoebus-2CF reactor, tested in July, and the Phoebus-2A reactor, scheduled for hot testing in early 1968.

In addition to the fabrication of nozzles for Phoebus-2 reactor program, Aerojet-General carried out 75 seconds of chemical test firing on a single Phoebus-2 nozzle during August 1967. Subsequent to these tests, a "margin" test firing was conducted in which the flow of coolant throughout the nozzle tubes was purposely reduced to establish the minimum coolant flow that could be tolerated during a hot reactor test. Both experiments were successful.

Feed System Development

The basic unit of the Rocketdyne-developed propellant feed system (called the NFS–3b) is the MK–25 turbopump. Two units are used in each system. For the NRX–A6 and Phoebus-1 series of reactor tests, a single turbopump was used and the feed system was run in what was called single-mode operation. For the Phoebus-2CF test, and future tests of the Phoebus-2A reactor, two turbopumps are coupled in a parallel arrangement (dual-mode operation) to provide the required flow rate. During the year, the propellant fuel system was operated in both the single and dual modes, and tests run on the system have demonstrated excellent performance.

NERVA Engine Development

The objective of the NERVA development effort is to provide the Nation with the capability for a broad program of space exploration

[8] Cooled by the same liquid hydrogen propellant that is later heated to provide the propulsive thrust.

[9] Rocketdyne Division, Canoga Park, Calif., of North American Rockwell Corp.

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NERVA engine now in the preliminary design stage to provide capability will have a thrust level of approximately 75,000 pounds, altitude specific impulse in excess of 800 seconds, and will be veloped using as much of the output of the NERVA technology pro- am as possible. For example, the reflector design that was tested in NRX–A6 reactor will be used after removing some of the excess terial. For the engine components, many of the valves, lines, and uators from the technology program will be used after appropriate provements and qualification testing.

Major system testing will be conducted at NRDS using the facilities w available. Test Cell "C" will be used for NERVA reactor testing. gine system testing through the demonstration of flight readiness ll be accomplished in Engine Test Stand Number–1 now being ifated for the first power tests of the NERVA technology ground- perimental engine. After the ground-experimental engine test pro- am is completed, the stand will be modified to support the NERVA gine flight readiness tests. These modifications will provide the pability for increased engine run time, higher propellant flow rates, d simulated altitude.

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Chapter 9

SPECIALIZED NUCLEAR POWER UNITS

For several years, the AEC has been developing special purpose clear power units for space and terrestrial (land and sea) applica-s. (For information about other terrestrial nuclear power units, Chapter 5—Reactor Development and Technology.) The special-space and terrestrial units use heat from the decay of radioisotopes, e fissioning of uranium-235 in small nuclear reactors to make tricity. The isotopic systems can meet power requirements ranging m a fraction of a watt up to about 10 kilowatts (10,000 watts); power output from the reactor units will range from a few kilo-s to several megawatts.

PACE ELECTRIC POWER

uring the year, the AEC continued its program for developing testing nuclear electric power units for space use, and developing mily of long-lived reactor and isotopic systems which could supply about 50 kilowatts of electricity in the late 1970's. In addition, gress is being made on technology improvements required for the missions of the more distant future and to make possible higher-erature capability and more efficient power conversion for safe, ble, and economic performance while meeting expanding space tric power needs.

REACTORS FOR SPACE

A nuclear reactor designated SNAP [1]–10A was launched during 1965 operated successfully in orbit for 43 days before the reactor was down by a faulty command within the spacecraft. An identical tem was operated on the ground in a simulated space environment

[1] SNAP—Systems for Nuclear Auxiliary Power.

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for 417 days. This is believed to be the longest uninterrupted endura run that any reactor has ever attained. The post-operation examinati of this ground test unit, completed in 1967, revealed no life-limiti problems or unexpected conditions in the system. To date, the 5 watt SNAP–10A, built by Atomics International, Canoga Park, Calif. is the only reactor unit to be orbited.

SNAP–10A and SNAP–8-class reactors are useful for power leve in the range of from about 1 to 50 electrical kilowatts.

SNAP–8

Another nuclear reactor built by Atomics International, the SNAP 8, was operated for more than 10,000 hours producing more total energy at full power operating conditions than is required by the SNAP- system (5.1 million kwh. *vs* 4.5 million kwh.). When the reactor wa disassembled, cracks were found in the cladding of the fuel elements The cracks apparently were caused by swelling of the fuel and by the brittleness of the cladding. The fuel element design has been mod fied.

Fabrication of a second generation SNAP–8 reactor was underway during 1967. Power testing of this reactor system is expected in 196 It is to be used to demonstrate automatic startup and extended reactor operation at design conditions of 1,300° F. outlet temperature and 6 kilowatts, thermal (kwt.) and to obtain data on long-term fuel be havior, reactor component performance and systems required for de velopment of improved reactors of this type.

Advanced Space Power Development

More advanced reactor systems for use in space are being examined by the AEC. These reactors must meet the power needs of very long lived missions which require hundreds and possibly thousands of kil watts. Two advanced concepts under development are a liquid metal cooled reactor, and a reactor containing a thermionic power conversion system. Development activity on a third advanced concept (a gas cooled reactor) is being closed out in order to allow for a more con centrated effort on the concepts which promise to be applicable to a wider power range. The liquid metal reactor test program being con ducted at Lawrence Radiation Laboratory, Livermore, uses a potas sium Rankine cycle[2] for power conversion, but may also provide the

[2] Rankine cycle power conversion is a method of converting heat to mechanical energy using a two-phase (boiling and condensing) working fluid cycle. In space power systems the reactor coolant liquid takes heat from the reactor core and conveys it to a heat-exchanger boiler where the liquid-metal in the Rankine loop is converted to vapor. The vapor drives a turbine, which is linked to an electric generator, and then passes through a radiator-cooled condenser where it is condensed back to liquid which, in turn, is pumped back into the boiler.

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...n of coupling with other power conversion cycles in the 100 to ...W electrical kilowatt range. During 1967, research on this program ...ired an identification of reactor characteristics and development ...els and materials technology.

...he in-core thermionic [3] reactor research during 1967 was directed ...arily toward the development of thermionic fuel elements with ... endurance operation at emitter temperatures above 3,000° F. ...k on the thermionic reactor is being conducted by Gulf General ...mic at San Diego, Calif., by General Electric at Vallecitos, Calif., ...by the Los Alamos Scientific Laboratory.

ISOTOPIC POWER SYSTEMS FOR SPACE

...arious radioisotopes may be used for electric generators. The heat ...m the radioactive decay of the fuel is converted directly into ...tricity by thermocouples [4] in close proximity to the fuel or, in a ...re advanced concept, by an inert gas-driven turbine-alternator ...le.

...AP-3 In Seventh Year of Operation

...he isotopic power system concept available for use in space sys... is a radioisotopic-thermoelectric generator (RTG) fueled with ...onium-238. This concept has been in active use since the first ...AP-3 power system was launched aboard a navigational satellite ...961.

...n June 29, 1967, the SNAP-3 unit celebrated its sixth anniversary ...peration in space. It has already operated 1 year beyond its 5- ... design life, and is still in operation. By the end of 1967, the ...y's experimental navigational satellite powered by SNAP-3 had ...veled about 35,000 times around the world, continuing to produce ...io signals.

...uccessful early-flight operations of SNAP-3 led to the SNAP-9A ...gram to develop a 25-watt RTG for operational satellites.

...wo satellites with these SNAP-9A units on board were successfully ...ched into orbit in 1963. The generators provided all of the power ... the satellites, and although both satellites have ceased operations, ...metry indicates that both power units are still capable of operating ...reduced power levels. The plutonium-238 heat sources for the

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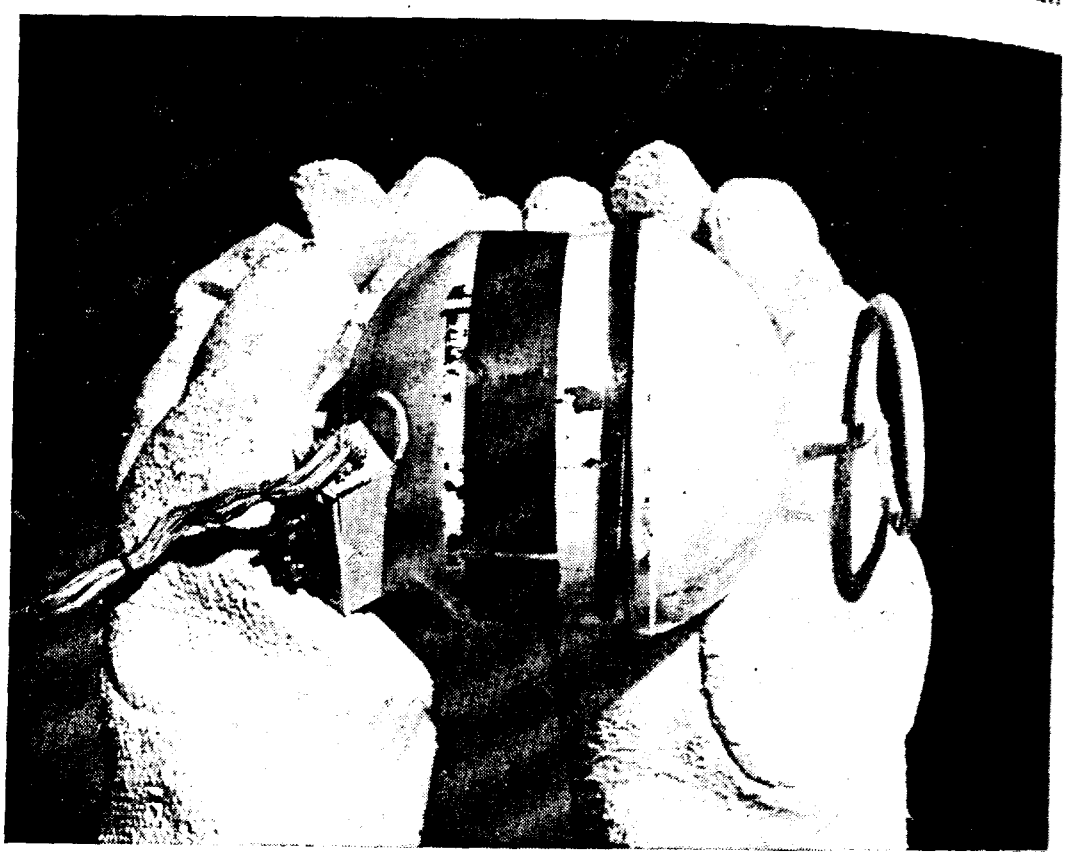
...By subjecting an emitter material to very high temperatures, electrons are boiled ...e emitter and are collected on a collector surface. This flow of electrons is a flow of ...tricity. This generation of electricity takes place within the reactor core.

...A thermocouple is made up of two dissimilar metals joined together at both ends ...a electrical circuit, producing a loop in which an electric current will flow when there ...difference in temperature between the two junctions.

SNAP–3 and SNAP–9A were developed and fabricated at the AEC's Mound Laboratory.

The SNAP–19 and SNAP–27 isotopic thermoelectric generators are nearing completion. The SNAP–19, developed for the AEC by the Martin-Marietta Co., is a 30-watt plutonium-238 fueled unit. A system comprised of two such units is planned to provide some of the power aboard the NASA Nimbus-B weather satellite scheduled for launch in the spring of 1968. The SNAP–19 units will supplement the solar cell generator which will be the main power source for Nimbus.

The SNAP–27, being developed for the AEC by General Electric, is also fueled with plutonium-238 and is designed to provide 50 watts of power. SNAP–27 systems are to be placed on the moon by astronauts during early Apollo missions. The SNAP–27 units will provide all



SNAP–3 in Seventh Year of Operation. Fueled with plutonium-238, the first SNAP unit to be placed in orbit—on June 29, 1961—is still in operation, more than a year past its designed life. The 5-pound, grapefruit-sized nuclear unit provided the heat to power two of the four transmitters aboard a Navy experimental navigational satellite. Intermittent signals are still being received from the nuclear-powered transmitters. Photo shows a duplicate unit, kept at the AEC's Mound Laboratory, whose isotopic-decay heat still makes it too hot to hold without asbestos gloves.

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Table 1 li
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[5] See pp. 205–2



SNAP–19 Under
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vibration testing
consists of two 3
with plutonium f

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power for Apollo Lunar Surface Experiments Packages (ALSEP)[5] for a period of 1 year after the astronauts return to earth. Table 1 lists the SNAP isotopic power systems already orbiting or planned for space use. Development of heat sources for these systems is described in the "Isotopic Fuels Development" section of this chapter.

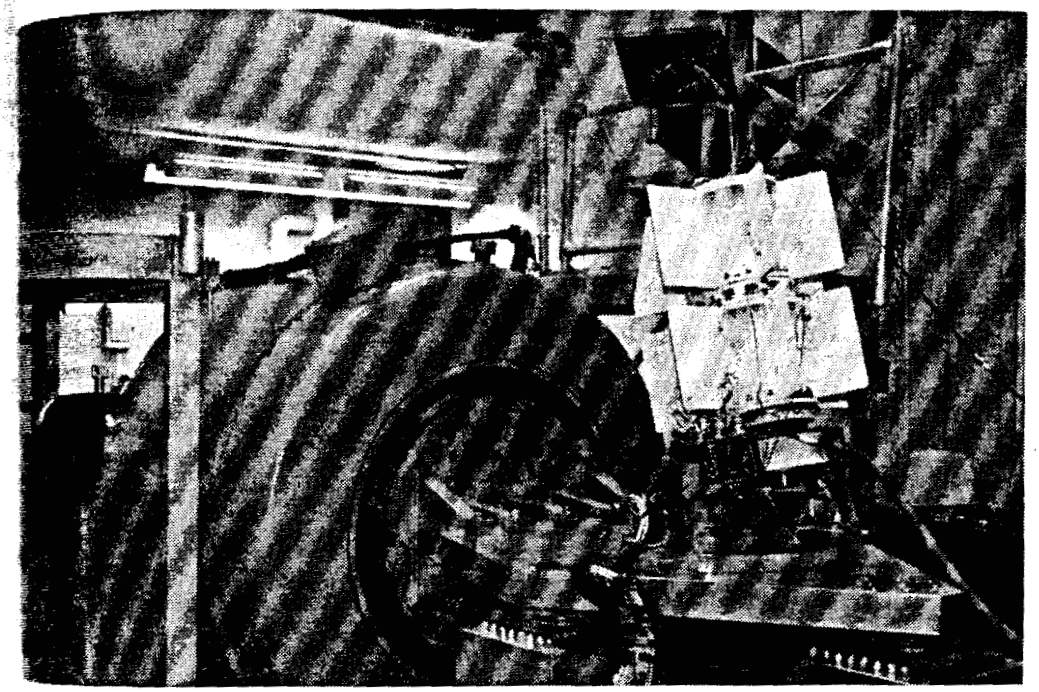
TERRESTRIAL ISOTOPIC POWER SYSTEMS

The AEC has been actively pursuing the development of isotopic power systems for terrestrial (land and sea) uses. The initial effort has concentrated upon the design and development of the first generation SNAP–7 systems which use strontium-90 for fuel.

The SNAP–7 series consisted of six experimental units in a power range of 7.5 watts to 60 watts for use in unattended remote environments. The SNAP–7 units still in operation are shown in Table 2.

The SNAP–7 program, which was successfully completed in 1966, demonstrated the feasibility of developing long-lived isotopic power

[5] See pp. 205–206, "Annual Report to Congress for 1966."



SNAP–19 Under Test. The SNAP–19 radioisotope space electrical power system for the Nimbus–B weather satellite is shown (*right center* of photo) on the vibration testing equipment at the Martin Co. in Baltimore, Md. The flight system consists of two 30-watt generators mounted end-to-end. The system will be fueled with plutonium for the scheduled launch in early 1968.

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TABLE 1.—SNAP ISOTOPIC POWER SYSTEMS FOR SPACE

Designation (SNAP No.)	Prime contractor	Electric power (watts)	Application	Fuel [1]	Unit design life	Status
3	Martin-Marietta Co.	2.7	Navigational satellites (DOD).	Pu^{238}	5 years	Unit launched in June 1961 is still operating in orbit; quantitive performance data not available.
9A	Martin-Marietta Co.	25	Navigational satellites (DOD).	Pu^{238}	5 years	Units launched in Sept. and Dec. 1963 are still operating but at a lower power level. Satellites inoperative.
11	Martin-Marietta Co.	25	Moon probe (NASA).	Cm^{242}	90 days	First fueling of a generator with curium-242 accomplished in July 1966. In Oct. 1966 fueled unit completed 90-day test under simulated lunar conditions.
19	Martin-Marietta Co.	30	Nimbus-B weather satellite (NASA) (Launch scheduled for 1968. Use of 2 SNAP-19 power units planned.)	Pu^{238}	1 year	Prototype fueled systems (consisting of two 30 watt RTG's tested in flight system qualification tests.
27	General Electric Co.	50	Apollo Lunar Surface Experiments Package (ALSEP) (NASA) SNAP-27 will provide power for experiments placed on the moon by early Apollo astronauts.	Pu^{238}	1 year	Electrically heated prototype system undergoing compatibility testing with ALSEP hardware. First flight generators delivered to NASA Oct. 1967.
29	Martin-Marietta Co.	200–1,000	Possible manned and unmanned space applications (DOD) and (NASA).	Po^{210}	3 months	Detailed design and subcomponents development initiated. Fabrications and testing of critical materials and components underway.
Radioisotope Brayton.	Not yet selected.	5,500	Manned space missions.	Pu^{238}	1 year	AEC will develop heat source; NASA the Brayton cycle. Prime heat source contractor to be selected early 1968.

[1] See "Isotope Fuels Development" section of this chapter.

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TABLE 2.—TER...

...signation	Power	
...AP-7B	60 watts	...
...AP-7C	10 watts	U
...AP-7D	60 watts	U
...AP-7E	7.5 watts	U...

...ems and also identified areas where significant technological ad-...ts were needed.

...AP–21 and SNAP–23

As a result of the success of the SNAP–7 program, the AEC is de-...oping a second generation of advanced isotopic power systems.

The SNAP–21 program is aimed toward development of a series of ...pact and highly reliable isotopic power systems (10 to 20 watts) for ...sea and ocean bottom applications. During 1967, the Minnesota ...ing & Manufacturing Co. (3M Co.), St. Paul, Minn., concentrated ...ontract efforts upon the design and development of the 10-watt ...sem. The 10-watt reference design will provide a basis of compo-... and systems performance testing for higher powered versions. A ...nology is being developed that will be common for devices of ...ious power ranges.

The SNAP–23 work is directed toward the development of highly ...able and long lived terrestrial systems that will be economically ...petitive with alternate power sources. The systems contractor for ...AP–23 is the Westinghouse Astronuclear Laboratory, Large, Pa., ... the 3M Co. is contractor for the power source. During 1967, major ...hasis in the SNAP–23 program was on the development of highly ...ient, segmented thermoelectric power conversion systems, and ...dardization of components adaptable to a power range of from 25 ...0 watts.

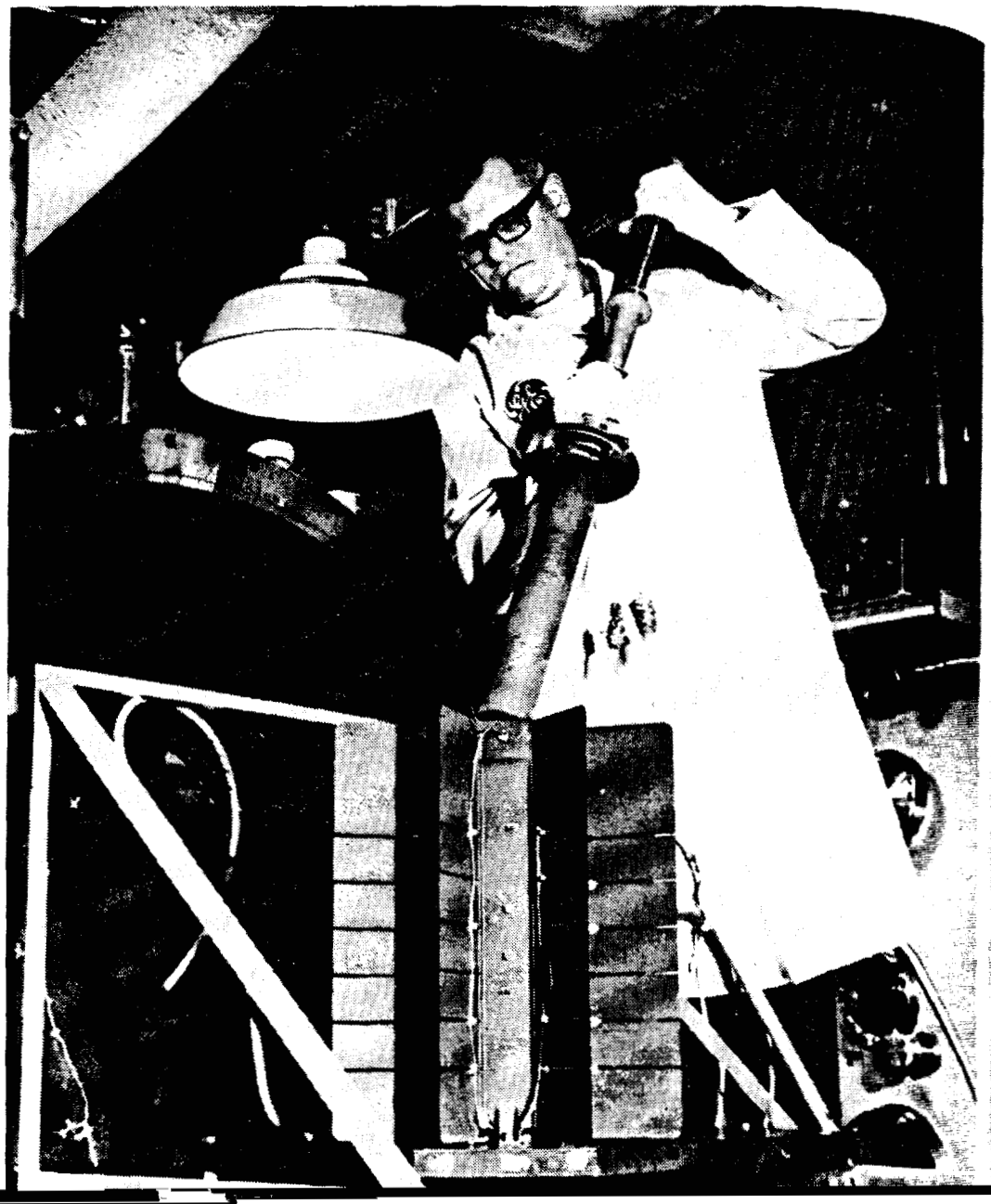
...clear Powered Cardiac Pacemakers

...o aid in the treatment of "heart block," a relatively common dis-... that causes interruption of the normal stimulation of the heart-

TABLE 2.—TERRESTRIAL OPERATING ISOTOPIC POWER SYSTEMS

...ation	Power	Use	Date of installation	Status
...B...	60 watts..	Offshore oil platform, Gulf of Mexico.	August 1966.....	Performance stable in Chesapeake Bay lighthouse for 2 years; then relocated to Gulf Oil Co., platform, operation satisfactory.
...C...	10 watts..	U.S. Navy weather station, Antarctica.	February 1962....	Operation satisfactory since installation.
...D...	60 watts .	U.S. Navy NOMAD weather station in center of Gulf of Mexico.	January 1964.....	System successfully withstood major hurricanes; performance is stable.
...E...	7.5 watts.	U.S. Navy acoustic beacon in Atlantic Ocean, off Bermuda, 15,800 ft. deep.	July 1964.....	System operating satisfactorily.

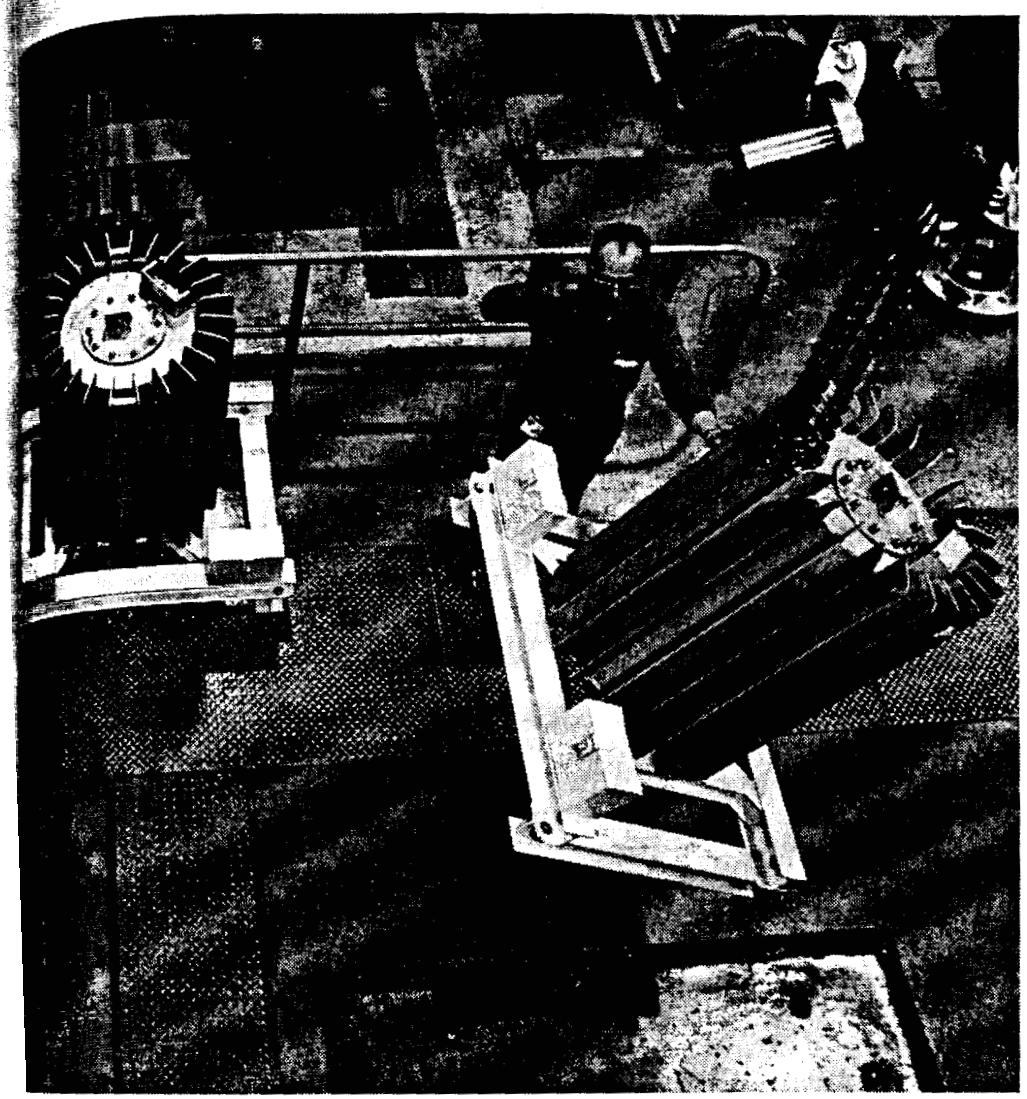
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the AEC is developing a plutonium-fueled cardiac pacemaker. Nuclear Materials and Equipment Corp. (NUMEC), Apollo Pa., prime contractor. The effort, to date, has resulted in an electrical -of-principle mockup. The device consists of a plutonium-238 thermoelectric generator coupled with the electronic circuitry nventional pacemakers. Since one of the major aims of this pro- is to develop a device of very long life—a minimum of 10 —with high reliability, the design of the thermoelectric genera- has been kept simple and uses low temperature metallic thermo-



-Finned Shipping Containers. For ground transportation of the SNAP-27 isotope heat source special shipping containers have been developed for al Electric's Missile and Space Division, Valley Forge, Pa., by the Columbus, Laboratories of Battelle Memorial Institute. The plutonium-238 heat source ed inside the container which is designed to keep the surface temperature radioisotope capsule below 525° F. A fluid-like bed of nickel spheres acts primary heat-transfer agent. A mixture of water and ethylene glycol as both the secondary coolant and radiation shielding.

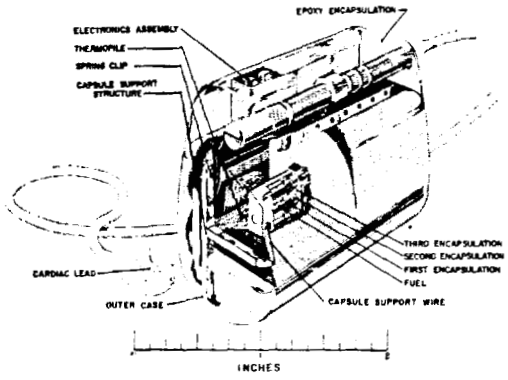
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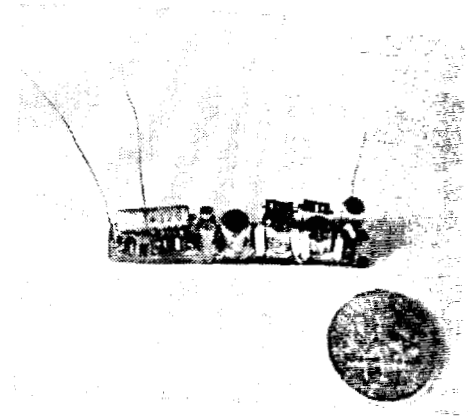
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couples which have provided dependable service in many industrial applications.

The thermocouple wires are interwoven into glass tapes which pre- vent electrical shorting between individual thermocouples and also thermally insulate the plutonium-238 heat source which will produce about 135 milliwatts (thermal). The entire unit is hermetically sealed and impervious to body fluids. A total of 1,056 thermocouples, con- nected in series-parallel, provide 162 microwatts. This is in excess of the power required to drive the conventional electronic circuit, which pro- duces regular pulses of electricity to shock the heart into its normal beating cycle.

A number of test units will be fabricated, fueled with plutonium-238, and tested to qualify the design under the present contract. Additional







Cardiac Pacemaker. A plutonium-238 fueled thermoelectric generator coupled with conventional pacemaker electronic circuits, is being developed for the AEC by NUMEC, Apollo, Pa. Implanted battery-powered pace- makers are used to stimulate malfunc- tioning hearts; the longer-lived nu- clear-powered unit could reduce the need for frequent surgical replace- ment. Drawing, *upper left*, shows the major components of the nuclear pacemaker; photo, *above right* shows the size of a prototype electronics in relation to a dime. Parts of a Mound Laboratory encapsulated plutonium-238 heat source for the unit are shown at *left*. The nuclear pacemaker will generate electricity from a total 0.135 thermal watt of isotopic power. Regu- lar pulses of electricity from the pace- maker will shock a defective heart into a normal beating cycle.

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ses of the program will require fabrication of generators for *in-*
vo (in laboratory glassware) and *in-vivo* (within the body) testing.
e medical profession now implants battery-powered pacemakers in
ain heart patients to stimulate the pulsing action of a malfunction-
heart. A long-lived nuclear powered unit would reduce the need for
quent surgical replacement required by the short life of the chemical
ery. The National Heart Institute, Bethesda, Md., and the Newark,
J., Beth Israel Hospital are consultants on medical aspects of the
elopment of the nuclear-powered pacemaker by the AEC.

dioisotope Power System for Artificial Heart

Four firms, Aerojet-General Corp., San Ramon, Calif.; Donald W.
glas Laboratories, Richland, Wash.; Thermo Electron Engineer-
Corp., Waltham, Mass.; and Westinghouse Electric Co., Pitts-
gh, Pa., were selected to conduct parallel design studies of an iso-
pic "engine" to power pumps which would assist or replace functions
a diseased or damaged heart. It is anticipated that by 1970, about
,000 persons could die and 2,000,000 could develop serious disabili-
annually from some recognizable disease of the heart. Of the pa-
nts who will succumb to heart disease, some 85,000 of those who
uld otherwise die are deemed suitable for an implantable circula-
assist device. In such a device, the heat from the decay of the
dioisotope would be used by a suitable thermodynamic converter to
vide power for the blood pump. Plutonium-238 and promethium-
are attractive radioisotopes for this application because of their
atively low shielding requirements. Other components of the engine
uld include a heat exchanger using blood as the cooling medium
a control system to regulate the power output of the engine. The
ine would supply a variable power output between 1 and 7 watts
the blood pump.

In connection with this project, two plutonium-238 fueled heat
rces (15 and 25 thermal watts) were designed and fabricated by the
C's Mound Laboratory and provided to Thermo Electron Engineer-
Corp., which is under contract to the National Heart Institute,
thesda, Md. The sources are being used in studies to determine the
its on the quantity of heat that may be safely dissipated within the
y by an implanted circulatory support system power supply.

topic Kilowatt Program

In 1967, an engineering design study was initiated to assess the needs
isotopic powerplants in the 1 to 10 kilowatt power range. There is
owing awareness that large compact isotopic plants could find ex-

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tended application for important programs, such as the Navy's "Man-in-the-Sea" program, underwater research laboratories, and anti-submarine warfare activities. The study is examining the use of cobalt-60, strontium-90, and cerium-144 coupled with various power conversion concepts. Primary responsibility for the study has been assigned to Oak Ridge National Laboratory, with assistance from the Savannah River Laboratory.

Thermal Conditioner for Aircraft Instruments

The AEC's Pacific Northwest Laboratory, in cooperation with the Air Force, fabricated a 65-watt promethium-147 thermal source to provide heat for an aircraft inertial guidance measuring system. The heater permits rapid response of the unit which otherwise would take from 30 minutes to 1 hour for temperature stabilization. The unit was ground tested by the Air Force during 1967.

ISOTOPE FUELS DEVELOPMENT

The thermal energy generated as radioisotopes decay can be used directly in situations where supplementary heating is required or it may be converted to mechanical energy by appropriate means. However, the characteristics—for example, the types of radiation given off, half-life, heat potential, chemical form stability—of each specific radioisotope are such that the isotopic fuel source must be "tailored" for its intended use. Thus, thorough development and test efforts are required to establish the characteristics and behavior of the various isotopic fuel forms in their intended environments. This is necessary to meet the stringent operational and safety requirements imposed on these devices when used as sources of heat or for power conversion.

Isotopic Heat Source for Brayton-Cycle System

NASA has requested the AEC to develop a large heat source suitable for operation with a Brayton-cycle power conversion system for a ground demonstration in mid-1971. To meet this request, Atomics International was selected, through competition, to develop a high temperature (2,000° F.) fuel capsule technology. In addition to the fuel capsule development, which began in July 1967, a plutonium-238 heat source subsystem design and development program will be initiated in 1968. These efforts could lead to a power system for space application in the mid-1970's. Development of the heat source for this system, which will consist of high temperature fuel capsules integrated into a flight package that meets aerospace nuclear safety criteria is a

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part of, and will temperature fuel for the 25-kwt. h

Polonium-210

Mound Labor for limited dura (thermal power ing. Rare earth-l or inert atmosp Pacific Northwe promise for sho on a program to the SNAP–29 u the chemical ins effort is being m reduce the pos conditions.

Methods for and purification the compounds Mound and Sav essential to redu this isotope that the reactor prod relatively large River. Another between dischar heat sources.

Curium-244

Curium-244 specific thermal availability of characteristics n However, the ne weight than oth polonium-210. (l—Source and S

During 1967, atory and Sava istics of curium

of, and will be fully coordinated with, the AEC's overall high-perature fuel source development program. Scheduled delivery date the 25-kwt. heat source subsystem to NASA is July 1971.

onium-210

Mound Laboratory is developing polonium-210 as a heat source limited duration missions that demand a high "specific power" ermal power per unit volume or weight) and a minimum of shield-. Rare earth-polonium compounds that remain stable under vacuum inert atmosphere environments are being studied at Mound and ific Northwest laboratories. These compounds offer considerable mise for short missions (several months). This effort is focused a program to develop and provide a polonium-210 fuel form for SNAP–29 unit developed by the Martin-Marietta Co. Because of chemical instability of available fuel compounds, a concentrated rt is being made at Mound Laboratory to develop a fuel which will uce the possibility of exposing the isotope to atmospheric ditions.

Methods for increasing the capability for production, separation, purification of the polonium metal—the starting material for compounds under investigation—are under study at both the und and Savannah River laboratories. Process improvements are ential to reduce the estimated costs for providing the quantities of isotope that would be required for heat sources. Improvements in reactor production of polonium-210, which is made by irradiating tively large amounts of bismuth, have been made at Savannah er. Another means to reduce cost is by decreasing the time lapse een discharge from the production reactors and delivery of the sources.

ium-244

urium-244 has the attractive combination of a reasonably high ific thermal activity, a relatively long operational life, and the lability of a thermally and chemically stable compound. These racteristics make it desirable for application in isotopic power fuels. wever, the neutron radiation of curium-244 does require more shield ght than other alpha fuels under development—plutonium-238 and onium-210. (See also "Curium-244 Production" section in Chapter Source and Special Nuclear Materials.)

During 1967, efforts were continued at Oak Ridge National Labor- and Savannah River Laboratory to determine the character- of curium-244 fuel forms, including the study of compatibility

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with encapsulating materials up to 2,000° C. Fuel forms have been prepared at Oak Ridge and partially characterized as to chemical, physical, radiation, and other properties; and capsule closure sealing methods and designs are under investigation.

Methods for encapsulating curium fuel forms are also under development at Oak Ridge National Laboratory and the Savannah River Laboratory.

Plutonium-238

During 1967, there was continued development of the metal, alloy, and oxide of plutonium-238 (87.5 years half-life) for use in radioisotopic power units. Process development of plutonium dioxide microspheres at the Mound and Oak Ridge laboratories was one of the items of research. Desirable properties of this material are relative chemical and biological inertness, high melting point, thermal, chemical, and radiation stability, and ease of handling. Using the oxide fuel form, heat sources were fabricated for several generator systems and for evaluation in the fuel technology program.

During 1967, the DART (Decomposed Ammonia Radioisotope Thruster) microthruster, a propulsion device for positioning a spacecraft in space, was designed, fueled, and demonstrated successfully in a simulated space environment. The DART was designed and fabricated by TRW Systems, Redondo Beach, Calif., and demonstrated at the Mound Laboratory. Mound also fabricated heat sources for the SNAP–19, which is the power supply of a Nimbus weather satellite, and the SNAP–27, the power system of the Apollo Lunar surface experiment package (ALSEP).

An alternative method to improve the economics and efficiency of processing the plutonium-238 oxide fuel to meet future demands was developed by the Oak Ridge National Laboratory and a pilot plant demonstration of the new processes was initiated in the fall of 1967. Mound Laboratory has developed a method for reducing the neutron radiation, and this will be tested on a pilot-plant scale in late 1968.

Consistent with the requirements of more efficient and demanding conversion systems, studies of new fuel forms, materials, and methods of containment compatible with the required increased temperatures have been initiated at Battelle Memorial Institute, Columbus, Ohio, and Mound Laboratory.

Promethium-147

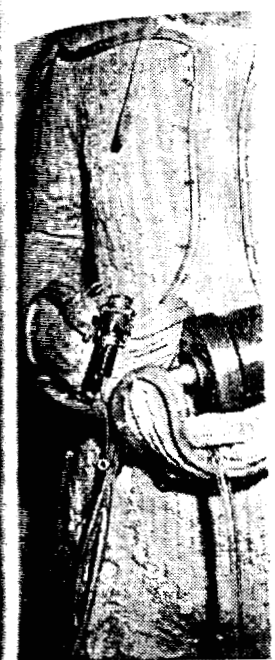
Capsule technology for samarium oxide, a nonradioactive stand-in for promethium-147 has been developed up to 1,100° C. and penetration

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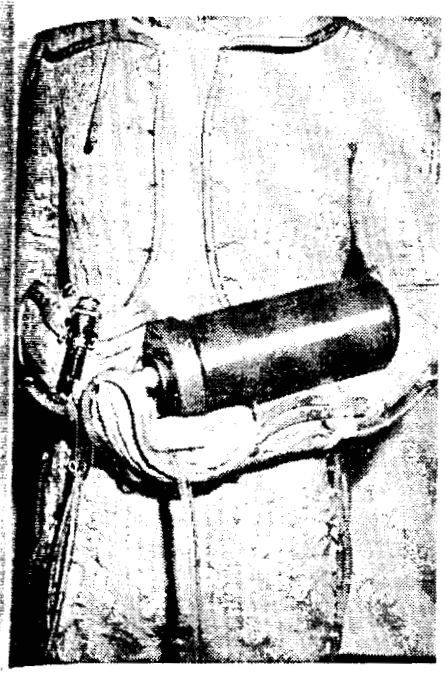
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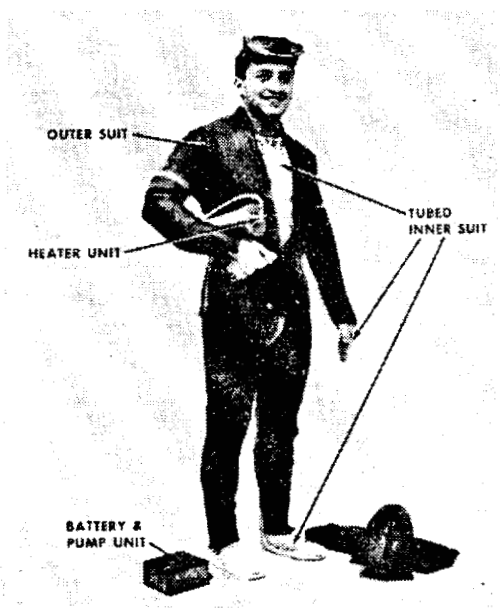
...s have been measured for 4,000 hours. Capsules loaded with sa...ium oxide were installed in furnaces at Pacific Northwest Labora... for up to 2-year exposures at 1,100° C. to establish fuel capsule ...patibility. This isotope is being investigated for the artificial heart ...tem and also has potential application in SNAP units.

A 60-watt (thermal) promethium oxide (Pm_2O_3) heat source was ...bricated at Pacific Northwest Laboratory and tested at Mound Lab...tory in a joint AEC–NASA microthruster development program.

...lium-170 and 171

The Savannah River Plant has performed a thulium-170 production ... and prepared a materials property report related to this test. The





RADIOISOTOPE SWIMSUIT HEATER

...clear Heater for Diving Suits. An isotopic-power swimsuit heater for divers, ...eloped by the AEC's Mound Laboratory, has been turned over to the U.S. ...y for deep-sea testing. Water heated by plutonium-238 in an aluminum ...der is pumped through small plastic tubes interwoven into the net garment, ...wn at *left*, worn underneath the diver's rubber "wet suit" as shown at *right*. ...heater is attached outside the suit. Radiation is sufficiently low to allow the ...er to perform normal work assignments without hazard. The heater, adaptable ...even lower temperatures, is presently designed for use in water temperatures ...about 45° F. and for ocean bottom depths of up to 600 feet. Similarly heated ...ts could serve pilots, astronauts, and Arctic researchers. After preliminary ...ls at the Naval Medical Research Institute, Bethesda, Md., the device will ...tested by Navy aquanauts assigned to Sealab III at the ocean bottom off the ...t of southern California performing experimental salvage techniques, ocean...raphic and marine biological research, and a series of physiological and human ...formance tests.

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thulium-170 fuels technology development activity has also been concerned with the assessment of requirements for, and the planning of, an off-site research and development program. The off-site program is to be provided with sufficient on-site support to assure the effective use of established technology.

An evaluation of large-scale thulium-171 production feasibility was completed by Oak Ridge National Laboratory and Savannah River Laboratory. The results show a very high cost of obtaining the requisite purity of thulium-171 for powering completely implantable circulatory support systems, such as the artificial heart. A problem in the production of thulium-171 is the concurrently produced thulium-170 contaminant whose more penetrating radiation requires greater shielding. For a shielded thulium-171 heat source to have reasonably low weight and external radiation it can contain only about 10^{-5} curies of thulium-170 per curie of thulium-171. Thulium-171 can be produced by reactor irradiation of natural erbium, natural thulium, or isotopically enriched erbium-170. It was found that two-cycle neutron irradiation of natural erbium is the only practical approach at present to the production of high-grade thulium-171. Using this mode of production, the principal cost is for neutron irradiation; a 1,000-megawatt reactor would produce about 0.4 kilowatts of thulium-171 per year, resulting in an estimated cost of several thousand dollars per thermal watt. The natural thulium procedure would produce about 0.2 of a kilowatt per year in a 1,000-megawatt reactor, doubling the product cost. The enriched-erbium procedure requires a large capital investment for isotope separation facilities—several billion dollars—with a resulting product cost equivalent to the natural erbium procedure.

Cobalt-60

During the year, efforts were directed by Savannah River Laboratory toward definition of maximum operating temperatures for encapsulated metallic cobalt-60 (Co^{60}) sources. Up to 850° C., it appears that "Inconel" 600 (a nickel, chromium iron alloy) is the best containment material based on diffusion, oxidation, and fabrication considerations. Satisfactory results were demonstrated for stable cobalt-59 encapsulated with "Inconel" 600, held for 5,000 hours at 850° C. and 1,000 hours at 1,000° C. Cobalt-60 has potential application as a kilowatt-level heat source for terrestrial uses.

Strontium-90

The most widely used fuel for terrestrial power systems is strontium-90. It probably will continue to be because of its long half-life,

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sonable power density, and ready availability as a fission product ilable directly from all power reactor operations in the civilian wer program. Being a beta emitter, strontium-90 uses for industrial diation processes are limited to those of low penetrability.

A continuing program at Oak Ridge National Laboratory is directed ward obtaining additional long-term information relating to com- und properties and encapsulation techniques that are needed for ontium use in isotopic power applications. These properties include rmal conductivity, solubility, compatibility with potential encap- ating materials, dimensional stability, and mechanical strength.

A strontium-90 long-range environmental safety testing program been initiated with the Naval Radiological Defense Laboratory, n Francisco, Calif., to test fuels, fuel capsules, and system compo- nts. This program includes sea environmental exposure tests as well laboratory tests and analyses.

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Chapter 10

ISOTOPIC RADIATION APPLICATIONS

Radioisotopes, in addition to their use as a source of heat for conversion to power, are making a substantial contribution to the public benefit through the AEC's isotopes development program. Applications for uses of isotopic radiation are being developed that range from food processing to tracing air and water pollutants. (This chapter deals only with applications involving use of radiations from isotopes; uses of isotopic heat are included in Chapter 9—Specialized Nuclear Power Units.)

FOOD PRESERVATION

As the result of a previous study [1] of the relative costs and economic benefits of food irradiation, the AEC decided that East Coast fish, Hawaiian papayas, and mangoes were products that should be emphasized in the AEC food irradiation program. Two additional studies, initiated in 1967, are designed to determine which of a limited group of other food products should be carried to the point of commercialization by the AEC food irradiation program.

TECHNOLOGY AND DEVELOPMENT

Progress has been made in the application of radiation to fresh seafood. Efforts have been directed primarily to gathering additional data to support Food and Drug Administration (FDA) requirements before the FDA can grant approval for public consumption of irradiated East Coast fish fillets. An AEC petition (request) for such approval is pending before FDA.

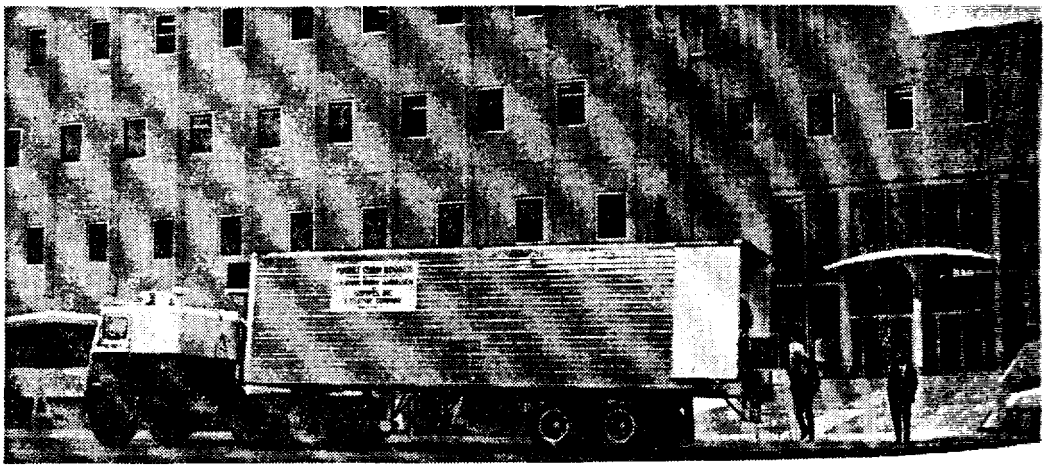
The Hawaiian papaya presently is placed under the United States Department of Agriculture Plant Quarantine Law and must be

[1] See p. 225, "Annual Report to Congress for 1966."

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Irradiator on Nation-Wide Tour. A portable, trailer-mounted food irradiator, loaded and tested at Brookhaven National Laboratory began a 2-year demonstration tour of the Nation during mid-1967 to demonstrate the benefits and commercial potential of food preservation by irradiation. The entire irradiator, which has a 170,000-curie source of cesium-137, weighs 18 tons. The trailer is 35 feet long and 8 feet wide, and is built of aluminum and steel. Photo *above* shows the irradiator inside the van as it was being tested at Brookhaven. Photo *below* shows the unit parked in front of the Federal Office Building in Richland, Wash.



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mically fumigated before being brought into the continental U.S. rid the product of the Hawaiian fruit fly infestation. Low-dose diation treatment (25,000 *rads*) [2] of this product will effectively sinfest the product. Higher doses (75,000 *rads*) provide effective elf-life extension of about 1 week plus disinfestation. At the present me, preliminary test shipments from Hawaii to the mainland by air d sea are being carried out to demonstrate the beneficial effects of e radiation process prior to large-scale demonstration shipments.

diation Facilities

Ten irradiators in support of the food irradiation program—nine ing cobalt-60 (Co^{60}) and one using cesium-137 (Cs^{137}) as the radia- n source—are now in full operation, and are categorized in Table 1.

[2] The basic unit of measurement of absorbed ionizing radiation.



d *Irradiation Demonstrations.* The first demonstration stop for the AEC's ler-mounted, cesium-137 food irradiator in its 2-year, nation-wide tour was at ington, Mass., during the August tomato-harvesting. During September and ber, the irradiator was demonstrated in Pennsylvania and North Dakota, in October it was used to demonstrate the use of radiation for disinfestation heat and wheat flour and sprout inhibition in potatoes during its visit to a Walla and the "tri-cities area" of Richland, Pasco, and Kennewick in hington. Sacks of irradiated potatoes were distributed free at the demon- tions along with a card on which the recipient was to mail in his opinion e processed food.

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TABLE 1.—IRRADIATORS SUPPORTING THE FOOD IRRADIATION EFFORT

Type Irradiator	Description	Location	Purpose
Research			
Research (4)	30,000–40,000-curie Co^{60}, pool-type unit.	Mass. Inst. of Tech. U. of Calif. (Davis). U. of Washington. U. of Florida.	On-site research.
On-ship #3 [1]	36,000-curie Co^{60}, 18-ton portable unit.	Seattle, Wash.	Irradiation at sea.
Portable cesium #1	170,000-curie Cs^{137}, 18-ton portable unit.	Various industry locations.	Demonstration to, and use by industry.
Pilot Plant			
Marine products development irradiator (MPDI).	250,000-curie Co^{60}, 1,000 lb./hr. at pasteurizing dose.	Gloucester, Mass.	Seafood irradiation.
Mobile gamma irradiator (MGI).	100,000-curie Co^{60}, 1,000 lb./hr. at pasteurizing dose.	Davis, Calif.	Fruit irradiation.
Grain products irradiator (GPI).	25,000-curie Co^{60}, 5,000 lb./hr. bulk or 2,800 lb./hr. packaged.	Savannah, Ga.	Grain products disinfestation.
Hawaii development irradiator (HDI).	225,000-curie Co^{60}, 4,000 lb./hr. at pasteurizing dose.	Honolulu, Hawaii.	Tropical fruits.

[1] See Table 2 for units #1 and #2.

Meat Irradiator Project

The AEC, in cooperation with the Department of the Army and the Department of Commerce, initiated a pilot plant meat irradiator project in July. A contract was signed with Irradiated Foods, Inc. (IRRADCO), of Allentown, Pa. The company, jointly owned by Teledyne, Inc.; Liggett and Myers Tobacco Co.; The Martin Marietta Corp.; and Uniroyal, Inc., was selected from among 10 proposals received in response to an AEC solicitation which had been sent to over 200 companies. Under the terms of the contract, IRRADCO will design, construct and operate a facility in Allentown capable of radiation processing 3 million pounds of product a year at sterilizing doses (5 million *rads*). IRRADCO's expenditures are estimated at $1,000,000. The AEC will provide $185,000 for the purchase of a 400,000-curie cobalt-60 source. The Department of Defense has agreed to purchase 300,000 pounds of meat annually for the first 3 years of operation. Construction of the plant would follow FDA clearance of the Department of the Army's pending petition for approval of irradiated ham for public consumption.

In addition to the planned commercialization efforts for foods—initially ham, following FDA clearance—IRRADCO also has a strong interest in the development and marketing of irradiated pet foods.

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Cooperation With Foreign Countries

The AEC has also initiated a program of irradiator support to selected countries conducting substantive food irradiation research projects. One of the program's products will be technical information pertinent to the AEC's work. More than 50 countries now have active programs in food irradiation, and 20 others have research plans in readiness. Irradiators are on loan, or projected for loan, to the countries indicated in Table 2. Generally, the initial loan is for a 1- to 2-year period.

TABLE 2.—IRRADIATORS ON LOAN TO OTHER COUNTRIES

Unit	Country	Date of loan	Products
...ship #1	Israel	March 1966	Citrus.
	Chile	June 1968	Potatoes, fish.
...ship #2 [1]	Iceland	April 1968	Fish.
...able cesium #2	Argentina	Spring 1968	Bovine blood, fruit, fish.
...able cesium #3	India	Spring 1968	Wheat products.
...search	Pakistan	Spring 1968	Wheat products.

[1] Formerly on U.S. Department of the Interior trawler *Delaware*, based in Gloucester, Mass.

ISOTOPIC SYSTEMS

For nearly 25 years, industry and science have taken advantage of the various kinds of radiation—alpha, beta, and gamma—given off by radioisotopes. Hundreds of different applications have resulted.

...mospheric Sulfur Pollution Analysis

A project has begun at Brookhaven National Laboratory employing stable isotopes of sulfur to study the source, quantities, and meteorological distribution of sulfur dioxide emitted to the atmosphere from stacks of fossil-fuel-burning plants in metropolitan areas. The approach is based on measuring the ratio of the sulfur-32 and sulfur-34 isotopes in samples of sulfur dioxide collected under varying conditions. Early results from the project have demonstrated the technical feasibility of the proposed air sampling and analytical procedures required for these ratio measurements.

...-Water Management

A long-term project with the U.S. Forest Service, Berkeley, Calif., in connection with its snow-water management control system, has led

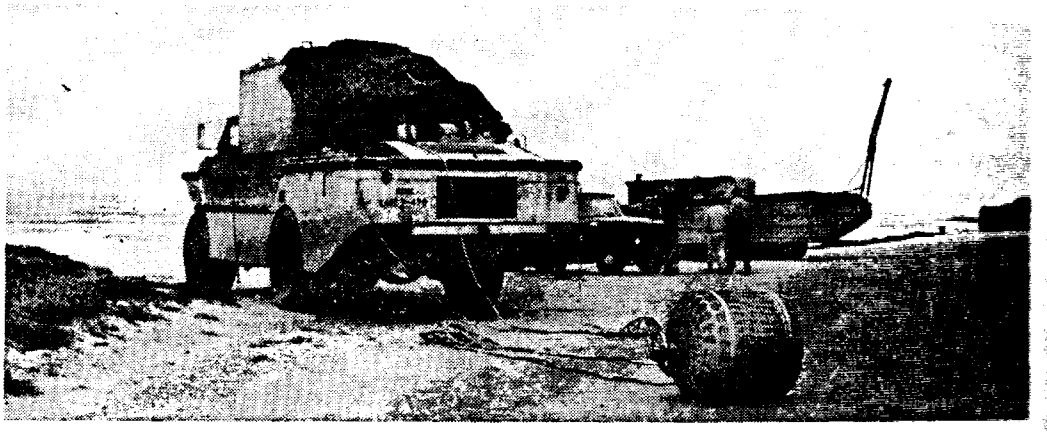
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to the development of a nuclear gauge that permits the study of internal snowpack conditions.

Two related subtasks concern: (*a*) exploring and evaluating the use of chemicals such as hexadecanol and octadecanol as a means of retarding evaporation of water from snowpacks—estimated at up to 2 million acre-feet annually in California's Sierra Nevada Mountains alone; and (*b*) isotope tagging of the water absorbed and used by trees in the growth process. In the first project, isotope tagging of the chemical showed that evaporation could be reduced by 90 percent through a single application by airplane of chemicals each snow season. In the second project, it was found that trees use considerable quantities of ground water even when the ground is covered with snow in the winter.

Littoral (Sand) Drift

Significant progress has been made in the development of a system for tracing littoral drift (shifting of coastal sand) with radioisotopes. Five Federal agencies—AEC, NASA, Department of the Army, Department of the Navy, Department of the Air Force—and the State of California's Department of Water Resources are cooperating in this project. Sand grains were tagged with xenon-133 and deposited



Tracing Littoral Drift. An amphibious vehicle is used to tow a 300-pound nickel-coated ball from the beach through the surf zone into deeper water for the surveying of sediment transport caused by littoral drift. The ball contains four cesium-iodide scintillation crystals, plus back-up electronics, to record the 30-kev. and 80-kev. photopeaks of the xenon-133 isotopic trace material contained in the deposited test sand. Also contained in the ball are temperature sensors, a microphone, and a revolution meter. The detector is towed over a grid pattern. Distribution of the xenon-133 radioactivity can be plotted from the radiation signals recorded aboard the tow vehicle. Five Federal agencies and the State of California are sponsoring the study at a beach site north of Santa Barbara, Calif. Information obtained from the study may help in reducing beach erosion.

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ear Point Conception, Calif., at an approximate 30-foot depth off-shore. A submerged ball containing radiation detectors was subsequently towed by an amphibious vehicle through the area and successfully determined the dispersion of the sand with time. This development is expected to be particularly useful in harbor siting and in selecting the best place for breakwaters to halt beach erosion.

Crime Investigation

A program, conducted by the AEC in close cooperation with appropriate law enforcement agencies, has resulted in the development by Parametrics, Inc., Waltham, Mass., of a radioisotope-excited X-ray fluorescence analysis technique for detection at-the-scene-of-the-crime of bullet holes in materials such as wood, steel, and aluminum. The gamma rays from a curium-242 source are used to excite X-rays in the lead residues near suspect bullet holes. Heretofore, the material containing a suspected bullet hole was removed and taken to a crime laboratory for confirmation that lead residue was present.

Aerospace

A significant radioisotope achievement during 1967 was the successful landing of an isotopic lunar analyzer on the moon. A small electronic device, weighing approximately 5 pounds, developed at the University of Chicago for NASA, was lowered from the Surveyors V and VI spacecrafts in September and November, respectively, to determine the chemical elements present on the moon. Alpha particles were used to bombard the lunar surface. The energy of the rebounding alpha particles is directly related to the elements present. The adoption of a small neutron generator for making precise chemical determinations on the surface of the moon or other planets is also being investigated. Neutrons are used to bombard the various elements present. The elements are identified by analyzing the gamma rays they give off after being irradiated with neutrons. The adaptation of radioisotopes to such unique tasks was to a large extent due to the creative imagination of the late Dr. Paul C. Aebersold, former Director of the AEC's Division of Isotopes Development.

Oil and Fuel Gauging

A program, undertaken by the AEC in cooperation with the Air Force, has resulted in the development by General Nucleonics Corp., Claremont, Calif., of a krypton-85 continuous oil gauging system

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which was flight qualified for installation in the F-104 interceptor. This gauge is capable of measuring oil level to within ±2 percent as contrasted with an accuracy of ±20 percent for conventional capacitance and float gauges. Of equal or greater importance, the nuclear oil



Lunar Activation Analysis Probe. Two nuclear probes were placed on the moon during 1967 as a part of the NASA studies to determine the mineral composition of the moon's surface. The alpha-particle probes reached the moon in September and November aboard the Surveyors V and VI spacecrafts. Photo shows the late Dr. Paul Aebersold, former Director of the AEC's Division of Isotopes Development explaining the operation of a lunar analyzer concept based on alpha activation analysis at a San Diego, Calif., exhibit.

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gauge provides accurate readings over a large range of attitude, altitude, and acceleration, and is not hindered in its operation by oil sloshing. The gauge—which has already been credited with preventing at least one aircraft accident—is currently in production for the F-104 and is also being considered for use on the C-5A aircraft.

A rocket propellant gauge, which will operate with less than 0.4 percent error under zero-gravity conditions, was also designed and successfully tested by TRW Systems, Inc., Redondo Beach, Calif. The gauge operates by correlating the radioactive density of krypton-85 in an expandable bladder, contained within the fuel tankage, with the fuel content of the tank.

PROCESS RADIATION

Radiation processing is the production or processing of chemicals and materials using ionizing radiation as a source of energy to produce chemical, physical, or biological change.

Basic Technology

During 1967, major emphasis was given to plastics and related hydrocarbon compounds and the use of radiation to assist in chemical reactions. Brookhaven National Laboratory continues to be the major site for the development of engineering technology involving very large (million curie) radiation sources and has recently shifted its attention from cobalt-60 to cesium-137.

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Chapter 11

THE PLOWSHARE PROGRAM

During 1967, Plowshare program activities brought advances in the technology needed to use nuclear explosions in underground engineering, excavation, and related research areas. A significant milestone was reached with Project Gasbuggy, the first Government-industry experiment to adapt an underground nuclear explosion to an industrial purpose. The experiment tested the use of a contained detonation to stimulate natural gas production in a low-producing formation.

UNDERGROUND ENGINEERING

When a nuclear explosion occurs underground at a sufficient depth it creates, in most types of rocks, a column-shaped area of broken rock called a "chimney." These chimneys, and the surrounding fractured areas, are potentially useful for the subsequent in-place recovery of natural resources or for storage. The dimensions of the chimney are dependent upon the energy and depth of the explosion.

NATURAL GAS STIMULATION

Nuclear explosions appear to offer an effective and economic means of bringing a greater number of gas fields into commercial production. Several experiments are planned to determine whether nuclear fracturing can increase gas production sufficiently to make this technique economically competitive.

Project Gasbuggy

On December 10, 1967, a nuclear explosive was detonated 4,240 feet beneath the surface in the San Juan Basin, about 55 miles east of

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Farmington, N. Mex. The explosion was part of Project Gasbuggy, a joint experiment of the AEC, the El Paso Natural Gas Co., and the Department of the Interior. The Lawrence Radiation Laboratory, Livermore, (LRL–L) provided technical direction of the project for the AEC.

The objectives of the Gasbuggy experiment are: (*a*) to determine changes in gas production and recovery rates; (*b*) to gather engineering knowledge of the use of nuclear explosions for gas stimulation; (*c*) to determine gas quality with regard to radioactivity and to evaluate various purification techniques; and (*d*) to refine the capability to predict the effect of ground motion on gas field equipment and other structures.

Preliminary evaluations of the data from the Gasbuggy detonation indicate that the explosive performed as expected, with a yield of about 20 to 30 kilotons (the equivalent of 20,000 to 30,000 tons of TNT). There was no measured release of radioactivity from the explosion although detectable amounts of some radioactive gases under high pressure did seep up through the insulation of the down-hole electronic cables which required the cutting and sealing of the cables. The ground motion from the explosion was felt in Dulce, N. Mex., 15 miles from the site and in other surrounding communities.

The degree of success of the primary objective of the experiment—the change in production and the increase in ultimate recovery of gas as a result of the explosion—will not be known for some time. Production testing will begin about mid-1968 after the radioactive iodine-131 has decayed. The testing will continue for several months.[1]

Dragon Trail Experiment Proposal

An experiment complementing Gasbuggy has been proposed to the AEC by the Continental Oil Co. (CONOCO), Houston, Tex., together with CER Geonuclear Corp. (CER), Las Vegas, Nev.[2] As currently conceived, the experiment, named Dragon Trail in the proposal, calls

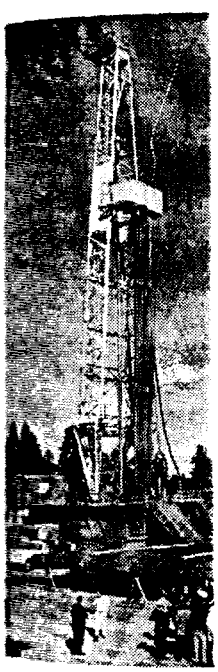
[1] Drilling into the detonation site began within hours after the explosion and, on January 10, 1968, the drills penetrated the zone of broken rock formed in the natural gas-bearing sanddstone formation. The reentry drilling indicates a chimney top at 3,907 feet below the surface—333 feet above the detonation point.

[2] In 1965, three firms—the Continental Oil Co.; EG&G, Inc. (formerly Edgerton, Germeshausen and Grier, Inc.); and Reynolds Electric Co.—formed CER Geonuclear Corp. to provide a complete "Plowshare Service" to interested firms. See p. 37, "Annual Report to Congress for 1965." On October 11, 1967, Lockheed Missiles and Space Co. (a division of the Lockheed Aircraft Corp.) Sunnyvale, Calif., announced it was ". . . prepared to participate actively in all aspects of the nuclear explosives application field. . . ."

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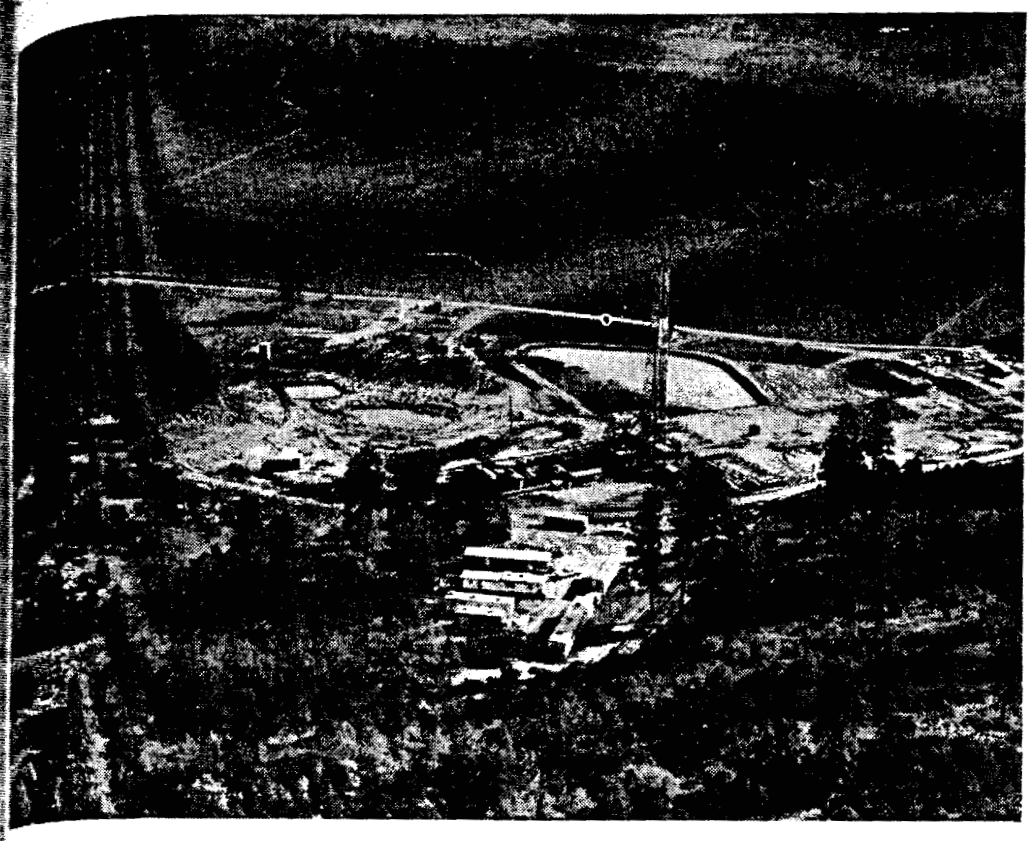
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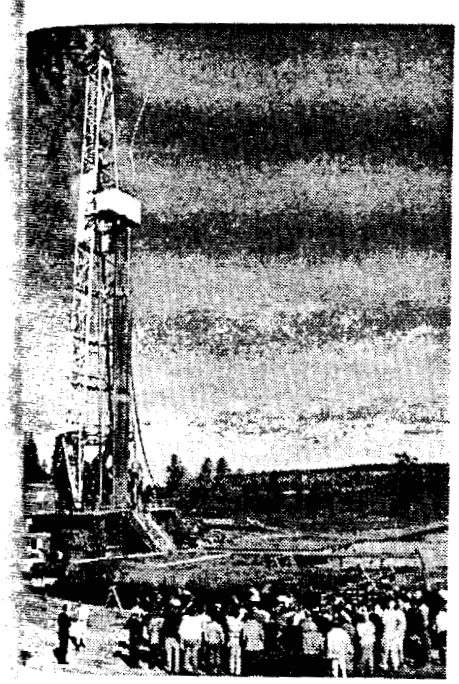




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the detonation of a 26-kt. nuclear explosive 2,700 feet underground site in Rio Blanco County, about 50 miles north of Grand Junction, lo. Substantial field work has been accomplished by CONOCO and ER to document the pre-shot production characteristics.





Project Gasbuggy. Photo *above* shows the Project Gasbuggy site in New Mexico where the first AEC-industry Plowshare Program (peaceful uses of nuclear explosions) experiment took place on December 10. Prior to the experiment, a technical symposium on Project Gasbuggy was held in Farmington, N. Mex., 55 miles west of the site on September 19. About 550 members of the scientific and industrial community and the news media attended. International interest was evidenced by attendance of representatives from Argentina, Australia, Brazil, Canada, France, India, Italy, Israel, Japan, Mexico, The Netherlands, Panama, United Kingdom, Venezuela, Euratom, and the International Atomic Energy Agency (IAEA). On September 20, the day following symposium, many of the attendees toured the Gasbuggy site. Photo at shows them viewing the emplacement hole drilling operation.

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The proposed experiment in a different type of gas-bearing formation would add to the results of Gasbuggy and could provide a basis for predicting results at still other locations.

Rulison Proposal

The Austral Oil Co. of Houston, Tex., and CER have proposed a third gas stimulation experiment, called Rulison, at a site in Garfield County, 45 miles northeast of Grand Junction, Colo. The experiment would require a larger yield explosion than either Gasbuggy or Dragon Trail, in the 2,500-foot thick Mesaverde formation some 7,500 to 8,500 feet underground. Because of the greater quantity of gas in-place at the proposed site, Rulison could be a test in a potentially commercial field, whereas the Gasbuggy and Dragon Trail projects are wholly experimental in character.

UNDERGROUND GAS STORAGE

The rapid growth of natural gas service throughout the United States is increasing the need for additional gas storage facilities. Nuclear-explosion-created chimneys of broken rock appear to offer the potential of providing storage facilities nearer consumer markets.

Ketch Gas Storage Proposal

A feasibility study, which examined the use of a nuclear-explosion-created chimney to store natural gas, was completed in mid-1967. It was prepared jointly by the Columbia Gas System Service Corp., New York City; the AEC;[3] and the U.S. Department of the Interior's Bureau of Mines.

On August 28, Columbia Gas System made a formal proposal to the AEC for a joint government-industry project, named Ketch. The proposal calls for the detonation of a 24-kt. nuclear explosive at a depth of 3,000 feet in a thick, impermeable shale formation at a site 12 miles southwest of Renovo, Pa. It is estimated that the detonation would create a rubble-filled chimney which would store about 463 million cubic feet of natural gas under high pressure.

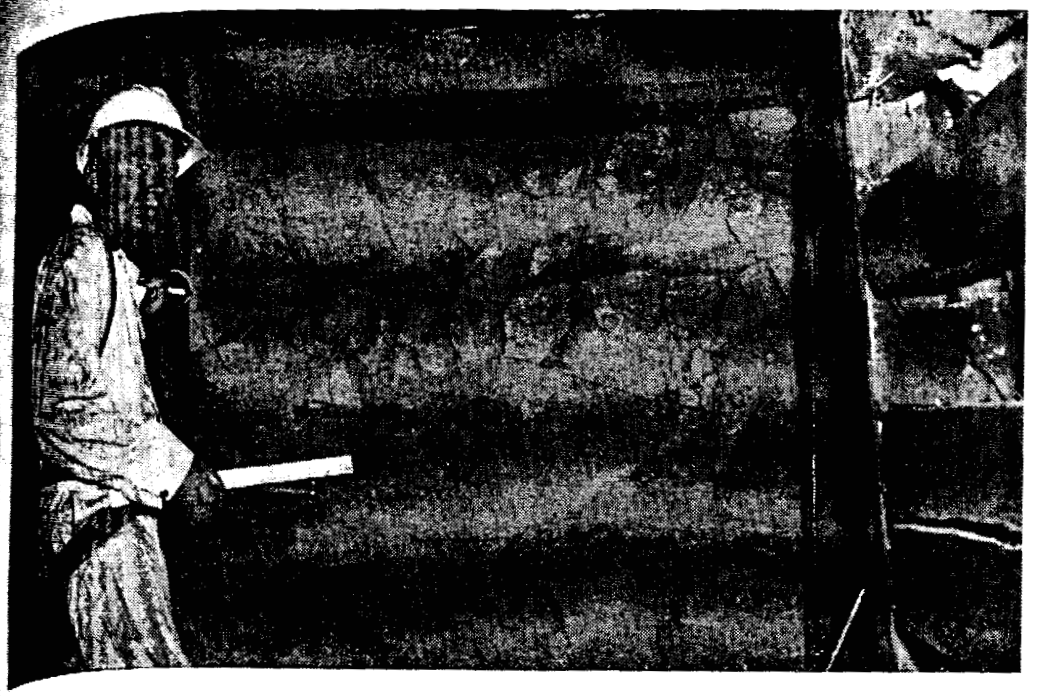
[3] The AEC's technical participation in Plowshare Program feasibility studies are centered primarily in the San Francisco Operations Office and Lawrence Radiation Laboratory, Livermore.



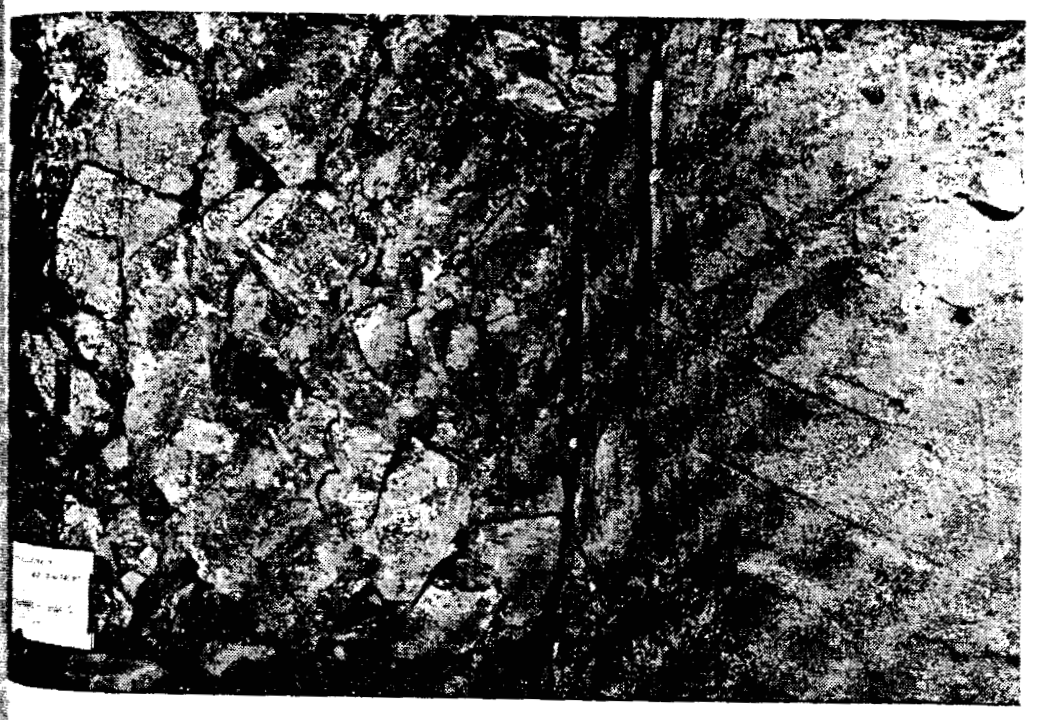
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"Chimney" Studies. To extend the knowledge of chimney development and characteristics necessary for fully developing underground engineering technology, exploratory work is underway on a chimney formed as a result of the Pile Driver event, a 60-kt. nuclear weapons effects test conducted in 1966 at a depth of 1,500 feet in granite at the Nevada Test Site. During 1967, a hole was drilled from the surface to the top of the chimney which was about 900 feet above the detonation point. Subsequent pressurization of the chimney indicated a total void volume of about 13 million cubic feet and an average chimney radius of 160 feet. Later, a tunnel, shown *above*, was dug to intercept the wall of the chimney about 100 feet above the detonation point. Photo *below* shows the boundary between the chimney wall and the chimney rubble. Work to further define the geometry of the chimney may be continued in 1968.



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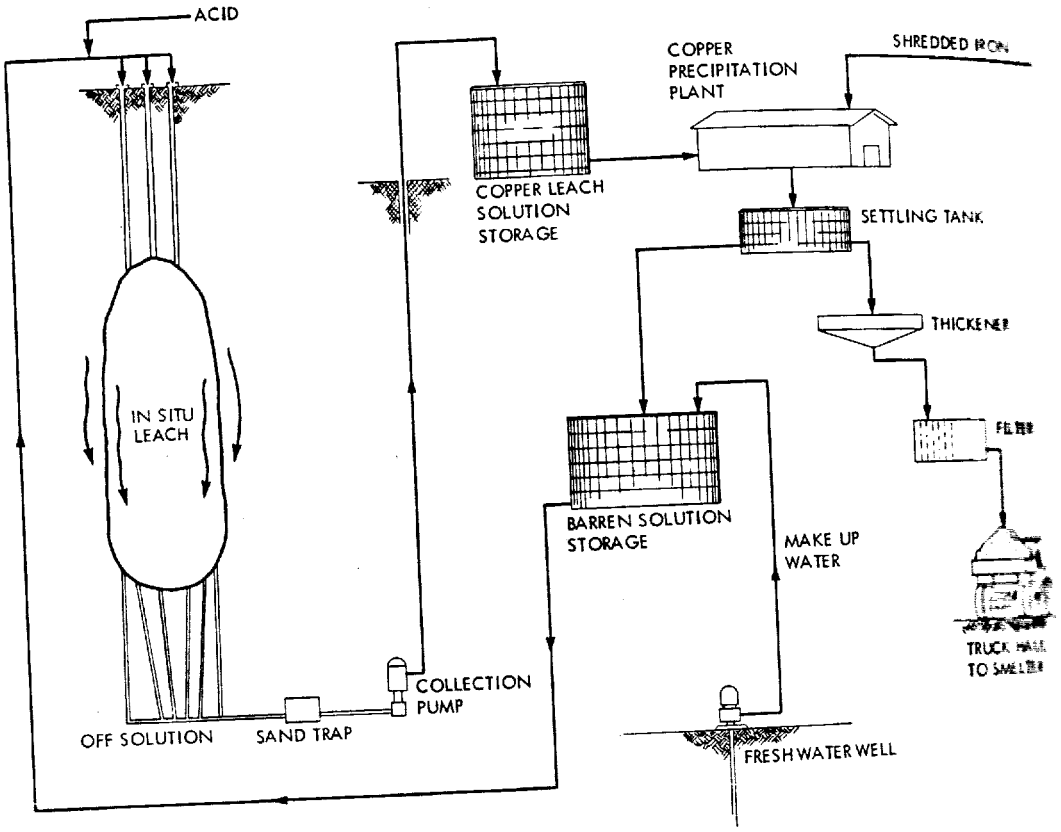
COPPER ORE LEACHING

Work continued in 1967 to design an experiment to investigate the use of nuclear explosions to prepare low-grade copper deposits for subsequent solution mining.

Sloop Proposal

In September, a detailed feasibility study of this concept was completed. Participants in the study were Kennecott Copper Corp., U.S. Bureau of Mines, and the AEC. This was followed by a proposal from Kennecott to Interior and the AEC to undertake the Sloop experiment as a joint Government-industry effort.

As presently conceived, Project Sloop would employ a 26-kt nuclear explosion 1,200 feet underground in a Kennecott-owned ore body near Safford, Ariz. The explosion is expected to produce a chimney of



Copper Leaching. The diagram is a pilot-plant process flowsheet for the proposed Sloop experiment. Such a plant, planned as part of the experiment, would be capable of treating about 2,000 gallons per minute of pregnant (copper-bearing) solutions obtained from the collection system in the rubble chimney and of returning the barren (stripped) solutions to the nuclear explosion-produced chimney.

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broken ore containing about 10 million pounds of copper, assuming a 0.4 percent copper content. After fracturing the ore body, a leaching system and copper-recovery plant would be installed and operated for at least a year by Kennecott to obtain processing and economic data.

OIL SHALE DEVELOPMENT

A program for recovering oil from shale rock, announced by the Department of the Interior, in early 1967, has spurred interest in developing this untapped resource. One part of the program proposes an investigation, jointly with AEC, of the use of nuclear explosions to recover oil from this rock. This concept involves using a nuclear explosion to fracture the oil shale which would then be retorted[4] in place.

Bronco Experiment

On October 25, 1967, CER Geonuclear (CER), on behalf of about 30 oil companies, formally proposed to conduct the Bronco experiment jointly with the AEC and Department of Interior. The proposal resulted from a joint feasibility study by the AEC, CER, and the Bureau of Mines. Project Bronco, as proposed, would use a 50-kt. nuclear explosion at a depth of about 3,350 feet in the Piceance Creek Basin, about 25 miles northwest of Rifle, Colo. It is expected that the explosion would produce a chimney containing about 1.3 million tons of oil shale. Assuming 24 gallons of oil per ton of rock as the average oil content (as shown by samples) in the shale, the chimney would yield about 750,000 barrels of oil. Efforts to retort the shale in the fracture zone outside the chimney would follow the retorting of the broken shale within the chimney itself. The project, as described in the feasibility study, would probably require 5 years to complete.

EXCAVATION TECHNOLOGY

Progress continues to be made in developing the technology necessary to use nuclear explosions for excavations such as the construction of canals and harbors, clearing waterways, or removal of overburden in near-surface mining operations.

[4] process by which the oil is produced by heating the broken rock, using the underground cavity produced by the nuclear explosion as the chamber or "retort." Two proposed methods of retorting the broken oil shale and associated fracture zones are: (*a*) igniting the broken rock and moving a combustion zone through it by injecting air through drill holes thus burning the residual carbon; or (*b*) injecting hot gases from an external source to increase temperature and force the release of oil. (See pp. 242–244, "Annual Report to Congress for 1966.")

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CRATERING EXPERIMENTS

Project Cabriolet

Preparations were being made during 1967 for Project Cabriolet, a 2.5-kt. cratering experiment in hard, dry rhyolite at the Nevada Test Site (NTS). Cabriolet is one of a series of experiments designed to determine the feasibility of using nuclear explosions to excavate a sea level canal across the Pan-American Isthmus. The objectives of the experiment are: (*a*) to obtain data on cratering mechanisms and final crater geometry to verify predictive capability; and (*b*) to refine existing models and atmospheric diffusion predictions relating to the released radioactivity. The experiment is planned for early 1968.

Project Buggy–I

Preparations began at NTS in the late fall of 1967 for Project Buggy-I, the first nuclear row-charge experiment. The experiment, planned for 1968, will involve the simultaneous detonation of five nuclear explosives, spaced 150 feet apart at a depth of 150 feet. It is expected that the resulting channel will be about 300 feet wide, 900 feet long, and 80 feet deep. The experiment will provide basic row charge cratering data in a hard, dry rock formation in level terrain. It also will provide information on the amounts of radioactivity released by a row charge explosion.



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Emplacement Techniques Development

A major goal in the nuclear excavation program is to reduce to a minimum the amount of radioactivity released to the atmosphere from cratering explosions. During 1967, two tests were conducted which contributed to this objective.

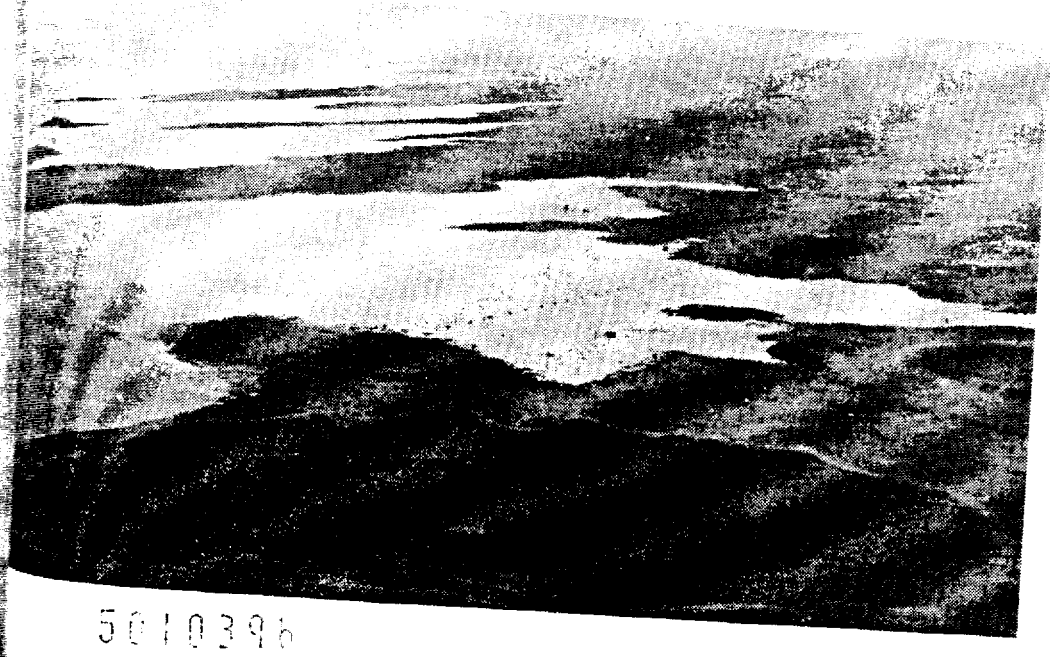
On June 22, the Switch event, a low-yield, fully contained underground nuclear explosion was conducted at NTS. Data indicated that the explosive tested was successful in keeping fission product and induced radioactivity to a minimum.

The Marvel experiment, a low-yield, fully contained nuclear test at NTS was conducted on September 21, as part of the effort to develop special emplacement techniques to entrap underground greater amounts of the radioactivity produced in cratering explosions. Preliminary evaluations indicate that the experiment was successful.

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Row-Charge Experiment. On June 28, 1967, a high-explosive row-charge crater-ng experiment was conducted adjacent to the Fort Peck Reservoir in Valley ounty, Mont. The experiment was part of the AEC-Army Corps of Engineers ent research program to develop the technology, costs, and other factors in-olved in nuclear excavation. This particular experiment, called Pre-Gondola was designed to investigate row-charge cratering characteristics and engi-ering properties of a wet clay-shale medium and to test the ability to connect row-charge detonation to an existing single-charge crater. The multiple explo-n shown *above*, consisted of the simultaneous detonation of two 40-ton and ree 20-ton high explosive charges. Shown *below*, is the resulting crater 280 et wide and 640 feet long—dimensions considerably greater than previously perienced in alluvium and basalt. The excavation connected successfully th the existing crater.



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Interoceanic Sea-Level Canal Studies

The AEC cooperated with the Atlantic-Pacific Interoceanic Canal Study Commission in developing data on the technology, costs, and safety of using nuclear explosions to excavate a sea-level canal. The Canal Study Commission is considering nuclear excavation as a part of its larger study of constructing a sea-level canal across the Pan-Amrican Isthmus.[5] Congress extended the final reporting date from mid-1968 to late 1969.

[5] See "Annual Report to Congress for 1966," pp. 252–255.

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Chapter 12

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Chapter 12

INTERNATIONAL COOPERATION ACTIVITIES

The U.S. "Atoms for Peace" program entered its 13th year during ...r. Originally conceived to enable friendly nations abroad to share the peaceful benefits of nuclear technology by supporting cooperative programs and projects and exchanging technical information, has evolved to include as well the sale abroad of U.S. nuclear equipment and materials. Agreements for Cooperation for power reactors made in recent years have included assurances of a supply of enriched ...nium for the nuclear power programs of foreign countries over ...g periods of time.

International interest in nuclear power and desalting plants continued to grow in 1967. A new concept, now under study at the Oak ...dge National Laboratory, involves the use of large combination ...nts to serve industrial agricultural complexes. Located in arid areas, ...h plants would supply low-cost energy for the production of electricity, water, fertilizers, and other chemicals. The concept shows promise for AEC's international program and is of particular interest to several foreign countries.

INTERNATIONAL AGENCIES

The way was paved in 1967 for several future international cooperative projects. Attendance at international meetings afforded the Chairman and his fellow Commissioners with opportunities to make informal arrangements for expanding cooperation in the nuclear field. Participation in discussions with atomic energy leaders, both overseas and in the Western Hemisphere, also enabled the Commissioners to ...the growth of international cooperation.

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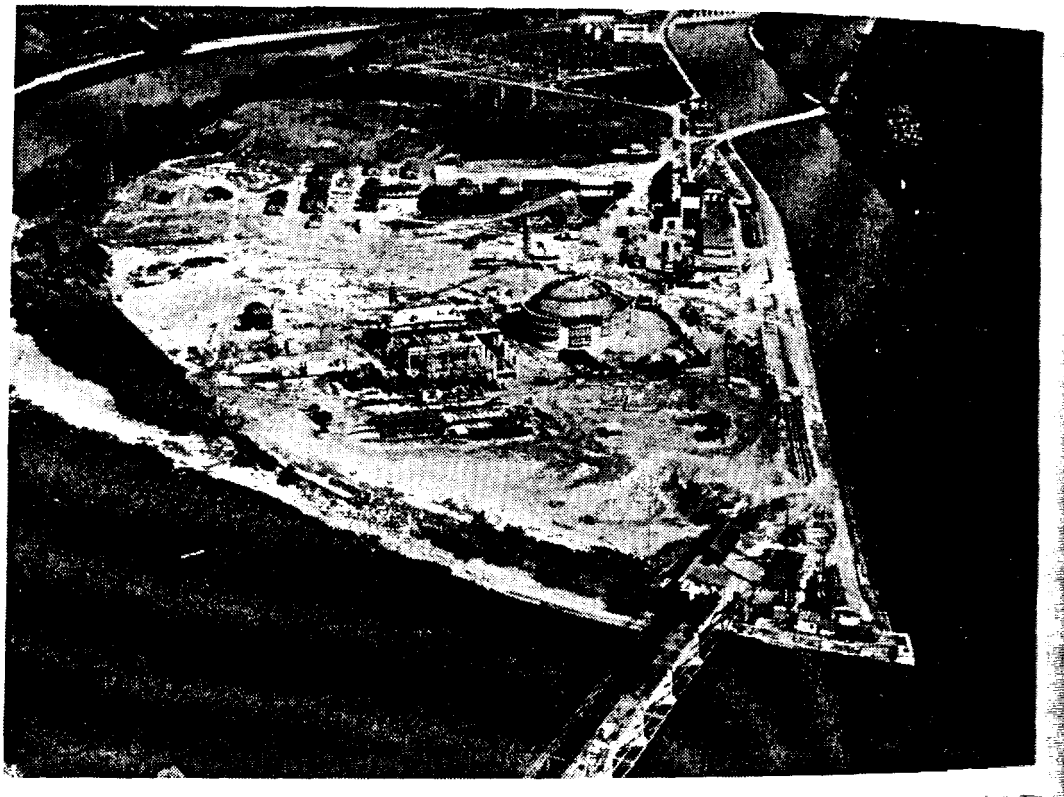
International Atomic Energy Agency

The U.S. policy of strong support for the International Atomic Energy Agency (IAEA) continued to be demonstrated through the provision of U.S. financial support to the IAEA's budget, cost-free experts, fellowships, equipment grants, technical information, and special nuclear materials—representing an amount close to $4,000,000. For the ninth consecutive year, the U.S. donated approximately $50,000 worth of special nuclear material for use in IAEA-sponsored research or medical therapy projects in various member states.

The 98-member organization continued its important work in all areas of the peaceful uses of nuclear energy and held its 11th General Conference in September 1967. At the suggestion of the United States, consideration is being given to the extension of the IAEA safeguards system to fuel fabrication plants. This will be in addition to existing coverage of reactors and processing plants.

European Atomic Energy Community (Euratom)

Close cooperation with the European Atomic Energy Community (Euratom) continued primarily in two research areas: (*a*) the joint



Swiss Powerplant. Shown is an air view of the 350-Mwe. pressurized water reactor being built by Westinghouse for Nordostschweizerische Kraftwerke A. G. (NOK), Switzerland's largest electric utility. The plant is located on Beznau Island in the Aare River near Baden, Switzerland. Electric power production is scheduled to start in the summer of 1969.

search and development program aimed principally at improving performance, including lowering of fuel-cycle costs, of U.S. light ter reactor types built and operated in Europe under the joint pro-am; and (*b*) fast breeder reactors.

To meet the material requirements for Euratom's reactor develop-ent and nuclear power program, legislation was enacted by the ngress to permit the AEC to transfer to the Community 1,000 kilo-ams (kg.) of plutonium in addition to the 500 kg. previously au-orized, and 145,000 kg. of uranium-235 (U^{235}) in addition to the ,000 kg. previously authorized. This legislation also authorized AEC provide Euratom with enrichment services after December 31, 1968. e provision of toll enrichment promises to be very important to ratom as well as to those nations cooperating with the U.S. now nning large-scale nuclear power programs. (See Chapter I—Source Special Nuclear Materials.)

opean Nuclear Energy Agency

The AEC has continued its collaboration with the European Nu-r Energy Agency (ENEA) through information exchanges, par-pation in ENEA study groups, and cooperation in the ENEA's den Boiling Water Reactor Project in Norway, the Dragon High-perature Reactor Project in England, and with Eurochemic (Euro-n Company for Chemical Reprocessing of Nuclear Fuels) in gium.

NUCLEAR DESALTING STUDIES

International interest in dual purpose nuclear power-desalting nts continued to grow in 1967. The International Atomic Energy ncy continued to play an important role in fostering or monitoring perative efforts in the field of nuclear desalting. U.S. officials par-ated in several IAEA panel meetings, and IAEA officials par-ated in several desalting studies that the U.S. has had underway other countries. Commissioner Ramey held discussions on nuclear gy for electric power and desalting of seawater with atomic energy ials of India, Israel, and Pakistan.

ed Studies

U.S.-IAEA-Mexican nuclear desalting study group is consid-g the technical and economic feasibility of installing a very large ar power-desalting plant on the Gulf of California in Mexico to

produce fresh water and electric power for the arid regions of Arizona and California in the United States, and the states of Baja California and Sonora in Mexico. The study group's report is expected to be completed in 1968.

A jointly financed study, completed in 1966 by the U.S. and Israel, of a dual purpose 200-megawatt plant producing 100 million gallons of water per day for operation in Israel by 1972, was updated in 1967 on the basis of a 300-megawatt, 100 million gallons per day plant for operation in 1975. The updated study concluded that it would be technically feasible to install such a large nuclear power-desalting plant, and affirmed its economical potential for Israel.

Discussions were also held with several other nations interested in dual purpose reactors, including Brazil, France, Greece, Italy, Spain, and the United Arab Republic.

International Conference on Water for Peace

The International Conference on Water for Peace was held in Washington, D.C., May 23–31, 1967, and was attended by representatives from 94 countries and 24 international organizations. The conference was opened by President Johnson. In his address, the President highlighted nuclear desalting and noted that the nuclear desalting plants to be built near Los Angeles (see section in Chapter 5 on "Desalting and Processing Uses") will produce three thousand times as much water as the world's entire desalting water production of 10 years ago and at one twenty-fifth the cost. The AEC participated in planning the conference and exhibits.

AGREEMENTS FOR COOPERATION

At the end of 1967, the United States had 34 Agreements for Cooperation for civil uses of atomic energy in effect with both nations and groups of nations (see Appendix 7 for listing). Following consultation with the governments concerned, and consistent with similar actions taken earlier with Belgium and France, the bilateral agreements with the following Euratom member states were allowed to expire with the objective of channeling and consolidating future transfers of special nuclear materials to these countries through the U.S.-Euratom Agreements for Cooperation: the Federal Republic of Germany (Aug. 6, 1967), the Federal Republic of Germany on behalf of the City of West Berlin (July 31, 1967), and The Netherlands (August 7, 1967). Direct technical cooperation will continue with these countries in such areas as the exchange of information and personnel.

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New Power Agreement

A superseding Agreement for Cooperation concerning the Civil Uses of Atomic Energy was signed with Norway covering both power and research activities. This agreement is for 30 years and, as in similar cases, it provides for the supply of quantities of enriched uranium sufficient to cover Norway's long-term requirements for such fuel for its nuclear power program. The agreement also reflects the changes made in 1964 in the Atomic Energy Act permitting private ownership of special nuclear material, and the export under license, of such materials by private parties.

Amendments to Agreements

Amendments to existing Agreements for Cooperation were negotiated with Australia, Colombia, and South Africa. In the case of the Australian and South African amendments, the agreements were extended for 30 and 10 years, respectively, and included private ownership and toll enriching features. The Colombian amendment covers research reactor activities and its major purpose was to extend the prior agreement for 10 years.

TECHNICAL ASSISTANCE AND COOPERATION

At the Conference of American Presidents held in April at Punta del Este, Uruguay, agreement was reached among the participants on the desirability of a more intensive regional development of science and technology, including nuclear energy. As a followup, Chairman Seaborg visited Argentina, Brazil, Chile, Colombia, Peru, and Venezuela. The visit served to strengthen existing U.S. cooperative activities with those countries and provide the framework for expanded cooperation in the areas of food preservation, agricultural and medical uses, insect eradication, reactor technology, and nuclear raw materials. In another followup to the Punta del Este Conference, the Inter-American Nuclear Energy Commission's Advisory Committee met to provide guidance on a new budget and program for the development of nuclear science and technology in Latin America and Commissioner Ramsson visited atomic facilities in Argentina and Brazil. Also, the 10th anniversary of the establishment of the AEC's Puerto Rico Nuclear Center (PRNC), was marked by a 3-day symposium in San Juan. The symposium was devoted to a discussion of the contributions nuclear energy can make to solving Latin American problems in the

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areas of public health and medicine; food supply and nutrition; and the development of natural and energy resources.

Other Countries

Canada. In March 1967, the AEC decided to close out work on the Heavy Water Organic-Cooled Reactor (HWOCR) concept. The decision led to a reassessment of AEC cooperation with Atomic Energy of Canada, Ltd. on this concept. As a result, it was deemed necessary to phase out the AEC's use of Canada's WR–1 reactor and associated facilities at Canada's Whiteshell Nuclear Research Establishment in Pinawa, Manitoba, as well as related loop studies in the NRU test reactor at Chalk River, Ontario. At the same time, the AEC's cooperative effort with Canada on the balance of the heavy water reactor programs was continued.

The third annual meeting of the AEC's Commissioners with the Directors of Atomic Energy of Canada, Ltd., took place in Montreal during May for an informal exchange of information on respective programs. Concurrently, the first tripartite meeting since 1945 was held by U.S., Canadian, and United Kingdom atomic energy leaders.

India. Several exchanges resulting from a comprehensive technical cooperation arrangement, negotiated with the Indian AEC in December 1966, were implemented in 1967. Studies were initiated by U.S. and Indian scientists of various reactor systems that might be best suited to India's power needs. In addition, some of the other areas being studied jointly are the technical feasibility and economic potential of nuclear power, India's resources of nuclear source materials, the advantages of locating an industrial complex in India around a large nuclear reactor and the use of thorium for the production of nuclear power. Comprehensive bibliographies of reports on the areas identified within the scope of the exchange (reactors, food irradiation, waste managements, radioisotopes in biology and medicine and particle accelerators) and engineering drawings were sent to India. Indian representatives participated in a study of energy center concepts at Oak Ridge National Laboratory during the summer, and Commissioner Ramey and a team of ORNL experts visited India in November to consult on the potential uses of nuclear energy in agro-industrial complexes.

Additional technical exchange arrangements were also negotiated with Italy, Japan, and Sweden. Implementation of more than 40 existing exchange arrangements continued.

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The AEC has offered unclassified training in increasingly sophisti-ted fields, and basic and applied research opportunities at the raduate and post-doctoral level to foreign scientists. These have flected the growing maturity of many foreign programs.

One of the most significant developments during 1967 has been the ightened interest in the peaceful nuclear energy field by Latin merican countries. There has been an increase in the number of atin American nationals who have sought assignments in the U.S. the fields of reactor operations, health and safety, and nuclear med-ine. Oak Ridge Associated Universities Inc., and the Puerto Rico uclear Center continue to offer a number of short-term courses in arious areas of interest.

Since 1955, over 4,500 foreign nationals have been provided un-ssified training, assignments or opportunities to perform basic and plied research.

operation With the Soviet Union

The U.S. Atomic Energy Commission and the U.S.S.R. State mmittee on Atomic Energy continue to exchange, on a monthly asis, unclassified reports in the peaceful nuclear energy field although ere is no formal exchange arrangement for this. Additionally, the EC, in coordination with the U.S. State Department, continue to range the visits of U.S.S.R. and Soviet bloc scientists to unclassified EC facilities and their participation in AEC-sponsored conferences d symposiums held in the United States. AEC personnel, as well as EC-contractor personnel, also visited the U.S.S.R. and Eastern ropean countries to attend conferences and visit nuclear energy cilities.

boratory-to-Laboratory Arrangements

Cooperative laboratory-to-laboratory arrangements with a number nuclear research centers abroad have been developed. Under these ngements, various U.S. institutions provide sustained advice to search reactor centers which were financed, in part, by U.S. grants le under the "Atoms for Peace" program.

During 1967, such sister-laboratory arrangements were continued ffect with the research reactor centers in the Republic of China iwan), the Republic of Korea, Thailand, Colombia, and Greece,

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and a similar cooperative arrangement was inaugurated with Pakistan. Under these arrangements, the Argonne, Brookhaven, and Oak Ridge National Laboratories and the Puerto Rico Nuclear Center provide periodic consultation and small items of equipment not readily available to the cooperating foreign laboratory.

INTERNATIONAL SAFEGUARDS

Significant international safeguards developments in which AEC participates are covered in Chapter 2—Safeguards and Materials Management. In carrying out its responsibilities in this area, AEC develops safeguards policies applicable to U.S. materials distributed abroad and maintains liaison with the Department of State, foreign governments, and international organizations.

On December 2, President Johnson announced that when safeguards are applied under a nonproliferation treaty for nuclear weapons "... the United States will permit the International Atomic Energy Agency to apply its safeguards to all nuclear activities in the United States—excluding only those with direct national security significance. . . ."

Trilateral Safeguards

The transfer of the responsibility to the IAEA for applying safeguards to materials and equipment distributed under various bilateral agreements for cooperation between the U.S. and other countries continued in 1967. To date, 16 countries have signed trilateral safeguard agreements with the U.S. and the IAEA under which the IAEA assumes this responsibility. Ten other trilateral agreements are in various stages of negotiation.

The AEC safeguards staff made inspections of 77 facilities in 9 countries during the year. These facilities are still subject to U.S. bilateral control.

Euratom Safeguards

The AEC maintains close liaison with Euratom safeguards officials to assure that each party has full information about safeguards materials control techniques, and practices of the other. In two liaison meetings held in 1967, the primary interest was in safeguards procedures relating to fuel fabrication with particular emphasis on plants

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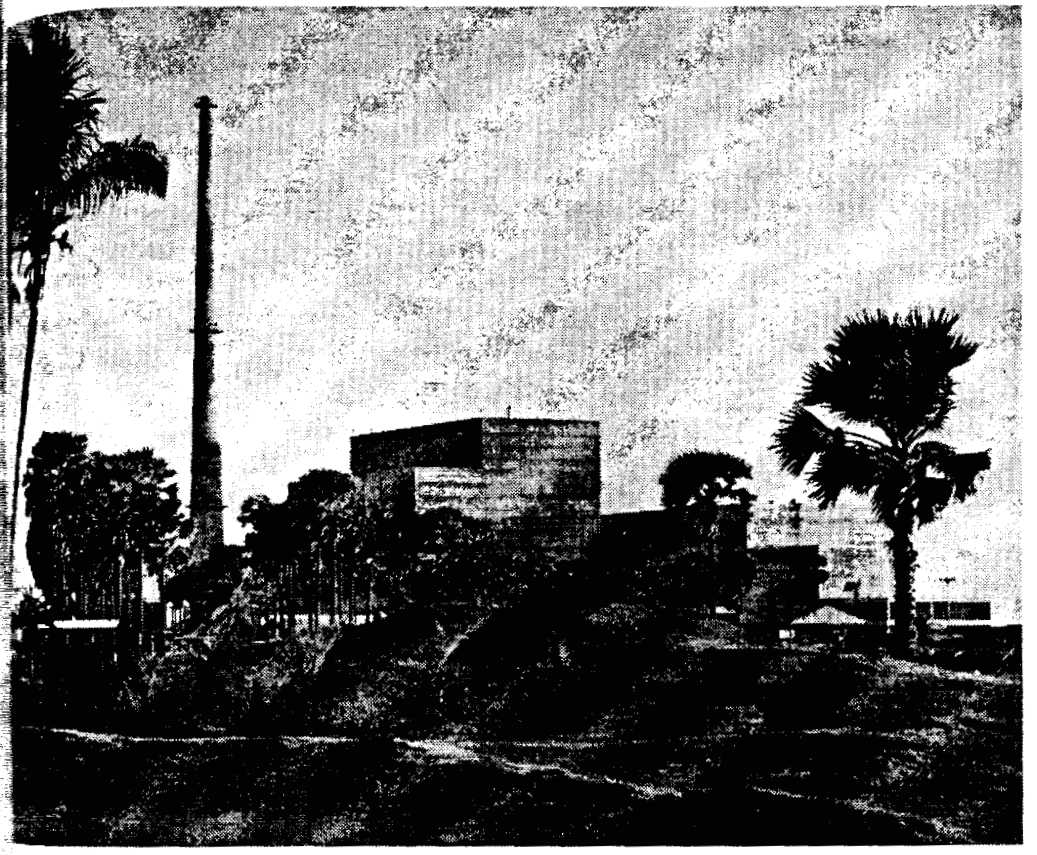
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fabricating fuel elements from plutonium and highly enriched uranium. These discussions (which have been closely related to the meetings of the Joint Technical Working Group mentioned in the Safeguards section of this report) have been of assistance to Euratom in the development of procedures that Euratom plans to use for safeguarding fuel fabrication plants. The procedures are based on the principle that resident inspections will be required in safeguarding those plants handling significant quantities of highly enriched uranium or plutonium.

COMMERCIAL COOPERATION

As of the end of 1967, there were 19 U.S. and U.S.-licensed power reactors operating, being built, or planned abroad.



Tarapur Nuclear Power Station. The first major commercial nuclear powerplant project in India and the largest such plant in Asia, the Tarapur project is expected to go into operation by mid-1968. The plant is located on the Arabian Sea coast about 60 miles north of Bombay. Bechtel Corp. designed and is constructing the overall plant for India's Department of Atomic Energy. The plant will use two direct-cycle 190-Mwe. boiling water reactor systems, fabricated and installed by the General Electric Co.

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POWER REACTORS

Plants Scheduled for 1968–1971 Completion

The 380-Mwe. twin boiling water reactor station being built by General Electric at Tarapur, India, is in the final stages of completion with startup expected by mid-1968. In January, 41,466 kg. of uranium (the largest single shipment of reactor materials yet supplied overseas by the AEC) were shipped to India for the first core loading of the Tarapur No. 1 reactor. A similar shipment was made in September for the first core of the Tarapur No. 2 reactor. The total value of these two cores is about $14.4 million.

Japan. The Toyko Electric Power Co. began construction in the Fukushima Prefecture of its 400-Mwe. boiling water plant, also GE-supplied. Erection of the containment vessel and site preparations are well advanced at the site of the Japan Atomic Power Co.'s second plant, a 400-Mwe., GE-built boiling water reactor located on the Tsuruga Peninsula. Completion of the plant is scheduled for the end of 1969. Site preparation and excavations were also well advanced at the Kansai Electric Power Co.'s site at Niu, Honshu, for a 325-Mwe. pressurized water reactor plant being supplied by Westinghouse. Completion of the facility is scheduled for October 1970.

Spain. Spain's first nuclear powerplant, the Zorita, a 153-Mwe. pressurized water reactor being built near Madrid by Westinghouse, was nearing completion at the end of 1967 with operation planned for mid-1968. The first core loading of Zorita fuel containing uranium valued at approximately $4.6 million was shipped in October.

The 460-Mwe. boiling water reactor, being built by General Electric at Santa Maria de Garona for the Spanish Nuclenor firm, was about 20 percent complete. Completion is expected in early 1970.

Switzerland. Work continued on the NOK, a 350-Mwe. pressurized water plant, being built by Westinghouse for the Northeast Swiss Power Co. at Beznau, Switzerland. Operation is scheduled for 1969. Site preparation outside Berne has begun for the 306-Mwe. Bernese Power Co. boiling water plant to be supplied by General Electric. Completion of the project is scheduled for 1971.



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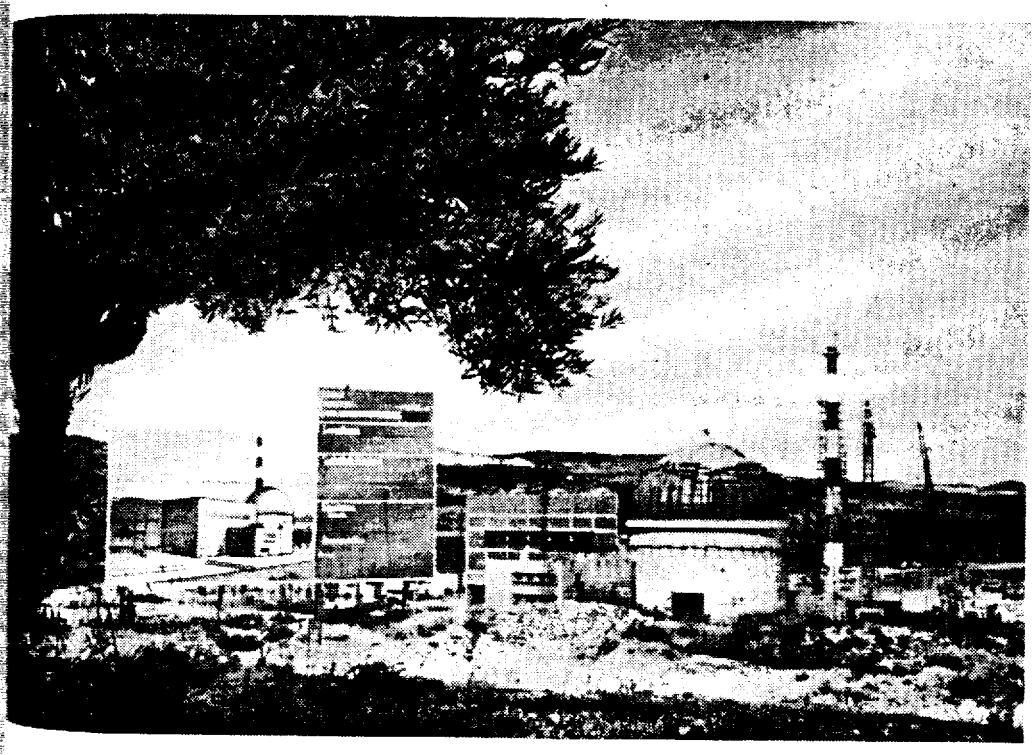


SUPPLY OF MATERIALS ABROAD

As of mid-1967, the AEC had distributed abroad through sale, lease, and deferred payment sales, special nuclear and other materials to the approximate value of $266.4 million, resulting in revenues to the United States of $171 million.



...ctors in Japan and Spain. The *above* is a view of the Japan Electric Power ... nuclear plant being built on the Tsuruga Peninsula. This is the company's ...ond plant and is rated for 325 Mwe. using a boiling water reactor being sup-...ed by the General Electric Co. It is scheduled for completion in 1969. Photo ...ow shows the Zorita, a 153-Mwe. pressurized water reactor plant, being built ... Spain by the Westinghouse Electric Corp. Located near Madrid, the plant is ...pected to be in operation by mid-1968. It will be Spain's first nuclear power-...nt to go into operation.



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On June 27, 1967, the AEC signed its first contract to provide uranium toll enrichment services for a reactor in a foreign country. The contract, with the Swedish company, Oskarshamnsverkets Kraft Grupp Aktiebolag (OKG), is for a term of up to 30 years for a 400-Mwe. boiling water reactor being built in Sweden. It is anticipated that the AEC will deliver to OKG during the contract period approximately 10,000 kilograms of U^{235} contained in slightly enriched uranium.

During the year, enriched uranium was shipped abroad for use in four West German projects and one in The Netherlands. The enriched uranium, in the form of uranium hexafluoride (UF_6), will be fabricated abroad into the first cores for the five western European projects. A fuel contract for the Swiss NOK project for the first core, plus a first replacement, was signed in May. In late 1967, 30 kilograms of plutonium were sold to Euratom for use in the Rapsodie reactor at Cadarache, France. Euratom has an option to buy an additional 37 kg. in 1968.

Services Provided

The United States provided chemical processing services to Canada, Sweden, and Japan. During 1967, there were 31 shipments of spent research reactor fuel to the United States. Processing services for this type of fuel continue to be available at the AEC's Idaho Chemical Processing Plant and the Savannah River, S.C., plant until services become available commercially (see Chapter 1—Source and Special Nuclear Materials).

The AEC continued to make available for foreign distribution limited quantities of the transuranium elements americium-243, californium-252, and curium-244 as sources for research purposes.

The AEC also assisted local and U.S. Coast Guard offices in approving two additional ports, Walla Walla and Pasco, Wash., to handle shipments of radioactive materials; 46 U.S. ports are now so cleared.[1]

[1] See p. 439, "Annual Report to Congress, for 1966" for complete list.

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Chapter 1

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Chapter 13

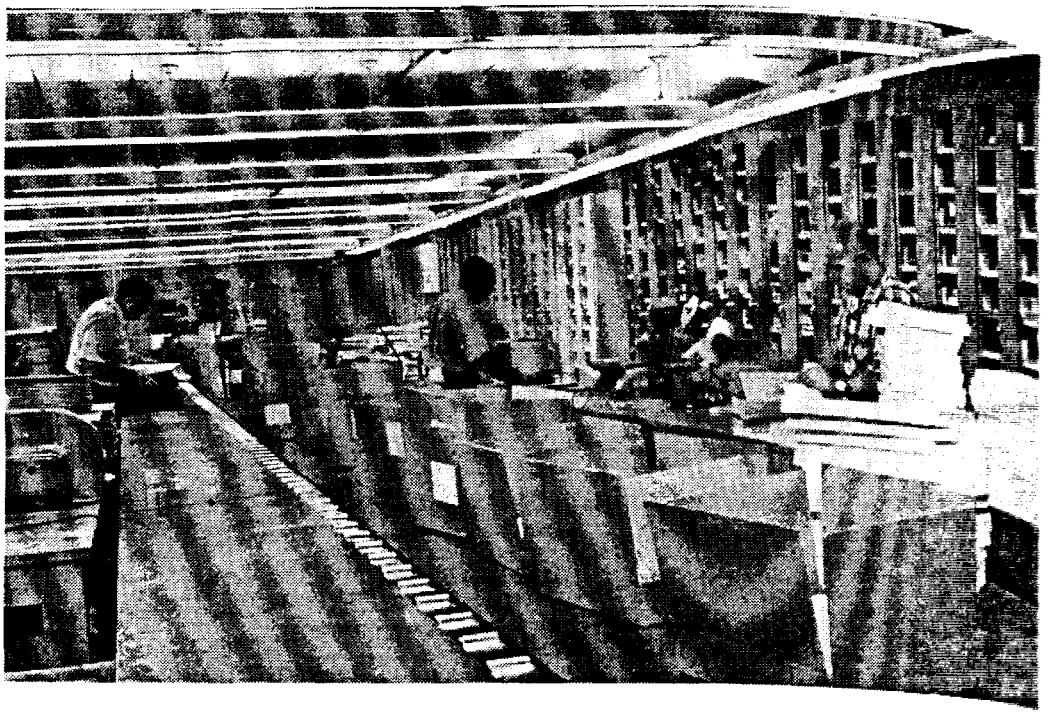
INFORMATIONAL ACTIVITIES

Twenty-five years ago, the atom and its potential usefulness was a mystery to all but a few scientists and government officials. Today, the energy source locked within the atom, while still mysterious to many, is more commonly known—not just to those technically-trained, but also by the general public. The AEC has the responsibility to increase continually the fund of information available to science and industry, and to foster greater public understanding of nuclear energy. The AEC is carrying out these responsibilities in several ways.

TECHNICAL INFORMATION

The AEC's technical information programs serve the scientific, technical, industrial, and academic communities, as well as the general public, both in the United States and abroad. The existing nuclear science literature is abstracted, indexed, and distributed in order to alert working scientists and engineers to what is available. The publication of scientific books and monographs, and technical progress review journals serves to repackage and compress the literature into convenient summary form as well as to review it critically. Educational literature is distributed to a wider audience, predominantly secondary school students and their teachers, interested in nuclear-related subjects. Specialized information centers offer conveniently categorized nuclear science reference sources. Selected scientific conferences are supported to provide opportunities for an exchange of ideas among scientists and technologists. Information is channeled to potential industrial users on AEC-developed technological innovations which have possible commercial application. Demonstrations and exhibits are presented at home and abroad to call attention to the peaceful uses of atomic energy and to United States achievements in their development.

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Distribution Center. Approximately 500,000 pieces of mail, principally technical reports and educational publications, were dispatched to domestic and foreign recipients during 1967 from this modern distribution facility at AEC's Division of Technical Information Extension at Oak Ridge, Tenn.

INFORMATION SYSTEMS AND SERVICES

Progress continues in developing cooperative international systems for dissemination of nuclear science information. Following endorsement by the Board of Governors of the International Atomic Energy Agency (IAEA) of the concept of an international nuclear information system—to be coordinated by the IAEA—representatives of the AEC met with IAEA staff members and representatives of other member states to continue system planning. Agreement was reached on descriptive cataloging standards and on magnetic tape formats for a machine system.

Cooperation continued between the AEC and the European Atomic Energy Community (Euratom) on the further development of machine systems for handling technical information. As part of this cooperation, most of the computer programs developed earlier by Euratom were made available for use in AEC's technical information system.

International Exchange of Technical Reports

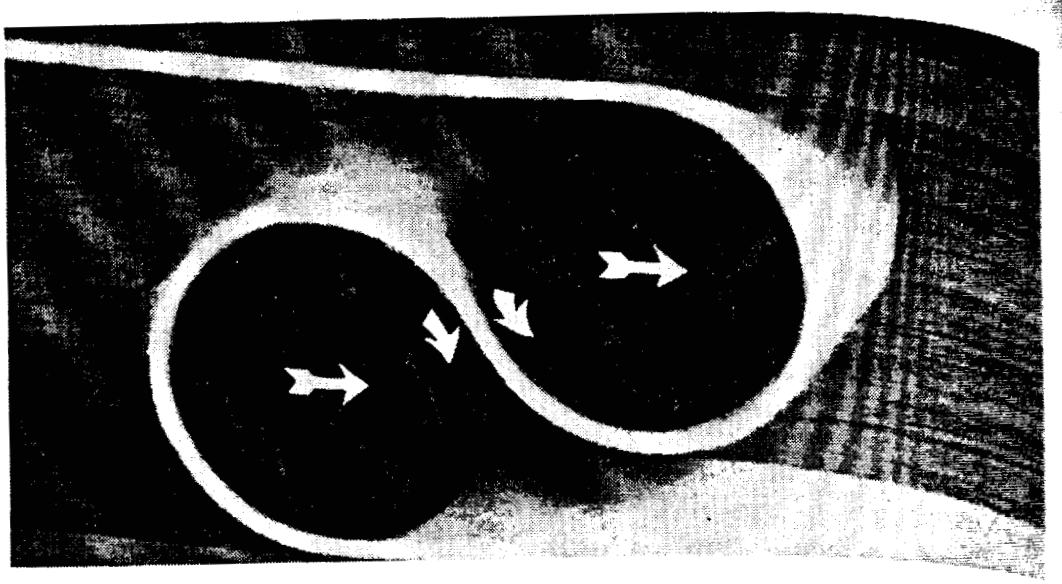
The first step in a planned reorganization of arrangements for international exchange of nuclear technical reports was completed

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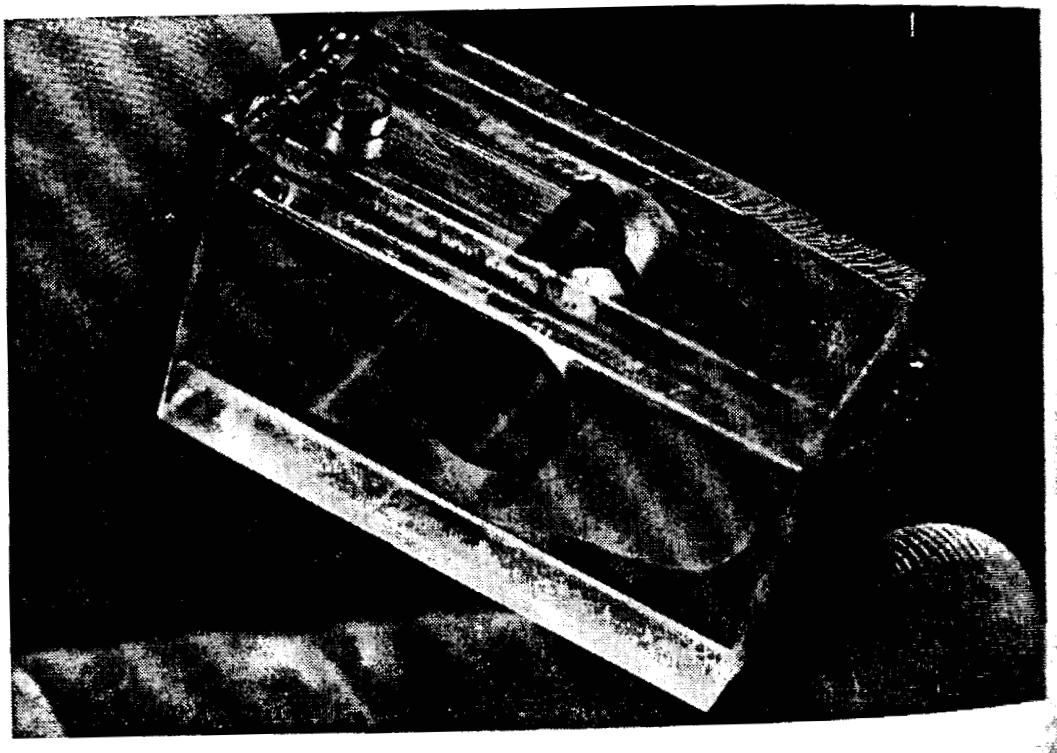
with the establishment of a European reports clearinghouse. Under the new system, copies of AEC reports will be sold by the National Lending Library in England to purchasers in member states of the European Nuclear Energy Agency (ENEA). The library also collects reports produced in these countries and makes them available to users in the U.S. If this arrangement works satisfactorily similar regional clearinghouses are planned in other areas.

Physics Exchange System

The American Institute of Physics (AIP) completed a study for the AEC of the feasibility of a centralized, rapid-distribution system [illegible] journal manuscripts ("preprints") among theoretical high-energy



New Mechanical Concept. Information on rolamite, a new mechanical design concept developed at Sandia Laboratory, has been released to the public by the AEC's Sandia Office of Industrial Cooperation in Albuquerque, N. Mex. A design principle applicable to a wide variety of uses in industry, space, and weapons manufacture, rolamite geometry can produce nearly all known mechanical and electromechanical functions in a wide variety of combinations. The basic device, a substitute for ball or roller bearings, consists of two rolling elements locked in an S-shaped "cluster" by elastic constraints of a metallic band under tension. It is virtually frictionless, easily microminiaturized, and extremely tolerant of production variations. Photo *above* shows the basic geometry of rolamite, showing the flexible band, "cluster" of two rollers, and parallel guide surfaces. Shown *below* is an example of a rolamite-based high-level G-switch approximately 1½ inches by ½ inch, but this is not a miniaturized model. The rolamite appears to offer solutions to many previously unresolved engineering problems or offer simpler solutions than some presently available.



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TECHNICAL INNOVATIONS

The AEC encourages industry—primarily smaller, non-nuclear enterprises—to make commercial use of technical innovations resulting from AEC-sponsored research and development. This effort was expanded with the establishment of a third Office of Industrial Cooperation.

Offices of Industrial Cooperation

A new Office of Industrial Cooperation was established during the year at the Sandia Laboratory. In function, it is similar to offices previously established at Argonne and Oak Ridge National Laboratories.[2] These offices are responsible for identifying AEC-generated technological innovations which are potentially useful to industry and for facilitating the transfer of the technology through government-industry meetings, briefings, laboratory tours, and individual visits with laboratory scientists and engineers.

"AEC–NASA Tech Briefs"

The issuance of "AEC–NASA Tech Briefs" expanded in both breadth of coverage and volume during the year. This series of business-oriented summaries was started in 1966. At first, it was limited to describing devices, processes and techniques developed at Argonne National Laboratory. During 1967, coverage was extended to innovations developed at Sandia Laboratory and in the space nuclear systems programs sponsored jointly by AEC and NASA. As of the end of 1967, 110 "AEC–NASA Tech Briefs" had been issued.[3]

PUBLISHING ACTIVITIES

During 1967, six foreign countries began providing English-language abstracts of their nuclear literature for Nuclear Science Abstracts, a new edition of the classic "Sourcebook on Atomic Energy" was published and the technical progress review journal "Nuclear Safety" began appearing bimonthly rather than quarterly.

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[2] See p. 320, "Annual Report to Congress for 1966."

[3] The "AEC–NASA Tech Briefs" are available, at 15 cents each, from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 37831. They may be subscribed to by category at the following annual prices: electrical (electronic), $5.00; energy sources, $2.50; materials (chemistry), $5.00; life sciences, $2.50; mechanical, $6.00; or all categories, $20.00.

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Nuclear Science Abstracts

The AEC's semimonthly journal "Nuclear Science Abstracts" (NSA)[4] abstracted and indexed approximately 47,000 items of the world's nuclear literature during the year. Canada, Denmark, Great Britain, Japan, Norway, and Sweden began providing English language abstracts of the nuclear science literature from their respective countries under cooperative agreements with the United States.

Mechanization of NSA progressed to the extent that the four indexes (personal author, corporate author, report number, and subject) to each issue are now machine arranged and composed. A 5-year cumulative index was completed for volumes 16 through 20 (1961–66). It totals 11,847 index pages in 19 books.

Scientific Books and Monographs

A revised and enlarged third edition of Dr. Samuel Glasstone's "Sourcebook on Atomic Energy" was published in 1967. This classic reference work, first published in 1950 and revised in 1958, has sold over 100,000 copies in its English version, and has been translated into Russian, Japanese, Spanish, Polish, Serbo-Croatian, and Korean.

The AEC sponsors preparation of books like the "Sourcebook" to meet the needs of scientists, engineers, and students for texts and reference works covering significant segments of nuclear science and technology. Most of the volumes are published by private firms which pay royalties to the government. A list of the more important 1967 publications appears in Table 2 of Appendix 8.

Technical Progress Reviews

The "Nuclear Safety" technical progress review journal was put on a bimonthly instead of quarterly publication schedule beginning with the issue for September–October, 1967. In view of the increasing interest in nuclear powerplants, it was felt that safety information should be provided on a more current basis. Beginning with the summer 1967 issue, the name of "Reactor and Fuel-Processing Technology" was

[4] *NSA* is available to the general public on a subscription basis from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, as follows: for the 24 regular issues, $30.00 domestic, $37.00 foreign. A single issue costs $1.75, plus 25 percent for foreign mailing. Domestic rates apply to the United States, Canada, Mexico, and Central and South American countries except Argentina, Brazil, Guyana, French Guiana, Surinam, and British Honduras. Foreign rates apply to the countries excepted above and to all other countries throughout the world. For the quarterly, semiannual, and annual indexes, the subscription prices are $22.00 domestic, $25.00 foreign.

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signed to the journal which combined "Power Reactor Technology" and "Reactor Fuel Processing."

The technical progress reviews are prepared for the AEC by major contractor laboratories to digest, summarize, and evaluate significant current developments in nuclear technology.

Educational Literature

Seven new titles were added to the AEC's "Understanding the Atom" series of educational booklets. The new booklets bring the total in the series to 44. Of these, 21 are available also in foreign languages. Total distribution since the series was inaugurated in 1961 has reached 2,100,000 copies. See Table 3, Appendix 8, for complete listing. The new titles included an index to the series prepared especially for teachers and a new general bibliography on topics related to nuclear science.

DEMONSTRATIONS AND EXHIBITS

To encourage widespread public interest in nuclear science and its many peaceful applications, the AEC presents exhibits and live demonstrations. These are presented where large audiences may be available, such as at schools, museums, fairs, and technical meetings. During the year, the AEC exhibits program was highlighted by five major overseas presentations. The secondary-school lecture-demonstration program was expanded, and preliminary plans were made for a Nuclear Science Center at the New York Hall of Science.

Presentations Abroad

"Atoms in Action" Centers

"Atoms in Action" Nuclear Science Demonstration Centers were visited by more than 450,000 viewers and participants during 1-month presentations in Ankara, Turkey (April 28–May 28), Panama City, Panama (May 4–June 4), Tehran, Iran (November 4–December 3), and Quito, Ecuador (November 6–December 8).

Presented at the invitation of the host countries, and in cooperation with their atomic energy and educational authorities, the demonstration centers feature exhibits and demonstrations for the general public, scientific investigations conducted in the Center's nuclear laboratories by host-country and U.S. scientists, training of host-country professional personnel in nuclear techniques, specialized instruction for

secondary-school science students and their teachers, lectures and seminars, and a technical library equipped with literature and films on nuclear subjects.

A feature of "Atoms in Action" at Ankara, opened in the spring by Commissioner Nabrit, was the presentation by the Turkish Medical Society of a symposium on the use of radioisotopes in medicine. The success of the symposium has encouraged the medical society to make it a yearly event.

At Panama City, national interest in possible construction of a second trans-isthmus canal led to a well-attended series of special lectures on the possible utilization of nuclear explosives for excavation projects. Commissioner Tape represented the AEC at ceremonies opening the "Atoms in Action" exhibit in Panama and in Iran.

In Iran, a carbon-14 radioactive-dating laboratory designed by Oak Ridge Associated Universities and placed in operation during the "Atoms in Action" presentation is being retained by Tehran University Nuclear Center. It will permit the dating of numerous artifacts unearthed by archaeologists in Iran and will thus contribute to a more complete understanding of early civilizations in the area.

At Quito, Ecuadorian and "Atoms in Action" scientists investigated preservation by radiation of bananas, potatoes, cherimolia, tree tomatoes, and naranjilla. In Ecuador, the potato—which originated in the Andes—is an important diet staple, the banana is the chief export crop, and tree tomatoes and naranjillas are delicious local products which could be exported if means were found for preserving them during their journey from tree to market.

In 1968, it is planned to operate the Demonstration Centers in Taipei, Taiwan; Seoul, Korea; Caracas, Venezuela; and Cordoba, Argentina.

Other International Exhibits

A special exhibit, "Nuclear Energy in Space," was presented at the 27th International Aeronautics and Space Salon held May 26–June 4 at Le Bourget Field near Paris, France. The AEC displayed a full-scale mockup of the NERVA nuclear rocket engine being developed by Los Alamos Scientific Laboratory and Aerojet General Corp. A duplicate of the SNAP–10 power reactor produced by Atomics International that operated successfully during an orbital test flight in 1966 was exhibited. Enlarged diagrams of other space applications for nuclear generators and engines were also shown. Some 300 thousand persons visited the AEC exhibit. Following its return to the United States, "Nuclear Energy in Space" was placed on display initially at the Chicago Museum of Science and Industry.

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"Nuclear Desalting," an explanation of nuclear dual-purpose plants for producing fresh-water and power, was exhibited April 13–25 in Milan, Italy, and throughout October in Sao Paulo, Brazil.

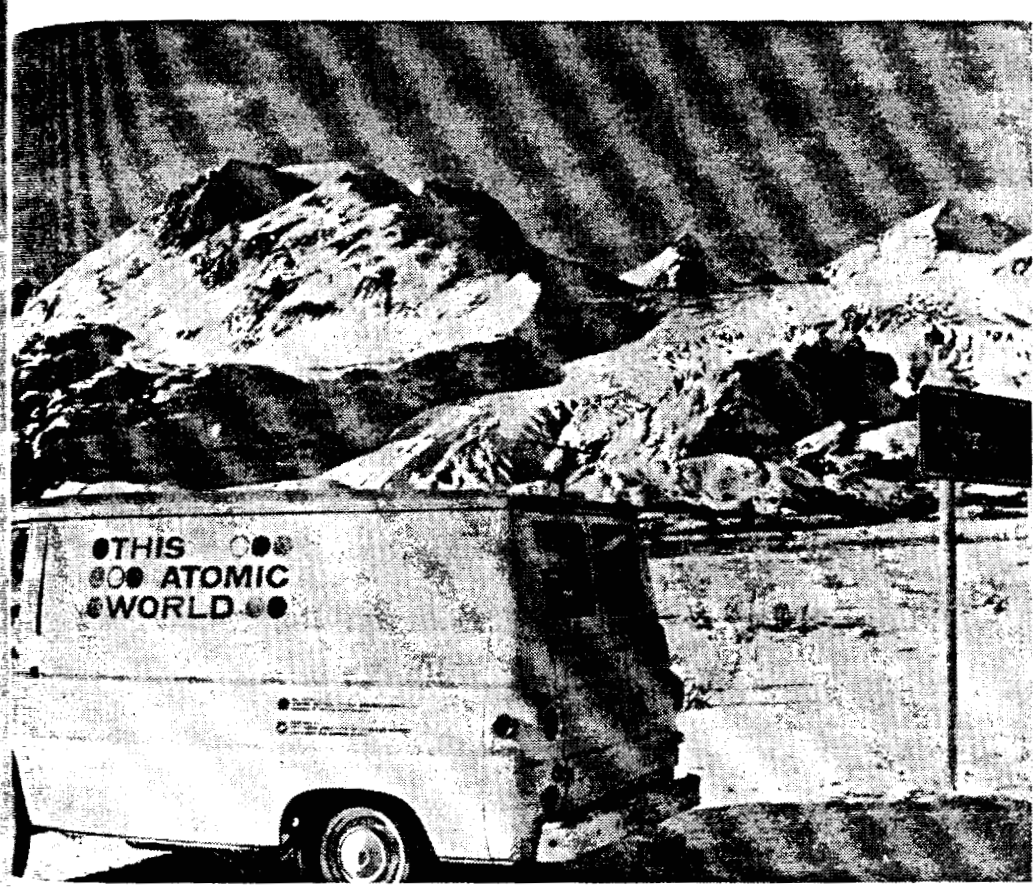
Presentations in the United States

AEC demonstrations and exhibits in the United States were viewed in 1967 by more than 4,800,000.

Secondary School Demonstrations

"This Atomic World" lecture-demonstrations were presented to a record 1,654,000 students and their teachers in some 1,880 secondary schools in 30 states during the year. Alaska was visited for the first time.

Eleven "This Atomic World" units were operated in U.S. secondary schools through May; 14 were in service when the schools reopened



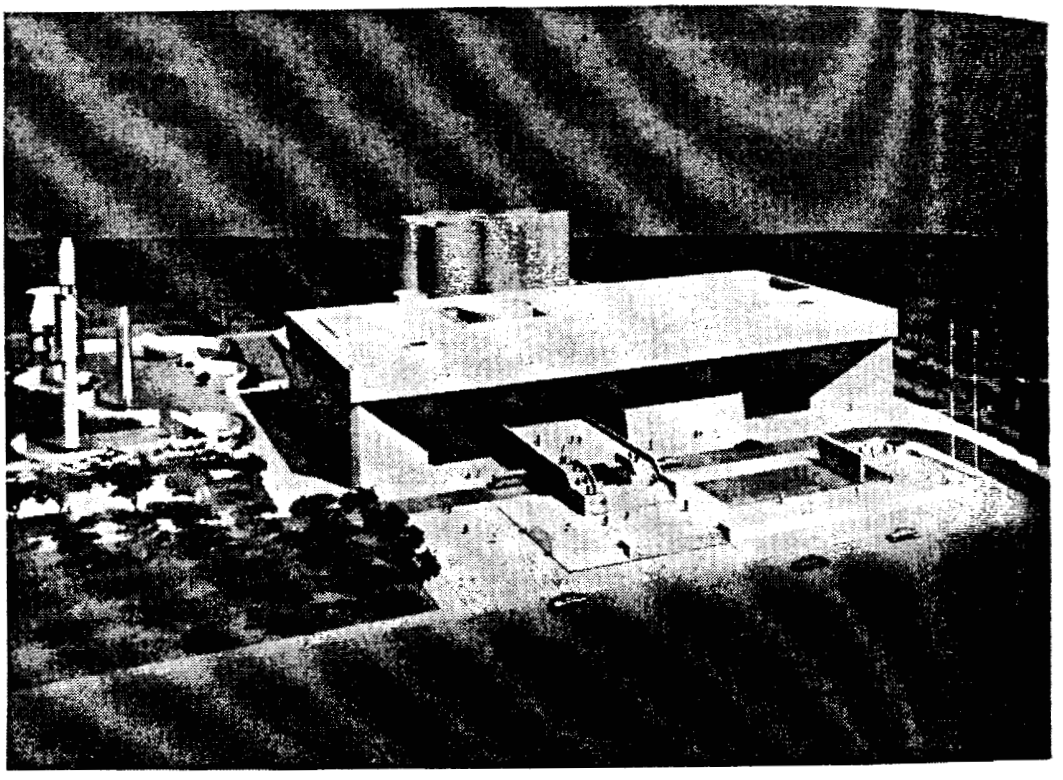
"Atoms-in-Action" on Tour. During the 1967–68 school year an AEC high school lecture demonstration unit visited schools outside the original 48 States for the first time. The truck is shown here on its way to Valdez, Alaska, population 555. For the 1968 spring term, this unit will be touring schools in Hawaii.

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in September. The expansion followed the successful testing during the 1966–67 academic year of a highly satisfactory cooperative arrangement in Texas whereby AEC supplied the demonstration equipment, the transport van, and training for the teacher-demonstrator. Texas A & M University recruited the demonstrator, paid his salary and expenses, and undertook the 9-months scheduling of presentations at Texas schools. During the current (1967–68) school year, this type of arrangement is being extended to Georgia, North Carolina, and New York. The cooperating state institutions are, respectively, Georgia Institute of Technology, North Carolina State University, and Empire State Atomic Development Associates.

Circulating Exhibits for Museums

The large manned exhibits developed specifically for extended museum engagements were booked solidly during the year and were visited by some 800,000 persons. "Atomsville, U.S.A.," the very popular children's exhibit, spent the year at the New York Hall of Science. "Life Science Radiation Laboratory," which features actual demon-



Planned New York Science Center. Artist's concept of the new building at New York City's Hall of Science at Flushing Meadows which will house a nuclear science center. Rocket display at *left* is part of the National Aeronautics and Space Administration space park developed for the recent New York World's Fair. Serpentine walls at *top center* are part of the original World's Fair Hall of Science building.

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ration of biological experiments, operated at the California Museum of Science & Industry in Los Angeles until June, then was moved to the Pacific Science Center at Seattle. "Radiation and Man" underwent extensive refurbishment before opening in March at McDonnell Planetarium in St. Louis; in September it was moved to the recently-established Center of Science & Industry in Columbus, Ohio.

Halls of Science

The AEC staff has been working with the staff of the Hall of Science of the City of New York in developing a Nuclear Science Center to be housed in a new building at the Flushing Meadows site. It is scheduled to open in 1971. The city has appropriated some funds and prepared preliminary plans for the building, which will house a research-and-training reactor, a gamma-irradiation facility, exhibits and demonstrations, and laboratory-learning areas.

During the year, conceptual plans were completed for exhibits and demonstrations to improve the nuclear science area at the Chicago Museum of Science and Industry.

New monthly and annual attendance records were set at the American Museum of Atomic Energy at Oak Ridge, Tenn. To better reflect the broad range of nuclear-related scientific applications which are explained and demonstrated, the museum is being renamed "The Oak Ridge Hall of Science—American Museum of Atomic Energy." The museum is operated for the AEC by Oak Ridge Associated Universities (ORAU).

PUBLIC INFORMATION AND FILMS

Throughout 1967, newspaper and magazine writers and editors and their radio-TV colleagues reflected continuing interest in the growth of nuclear power. Providing the news media and members of the public with timely and accurate information on atomic energy, is a major function of the AEC's information staff. This work includes answering questions, arranging interviews with Commissioners and members of the AEC staff, and providing similar services in preparation of radio and television programs.

Cooperation With Utilities

The AEC's public information staff meets with executives of utilities which are proposing nuclear powerplants, to discuss the informa-

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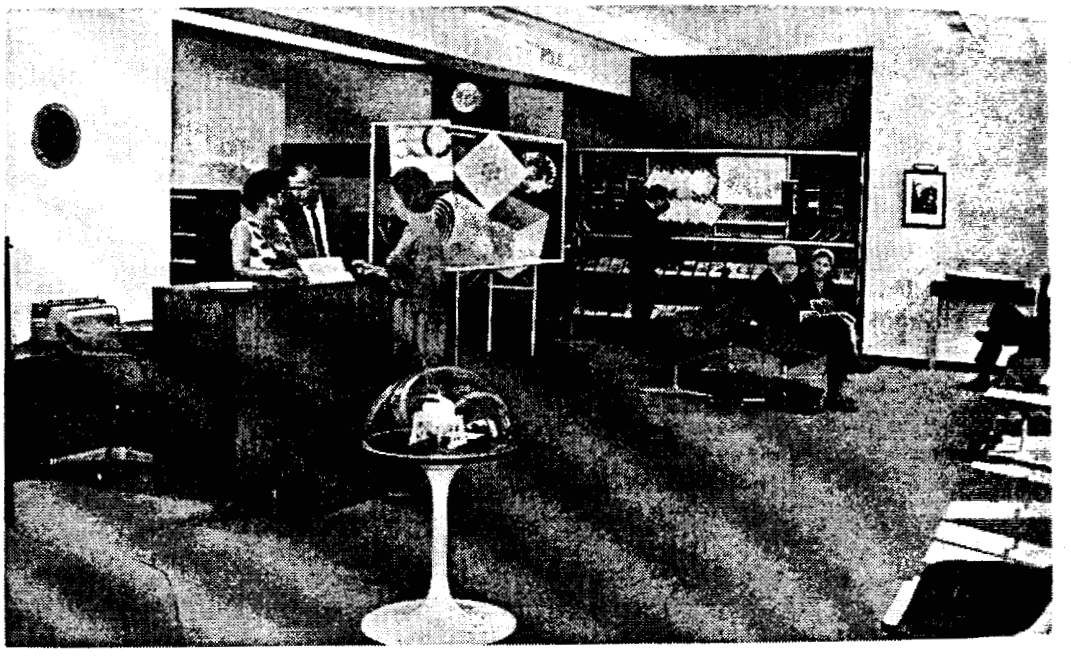
tional materials which are available for local "public education" programs. During 1967, there were 13 such meetings with utilities bringing the total since 1965 to 46.

Efforts are continuing to increase public use of AEC facilities; to supply speakers to civic, service, church, school and other groups; and to tell the atomic energy story through increased emphasis on exhibits and tours of AEC installations.

ATOMIC ENERGY FILMS

Public use of atomic energy films continues at a high level. The AEC's 10 domestic film libraries loaned popular-level and professional-level films on atomic energy for 109,499 showings, and 19 new motion pictures were added to the film libraries during the year.[5] AEC films were also used widely on television, at international exhibits, and were circulated by AEC and USIA libraries abroad. (See Appendix 9 for list of film libraries and titles of new films added during 1967.)

[5] Descriptions of films available for public showing are included in the "Popular Level" and "Professional Level" film catalogs available, without charge, from Director, Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.



Service and Information Center. During June, the AEC opened its new service and information center at 1717 H Street, Washington, D.C. Undertaken in cooperation with the President's program for improved service to the public, the new lobby is a one-stop information center where a trained receptionist handles all types of inquiries concerning the Commission and its programs, either answering questions directly or referring callers to proper AEC sources for additional information.

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Film Showings

Stocked with 9,803 prints of popular and professional-level films during 1967, the AEC's 10 domestic film libraries and nonprofit sub-libraries loaned films which were viewed by an estimated 3,872,000 persons in high schools, institutions of higher learning, industrial organizations, scientific and engineering groups, service clubs, and other community groups. Audiences estimated at 22 millions viewed many of the AEC films through 331 showings on educational and commercial TV channels.

International Aspects

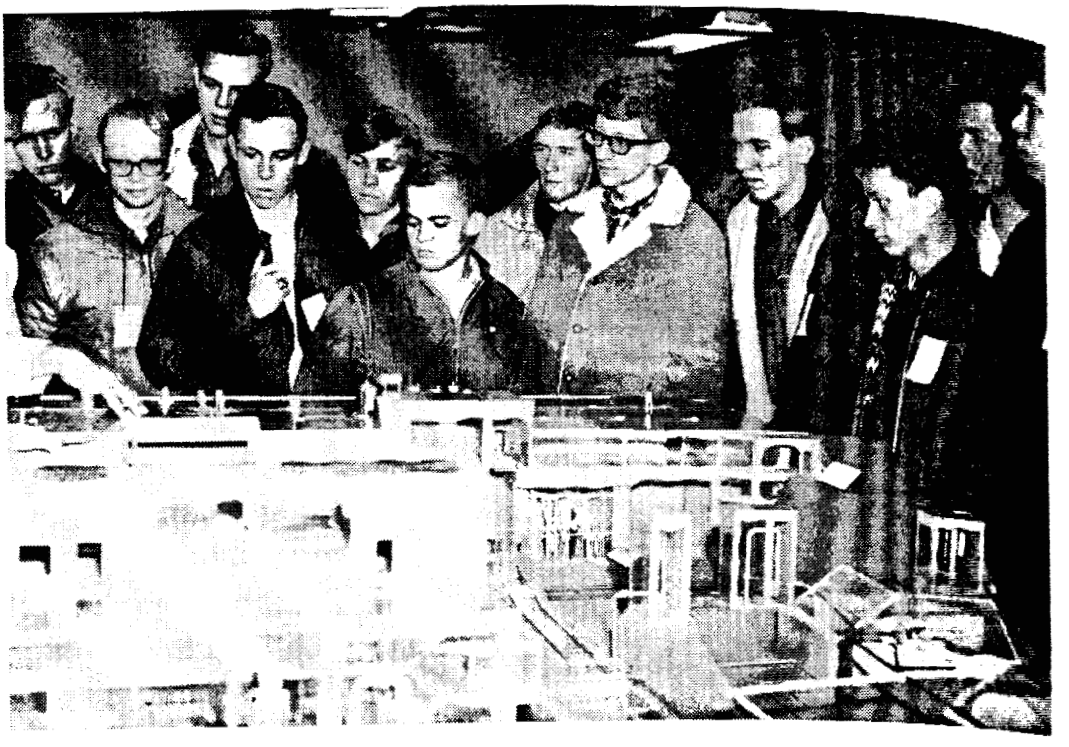
AEC motion pictures were integral parts of four "Atoms in Action Nuclear Science Demonstration Centers" in Ankara, Turkey; Tehran, Iran; Panama City, Panama; and Quito, Ecuador.

Loans of approximately 217 motion pictures, largely on a professional level, were made from AEC liaison offices in London, Tokyo, Brussels, and Buenos Aires, the latter two libraries supplying French and Spanish versions of many of these films. The use of AEC films by foreign scientific, industrial, and educational organizations has greatly increased during the past year with Australia, Colombia, Holland, Israel, and Peru leading the list. AEC assistance was provided to make Spanish and Dutch language versions of selected films, and to TV and film producers from the International Atomic Energy Agency (IAEA), England, Germany, and Japan in providing stock film footage, atomic energy information, and arranging for new photography.

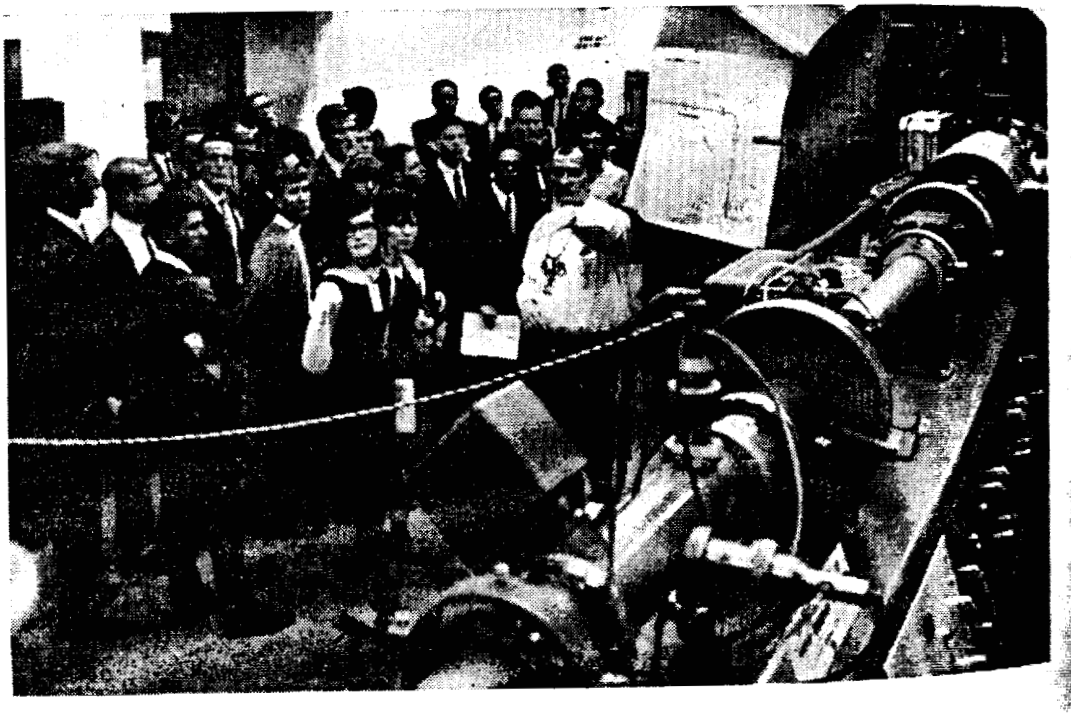
The depository of atomic energy films, both English and French versions, at the National Science Film Library of Canada (in Ontario) is serving increasing needs of Canadian scientists, industry, universities, and scientific and educational organizations. It provided many AEC films used in the science showings at EXPO 67. The AEC continued to supply films to the American Film Library at The Hague, the IAEA film library in Vienna, to the U.S. Information Agency (USIA) service office in Stockholm for use throughout Scandinavia, to the U.S. Agency for International Development (AID) for use in Central and South America, to USIA for use in Turkey and Singapore; and prints of such outstanding films as "Brookhaven Spectrum" and "Desalting the Seas" to USIA for world-wide distribution.

Two AEC films—"Atomic Power Today: Service with Safety," and "Brookhaven Spectrum"—were selected for international Gold Eagle awards by the Council on International Nontheatrical Events.

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Edison Day Student Tours. More than 5,200 junior and high school science students and their teachers visited 14 AEC laboratories and other facilities during the 120th anniversary observance of the birth of Thomas Alva Edison during February. The AEC and its contractors have held Science Youth Day tours for the past 11 years, for some 47,000 students and teachers. For each of the 11 years, the National Reactor Testing Station in Idaho has set the pace for attendance. Photo *above* shows some of the 1,700 Idaho, Montana, Wyoming, Utah, and Oregon students viewing a model of the Idaho Chemical Processing Plant on February 11, 1967. Los Alamos Scientific Laboratory in New Mexico drew the second largest group—800 students from 40 high schools in New Mexico, Arizona, California, Colorado, and Texas. A portion of the group are shown listening to a description of the Los Alamos Tandem Van de Graaff accelerator in photo *below*.



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DECLASSIFICATION ACTIVITIES

The AEC's declassification program has as a primary objective the prompt release of previously classified atomic energy information whenever this becomes possible. To fulfill the objective of making information available to science, industry, and the public, the AEC continuously reviews its classified programs to determine whether they may be declassified in whole or in part without undue risk to the national defense and security.

Additional Subjects Declassified

A comprehensive and detailed study of AEC classification policy was completed during 1967. In this study, the AEC and its Committee of Senior Reviewers (see Appendix 2 for list of members) found that a number of classified areas of information could be considered for declassification. The significance of this on the national defense and security was being evaluated at year's end. Among the areas considered are: (*a*) the Army compact reactors technology; (*b*) the remaining classified information in the aircraft reactors technology; and (*c*) isotopic heat sources. Portions of the SNAP reactor and production reactor programs are also being considered for declassification. In the gaseous diffusion separation program, separative capabilities and gross production rates, but not technology, were declassified.

Classification Reaffirmed

The AEC has also concluded that it would not be in the interest of the national defense and security to declassify new information in certain fields of activity and has reaffirmed the continuation of the present classification policy for: (*a*) weapons program; (*b*) Naval propulsion reactor program; (*c*) gaseous diffusion and gas centrifuge technology; (*d*) "any other method of isotope separation which achieves a reasonable potential for the practical production of special nuclear material in substantial quantities"; (*e*) Pluto program (nuclear ramjet); and (*f*) Rover program (nuclear rocket engine). Continuation of the present policy is also being considered in the case of the thermoelectric and thermionic converter programs.

Documents Declassified

During the year, 45,000 documents were reviewed for declassification and 36,500 were made publicly available. Since the beginning of

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the declassification program in 1946, a total of 440,000 documents have been made available on an unclassified basis to industry and science.

Access Permits

The AEC's Access Permit Program was established 12 years ago to permit industrial organizations to obtain classified information pertinent to civilian applications of atomic energy.

Continuing declassification of research and development work has caused the number of access permits to decline. There were 395 access permits (314 for access to Secret Restricted Data and 81 for access to Confidential Restricted Data) in effect on November 30, 1967, compared to 427 a year earlier (332 for Secret and 95 for Confidential).

PATENT INFORMATION

The AEC implements its program of dissemination of technical information by making inventions and patents available to the public through the issuance of patent licenses. The availability of these patents are made known through publication of abstracts in public announcements [6] and technical journals.

1967 Issuances

During the period November 22, 1966, to November 21, 1967, the U.S. Patent Office issued 301 U.S. patents to the AEC. There are 4,020 AEC-owned unexpired U.S. patents administered by the AEC now available for licensing. The AEC portfolio of foreign patents increased during this period by 428. This includes patents in some 15 foreign countries. The total portfolio of AEC-owned foreign patents numbers 3,514.

The AEC granted 35 nonexclusive licenses on Government-owned patents. In addition, 38 nonexclusive licenses have been retained by contractors. AEC contractors have retained exclusive licenses in fields other than atomic energy in 28 patents. In 30 instances, the title and rights in the patents were vested in the contractor, subject to a nonexclusive license in the AEC for governmental purposes.

[6] Listings published as AEC public announcements during 1967: No. IN-758 (U.S. Patents), February 13; No. IN-767 (Canadian Patents), March 16; No. IN-779 (British Patents), April 14; No. IN-781 (U.S. Patents), April 21; No. IN-790 (French Patents), May 19; No. IN-795 (U.S. Patents), June 8; No. IN-805 (U.S. Patents), July 14; No. IN-809 (Belgian Patents), July 25; No. IN-813 (British Patents), August 16; No. IN-835 (U.S. Patents), November 14; and No. IN-845 (U.S. Patents), December 29. Copies of listings are available from Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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Private Atomic Energy Applications

Under Section 152 of the Atomic Energy Act of 1954, as amended, the Commissioner of Patents refers privately owned U.S. patent applications in the atomic energy field to the AEC. The AEC filed 27 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 to 194. The AEC has acquired rights in 106 Section 152 applications, and in 68 cases the directives were withdrawn without acquisition of rights after completion of investigations. Pending applications total 20.

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Chapter 14

NUCLEAR EDUCATION AND TRAINING

The AEC supports nuclear training activities in association with the Nation's educational institutions. Assistance to the academic community is both direct and indirect. The major emphasis is upon graduate education, but activities also include aid to secondary school science teaching, technician-level participants, and training at the undergraduate level. AEC laboratories, other AEC contractors, and educational institutions cooperate to improve the capabilities of institutions of learning to maintain an adequate flow of nuclear scientists, engineers, and technicians to meet the demands of the growing nuclear industry.

CHANGES IN EMPHASIS

The academic community is being provided with even greater opportunities for use of the unique facilities in AEC laboratories. The formation in 1967 of the Associated Western Universities[1]—an enlargement of the former Associated Rocky Mountain Universities—will facilitate assigning teachers and students from nine or more additional educational institutions in the West to AEC laboratories for special training in nuclear fields. A survey was completed of the interest of colleges and universities in the Northeastern States in nuclear training, with a view to forming an association to work more

[1] Participants in Associated Western Universities are: Brigham Young University; Colorado State University; University of Colorado; University of Denver; Idaho State University; University of Idaho; Montana State University; University of Montana; New Mexico Institute of Mining and Technology; New Mexico State University; University of New Mexico; San Jose State College; Texas A and M University; Utah State University; University of Utah; and University of Wyoming.

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closely with the AEC's laboratories. Prospective participants are working on a charter.

New programs are being offered in radiation biology to provide specialized nuclear information for use by college and high school science teachers.

New Health Physics Training

In January, a new 4-week training program in Accelerator Radiation Monitoring and Health Physics was held at the AEC's Lawrence Radiation Laboratory in Berkeley, Calif. This training was designed to provide a thorough presentation of advanced techniques in accelerator radiation monitoring and practical training in the use of these techniques. Fifteen health physicists representing the AEC and its contractors, universities, and State or Federal Government agencies participated.

Postdoctoral Fellowships Emphasized

Increased emphasis is being placed on postdoctoral fellowships. These fellowships are offered to individuals who are currently teaching or plan to go into university graduate-level teaching and who wish to extend their research training by a year or two of concentrated work experience with highly specialized scientists and technical equipment.

Manpower and Training Studies

The increase in back orders for the manufacture and construction of nuclear powerplants has created a need for increased training programs and facilities to meet the increased manpower requirements. The AEC is attempting in several ways to assess the future manpower needs and to assure the availability of adequate training capabilities for the nuclear industry and the academic community. A detailed examination of utility staffing and training needs is underway. Alternative methods of meeting such needs are also being sought as guidance to both industry and the educational community. The 1967 Bureau of Labor Statistics survey on scientific and technical manpower conducted for the AEC was revised from past annual surveys to report on specialized occupations in the industrial segments of the atomic energy field. The AEC has also contracted for a study to assess the foreseeable manpower, education, and training requirements in the entire nuclear field and the adequacy of facilities to meet such needs. This study is being made jointly by the American Society for Engi-

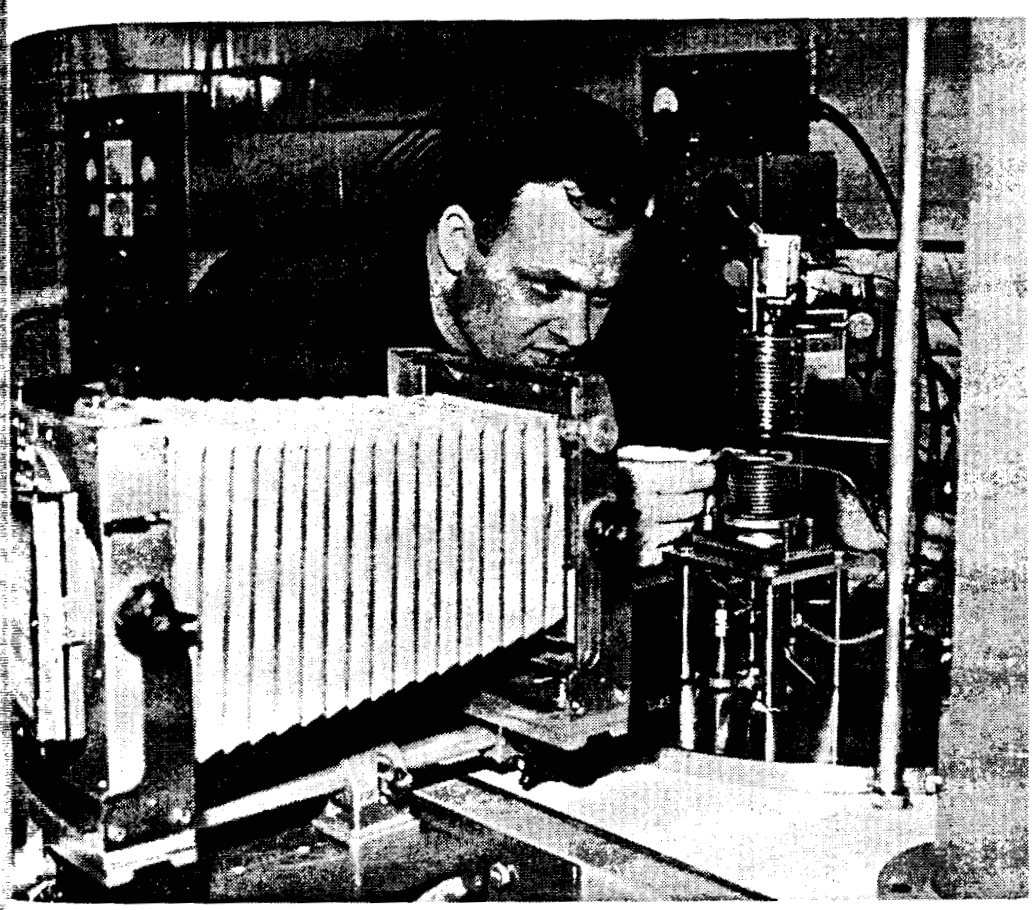
ering Education and the American Nuclear Society; it is to be com-
eted early in 1968.

TRAINING PROGRAMS

The AEC's nuclear training programs primarily encompass activ-
es conducted by its major contractors and laboratories, in associa-
on with colleges and universities.

AEC-CONTRACTOR PROGRAMS

AEC contractors support a variety of educational programs for
eir employees, as well as for college faculty and students. Various
rsonnel-development programs encourage contractor employees to



sis Research. During its 25-year history, the facilities of the AEC's Ames
oratory at Iowa State University (Ames, Iowa), have provided opportunities
more than a thousand graduate students to associate with mature scientists
e carrying out their thesis research for M.S. or Ph. D. degrees. Photo shows a
duate student preparing to photograph the silhouette of a single liquid metal
p as it rests on the surface of proposed container material for a liquid metal.
asurements of this type are fundamental to modern liquid metals technology.

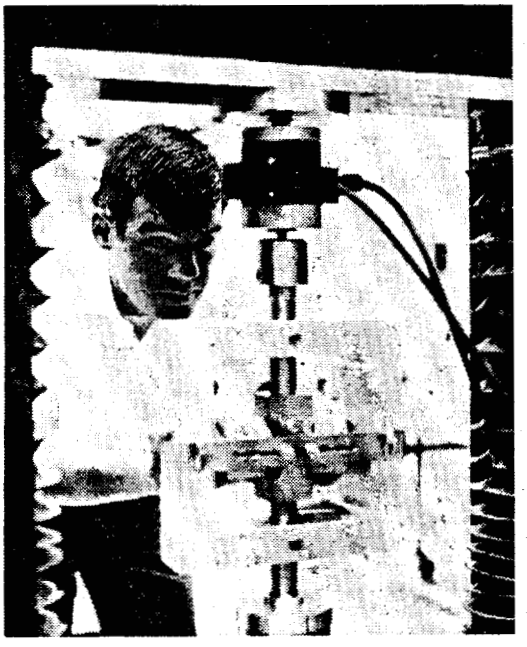
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receive college-level training through tuition aid, time off for classes, tuition-free off-hours courses, or temporary assignments for research beyond their regular work assignment. During 1967, it is estimated that more than 6,000 contractor employees received over 600,000 hours of formal college-level training.

Some contractors offer reciprocal programs that enable senior laboratory staff members to reenter the academic environment or to develop new competence required for their laboratory assignments. In return, these programs create opportunities for faculty members to pursue research at AEC laboratories or facilities.

Specialized Employment

During the year, more than 2,000 faculty and students were employed by AEC contractors on a temporary or part-time basis. They were placed in programs designed to give research experience in a specialized laboratory in fields compatible with the participants' academic pursuits. Programs offered by contractors also included





Summer Training. More than 230 students were employed at the Los Alamos Scientific Laboratory (LASL) during the summer of 1967 in tasks that would further their nuclear training. *Left* photo shows a Harvard University (Cambridge, Mass.) graduate student working with a helium-3 dilution refrigerator component in LASL's Cryogenic Laboratory. On the *right*, an Albany State College (Albany, Ga.), summer research student participant at the Medical Division of Oak Ridge (Tenn.) Associated Universities (ORAU) collects minute samples of a thin-layer chromatogram containing various lipid fractions. The automatic zonal scraper and sample collector was developed at the ORAU facility for radioassay of carbon-14 and helium-3 labeled metabolites.

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rticipation in work-experience training for employees of other or-anizations having objectives concerning the general development of omic energy.

The technician scholarship program continued on a pilot basis. This rogram provides financial support to selected AEC contractor tech-icians to enable them to complete their undergraduate education. uring this second pilot year of the program, the first three technicians eceived their bachelor's degrees and returned to work, 12 new appoint-ents were made, and seven remained in the program from 1966.

COLLEGE AND UNIVERSITY PROGRAMS

The primary purpose of research conducted at AEC laboratories nd under contracts with universities and other institutions is to extend uclear knowledge in the physical and life sciences, and in engineering. owever, an important secondary benefit in training is received by raduate students who assist principal investigators as salaried em-loyees. During the year more than 5,400 graduate students benefited rom, as well as contributed to, AEC research activities. Of these, bout 1,200 were in AEC laboratories and 4,200 were in universities nd other institutions.

ellowships

Important educational assistance is provided by the AEC's six ellowship programs in nuclear disciplines through annual appoint-ents of selected graduate students.

For potential scientists and engineers working on their advanced egrees, fellowships of typically 3 years duration were awarded in uclear science and engineering. Contracts with selected universities rovided traineeships for the support, also usually for 3 years, of ther outstanding graduate students in nuclear-oriented disciplines. n addition, research facilities at AEC laboratories were made avail-le for up to 2 years to graduate students in nuclear science and ngineering for thesis completion.

A postdoctoral fellowship program is offered, for 1 year with tion for renewal, to recent Ph.D. recipients to pursue research ac-ities under highly specialized leadership in AEC laboratories in reparation for graduate-level teaching.

In health physics, fellowships are offered for up to 3 years of ecialized study including 3 months training at AEC laboratories. edical doctors are also offered fellowships in industrial medicine ich provide training in the industrial hazards associated with

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radiation and the use of radionuclides in diagnosis and treatment of disease.

As of November, the 1967 fellowships, including extensions, were distributed as follows: nuclear science and engineering, 209; traineeships, 151; laboratory graduate fellowships, 103; postdoctoral fellowships, 29; health physics fellowships, 69; and industrial medicine fellowships, 11.

Faculty Training Institutes

Institutes for special study in such fields as radiobiology, nuclear physics, isotope technology, and radiation biochemistry were sponsored by the AEC and the National Science Foundation. These institutes provide high school and college science faculty with additional training and thus promote the teaching of nuclear science in the regular curriculums of the participants' own institutions.

Summer sessions of 6- to 10-weeks each were held at 22 colleges and universities, at Argonne National Laboratory (ANL) near Chicago, and at the Oak Ridge Associated Universities (ORAU) Special Train-





Research Experience. During 1967, AEC contractors employed more than 2,000 faculty and students on a temporary or part-time basis. Their work assignments were designed to be compatible with their academic studies. On the *left*, a Western Kentucky State College (Bowling Green, Ky.) student trainee at the Medical Division of Oak Ridge Associated Universities, checks the data output tape from the low-level, whole-body counter. On the *right*, a student from Colorado State University (Fort Collins, Colo.), is shown performing a test in the Industrial Hygiene Laboratory at Los Alamos Scientific Laboratory.

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Division in Oak Ridge, Tenn. Of these institutes, 13 were oriented toward college faculty and 18 were for high school teachers. A total of 238 college and 410 high school faculty attended these sessions.

Five in-service institutes, which enable science teachers to obtain training comparable to the summer institutes at evening and weekend classes throughout the school year, were attended by 91 high school faculty. These institutes were held at three colleges and by Brookhaven National Laboratory and ORAU's Special Training Division.

A year of full-time graduate study was possible for 57 college and high school faculty at academic-year institutes conducted at two universities and ORAU.

Seven faculty research participation institutes were held at six universities for faculty having previous nuclear science training in other AEC institutes. Forty-two participants performed research in small groups as junior colleagues of experienced staff investigators.

Equipment Grants and Services

Grants for nuclear training equipment, loans of nuclear materials, and financial assistance for university reactors continued to be made to institutions for the strengthening of their nuclear science and engineering teaching programs. Equipment grants on a matching basis, amounting to more than $500,000, were made to 57 schools with graduate-level programs of proven high quality or with undergraduate programs which produce a high percentage of graduates who move on to advanced degrees in nuclear-oriented disciplines.

PROGRAMS THROUGH AEC LABORATORIES

The specialized nuclear facilities and scientific and technical staff of the AEC's major contractor installations continued to provide a variety of educational and research training opportunities for faculty and students. Expansion of the training effort in AEC laboratories occurred during 1967 in numbers of persons and institutions participating, in programs offered, and in the number of laboratories making their facilities available to the academic community.

The use of AEC laboratories for training programs is promoted to a large extent by cooperative arrangements through contracts with associations of universities in proximity to the laboratories. However, all faculty and students are permitted to use the facilities without regard to membership in associations or geographic proximity. Thir-

teen major AEC laboratories [2] were engaged in a wide variety of cooperative training activities for 2,600 students and 630 faculty during the academic year.

Faculty Training

College and university faculty members participated in several AEC programs designed to provide research training experience which would ultimately improve the educational programs in their home institutions. Faculty research participation in summer months was most important. Weekend workshops were attended by college faculty members at Argonne National Laboratory (ANL) covering a variety of subject areas, including radiobiology, radioisotope technology, X-ray diffraction, nuclear magnetic resonance spectroscopy, optical spectroscopy, computers, neutron physics, and practical electronics

[2] Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, E. O. Lawrence Radiation Laboratory (Berkeley, and Livermore), Los Alamos Scientific Laboratory, National Reactor Testing Station, Oak Ridge National Laboratory, Pacific Northwest Laboratory, Puerto Rico Nuclear Center, Sandia Laboratory, Savannah River Laboratory, and University of Rochester Atomic Energy Research Project.



Research Participation. The AEC offers opportunities for faculty and students to do research work together in many areas of science and technology. Shown here, a professor of biology from George Washington University (District of Columbia), and a student from the University of Georgia (Athens, Ga.), prepare a sampler used in their study of photosynthesis under Oak Ridge Associated Universities sponsorship. The sample is being taken from a Savannah River Plant (near Aiken, S.C.) man-made lake used to supply part of the cooling water for the AEC's production reactors.

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her faculty were given temporary appointments as staff members function in a variety of capacities in AEC laboratories.

Argonne National Laboratory provided university faculty with a mester's research through the PACE (professional activities for ntinuing education) program.

raduate Student Training

In addition to fellowships and employment in research projects, as-tance to graduate students was provided through a variety of ecial programs at AEC laboratories. For example, candidates for anced degrees in nuclear-oriented disciplines were given graduate dent thesis appointments in order to use AEC facilities for thesis search. Graduate students in engineering or applied science received porary appointments at the Oak Ridge and Argonne laboratories in gineering practice schools.

dergraduate Training

During the summer of 1967, nearly 400 students worked as student inees on research and development projects with experienced staff mbers at AEC laboratories. Other undergraduates, through coop-tive honors programs, received college credit for a semester of study d research at an AEC laboratory. In a 2-year program on radiation tection techniques program sponsored by AEC, 22 technical in-tute students from Idaho State University spent the summer at the tional Reactor Training Station gaining practical health physics ex-rience. About 50 small colleges hosted 2-week visits by AEC's mobile boratories from Oak Ridge during 1967, allowing faculty, students, d other participants to receive special training in basic radioisotopes hniques. Science classes from colleges and universities conducted dent experiments at ANL under the direction of their own faculty ring the academic year.

SPECIAL PROGRAMS

Special programs reaching beyond the academic community to many ups in medicine, local and State governments, and a wide variety other fields, attempt to meet training needs in this growing field of clear energy. These programs included courses in radioisotope tech-ques at ORAU which were attended by government, industry, and dical personnel, faculty and students; medical qualifications

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courses, also at ORAU, in which physicians spend 1 to 3 weeks receiving instruction in the uses of radioisotopes in diagnosis; and orientation sessions for many special groups.

In another phase of its training program, three one-half hour color motion pictures are near completion and will be available for loan to schools and organizations during 1968. The films are designed to motivate undergraduate college students and high school seniors to select careers in nuclear science and engineering.

Puerto Rico Nuclear Center

The AEC continued its contract with the University of Puerto Rico for the operation of diverse nuclear-oriented graduate-level research and training programs in engineering and life and physical sciences at three locations of the Puerto Rico Nuclear Center. The Rio Piedras site



International Group Study. The AEC-supported Puerto Rico Nuclear Center (PRNC) at San Juan, Puerto Rico, celebrated its tenth anniversary during 1967. It provides nuclear training not only for Central and South Latin American students, but from other countries as well. In the photo, nuclear engineering graduate students of the University of Puerto Rico (which operates the center for the AEC) from Taiwan, Puerto Rico, and Mexico are shown receiving training on the operation of the PRNC's pool-type research reactor.

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atures programs in medical, biological, and agricultural sciences. The El Verde tropical rain forest is the site of Ph. D. and M.S. thesis research work in rain forest ecology. At Mayaguez, research and training programs are conducted in nuclear science and technology, nuclear engineering, agriculture, and health physics. During the 1966–67 academic year, 236 students were enrolled in educational programs at the center, including 26 from Central and South American countries.

In celebration of the tenth anniversary of the founding of the Puerto Rico Nuclear Center, an international symposium on nuclear energy and Latin American development was held October 30 through November 1. Representatives attended from 15 Latin American nations, the United States, and the International Atomic Energy Agency. Papers and discussions concerned the role of atomic energy in solving Latin American problems in the areas of food and nutrition, public health and medicine, and natural and energy resources.

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Chapter 15

BASIC RESEARCH

The AEC sponsors a broad range of basic research studies in the and physical sciences. This chapter mentions, in "highlights" form, me of the more noteworthy recent advancements in basic research ch are more fully covered in the supplemental report, "Funda- tal Nuclear Energy Research—1967,"[1] and briefly describes new lities being planned, or provided, for conducting the fundamental earch and development program.

HYSICAL RESEARCH

The AEC's basic physical sciences research program encompasses en areas of research. All have the unifying goal of furthering man's derstanding of the natural laws and phenomena which are relevant the atomic energy program. Both theoretical and experimental re- rch is conducted in high energy physics, medium energy physics, energy physics, mathematics and computers, chemistry, metal- gy and materials, and controlled thermonuclear research. The actual earch is accomplished through work done at major research centers through a research contract program. A large portion is accom- hed at "on-site" locations which include the AEC national labora- es, other multiprogram laboratories, and special research centers. ring 1967, about 542 research projects, supported by AEC contract, e at "off-site" locations. Of these, 509 were at educational institu- s with the remainder of the contract research going forward at profit institutions, industrial research organizations, and at other eral agencies.

The nation benefits in a three-fold way from this approach to re- rch: (*a*) it provides knowledge for the continued advancement of lear science; (*b*) it aids specific scientific disciplines fundamental

[1] Available from the Superintendent of Documents, U.S. Government Printing Office, ington, D.C. 20402, for $2.50.

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to the AEC programs; and (*c*) it contributes to the supply of trained scientists and engineers in fields directly related to the AEC's programs.

RECENT ACHIEVEMENTS

A major portion of the supplemental report, "Fundamental Nuclear Energy Research—1967" [2] is devoted to the achievements being made in the seven areas comprising the AEC's physical research program. In capsule form, some of the more important recent advancements are listed here.

High Energy Physics

- Calculations have been made to test the new "quark model" based upon the existence of three particles which may have fractional electric charges and which may be the fundamental constituents of matter.
- An interference model has been developed to explain the experimentally observed features of high velocity collisions between two types of particles—pions and nucleons.
- Interpretation of very high energy experiments conducted at electron accelerators have confirmed the theory that electromagnetic radiation manifests several forms upon interaction.
- A number of new enhancements, possibly "resonant" particles, have been discovered by measuring the total cross section for K^- and K^+ mesons on protons and deuterons.
- A new photoproduction method has resulted in the discovery of two new members of the Y family of particles.
- The successful extraction of the proton beam directly into a large experimental hall makes it possible to obtain mesons produced at 0° to the forward direction.
- Superconducting beam magnets have been developed which produce magnetic fields two to three times greater than the 20-kilogauss limit for iron pole beam magnets.
- A unique tool, which employs the conversion of photons into electron-positron pairs, has been developed to analyze the spectrum of a beam of high energy photons.

Medium Energy Physics

- K-mesonic atoms of lithium, beryllium, boron, and carbon have been identified.

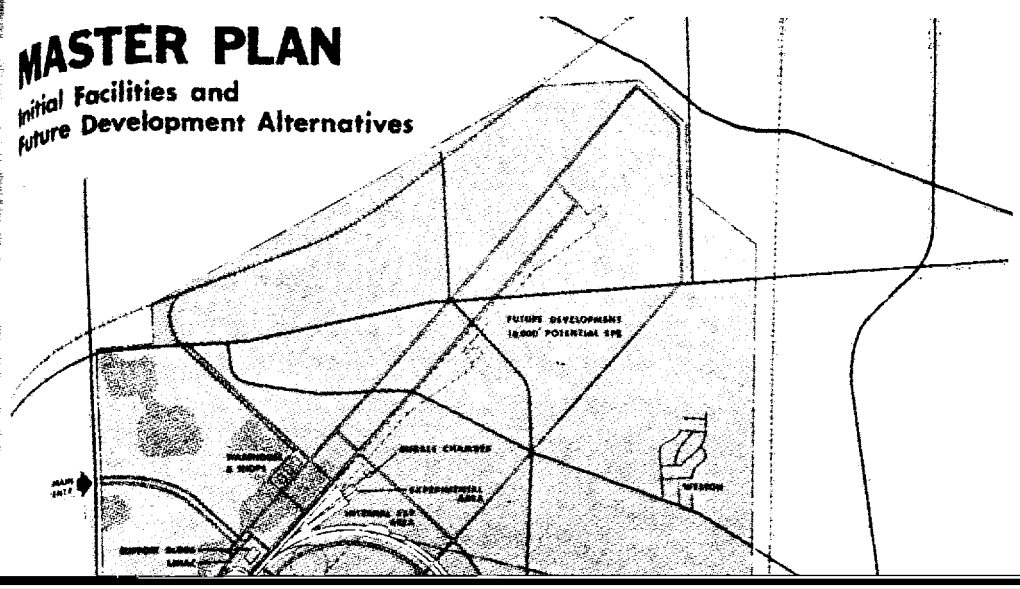
[2] See footnote 1, p. 251.

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Low Energy Physics

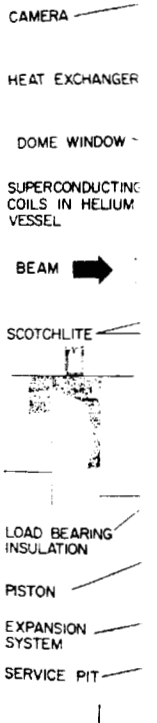
- A combination of the *Coulomb* excitation process and *Doppler* shift is being applied to the study of nuclear lifetimes in the 10 pico-second (10^{-11} of a sec.) range.
- One particularly significant result of nuclear reactions induced by tritons from a three-stage tandem Van de Graaff accelerator is the discovery of the nucleus, helium-7.
- Radioactive iodine, alive in the early times of the solar system, but now completely died out, has brought forth the discovery that an extinct radioactivity clock can be extremely useful in dating other events in the early solar system.

Chemistry Research

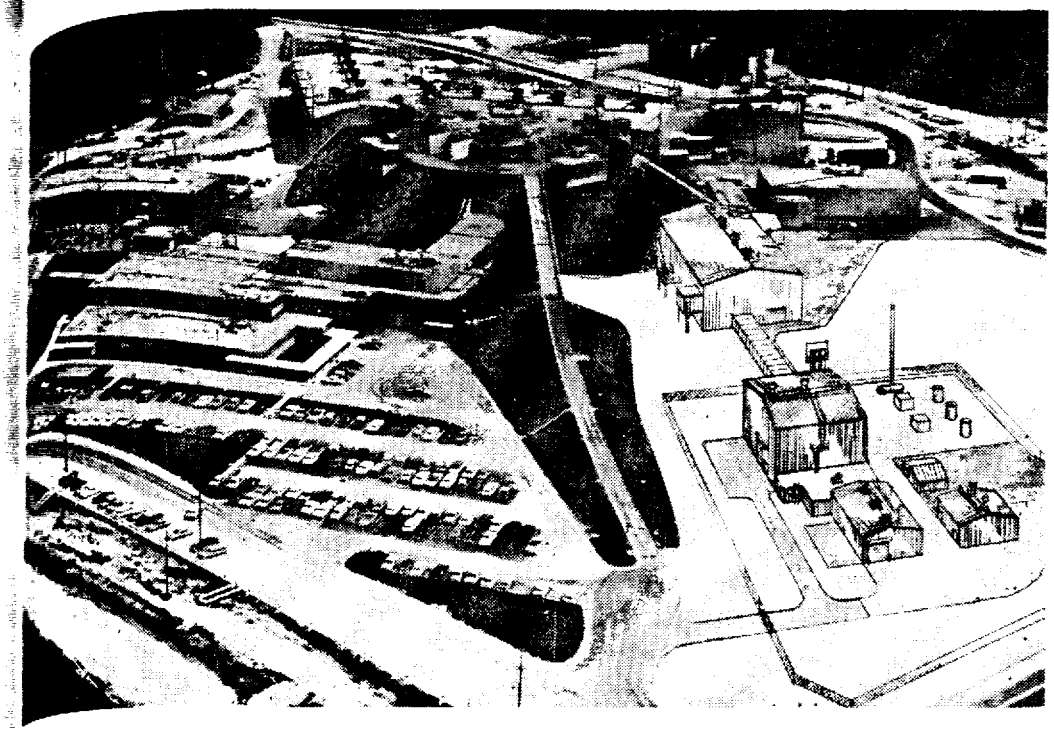
- New techniques of measurement have resulted in the discovery of nuclei of boron and lithium never before identified. These include boron-14, boron-15, and lithium-11. Many other details of important nuclear reactions are being unraveled by this method.
- Lithium-drifted germanium detectors have recently been applied to new measurements of neutron activation cross sections, which are used in activation analysis of a wide variety of materials. The new techniques permit more rapid analyses at lower cost because no chemical separations are necessary.
- Major advances in spectral interpretations of the electronic structures of the actinide elements have been made at a number of AEC laboratories using computer programs to make theoretical calculations.
- The iron-57 isotope has been used in *Mössbauer* spectroscopy to give new information about the chemical composition or state of combination of iron in native coal. This information is expected to be useful because it is related to problems of ash and clinker formation, waste disposal, and of possible pollution control.
- All ordinary compounds of silicon have a valence of four, i.e., each silicon atom is chemically bonded to four other atoms. Recently, a compound of silicon showing a valence of five has been prepared and its structure determined for the first time. This opens up a new field of silicon chemistry of considerable theoretical and possible practical interest.
- New experimental and theoretical investigations, including the development of laser-excited *Raman* spectroscopy, are providing improved understanding of the compositions and structures of fused salts.



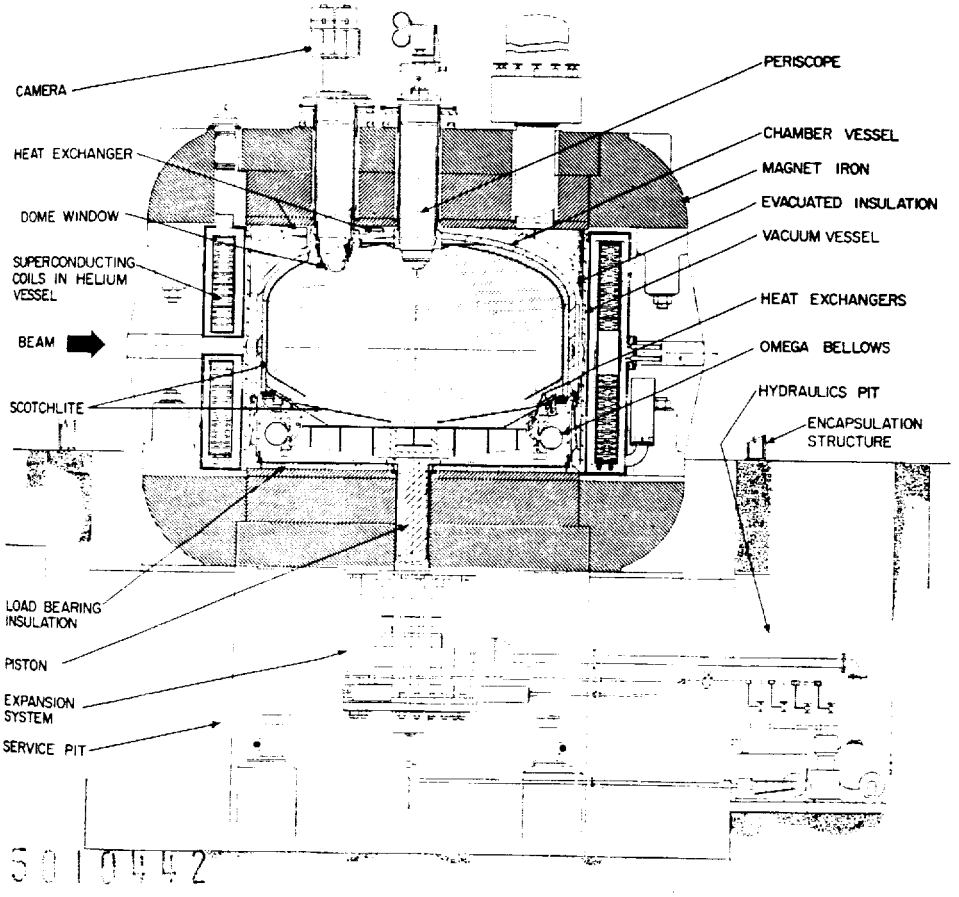
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GS Modifications. The *above* aerial view of the Zero Gradient Synchrotron (ZGS) at Argonne National Laboratory shows components being added to the big celerator drawn in at *right*. The new buildings comprise an additional experimental area for the ZGS and will house the world's largest hydrogen bubble chamber. The diagram *below* shows a cross section of the chamber, which will rest in the coils of a superconducting magnet. The chamber, now under construction, an outside diameter of 13.5 feet.



Metallurgy and Materials

- In experiments on channeling, iodine ions of 50 Mev. energy were found to pass through gold crystals and emerge with discrete energy bands.
- Normal grain boundaries in nickel have been observed to absorb defects created during neutron irradiation more readily than twin boundaries.
- A device has been developed for measuring temperature-induced length changes of the order of one percent of the average spacing between atoms in the solid—ten times better than previously possible.
- A new superconducting phenomenon has been discovered involving electronic tunneling between superconductors.
- A new electron spin resonance technique has been developed and used to study the excited states of impurity atoms in crystals.
- A new limit for the electric dipole moment of the neutron has been established by neutron scattering of a high flux beam of neutrons.
- Recent observations on superplasticity in metallic materials point to a plausible explanation for this phenomenon, namely the appearance and growth of new grains and the constant motion of grain boundaries during stretching.
- A new high-strength-high-ductility material, TRIP (transformation-induced plasticity) steel, has been developed.

Controlled Thermonuclear Research

- For the first time, a high temperature plasma has been contained in a low-beta toroidal device without the existence of anomalous diffusion.
- The Astron device achieved magnetic field reversal of a few per cent which represents a significant step toward proving the feasibility of the Astron thermonuclear concept.

Mathematics and Computers

- Two devices to assist in the computer processing of line drawings employing novel high-speed digitally controlled analogue circuits have been developed under AEC sponsorship. The machines are relatively cheap and offer the possibility of considerably simplifying the operations of computer graphics.
- A method has been developed for calculating the circulating motion which occurs when a layer of compressible heat-conducting viscous liquid is heated from below. This type of phenomenon occurs

frequently in nature. As a result, the work is of interest to scientists in many fields.

• Important information concerning the generation and maturation period of red blood cells has been discovered as a result of a mathematical model which was developed to simulate the behavior of such blood cells and their precursors (erythrons).

NEW AND PROPOSED FACILITIES

The very nature of the physical research program calls for unusual and often highly sophisticated research facilities. During the year, one new major physical research facility was dedicated, construction was started on three, and two were in the planning stage.

Stanford Linear Accelerator

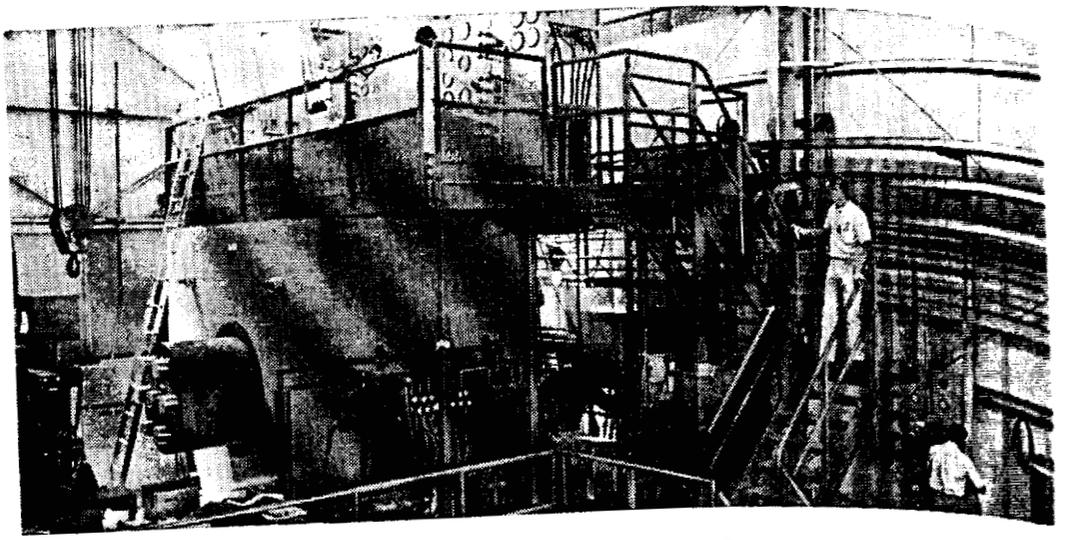
The Stanford Linear Accelerator (SLAC) near Leland Stanford, Jr., University, Palo Alto, Calif., was formally dedicated on September 9, 1967. The 2-mile long, $114 million linear electron accelerator was operated for the first time in May 1966. Shortly thereafter it achieved its design energy of 20 billion electron volts (Bev.). The accelerator has met, or exceeded, all major specifications set for its performance. Particle interaction physics experiments already underway at SLAC were expanded to new areas in the summer of 1967 with the first operation of the SLAC 40-inch hydrogen bubble chamber.

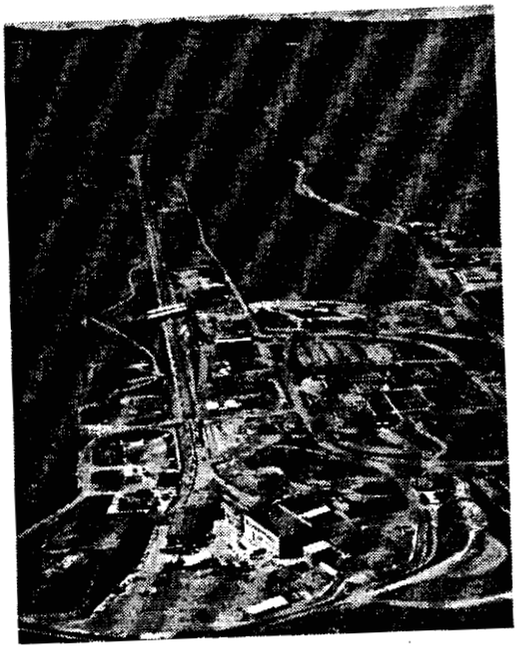
Argonne Advanced Research Reactor

Construction of the Argonne Advanced Research Reactor (A^2R^2 or AARR) was started in mid-1967. The principal feature of the A^2R^2 will be its very high neutron flux of 5 quadrillion neutrons passing through an area of one square centimeter (5×10^{15} neutrons per cm^2), in 1 second. Its 100-thermal-megawatt operating level and abundant supply of neutrons will provide Midwestern University and Argonne National Laboratory staff scientists with a new tool for highly sophisticated investigations in the fields of nuclear physics, chemistry, metallurgy, and materials.

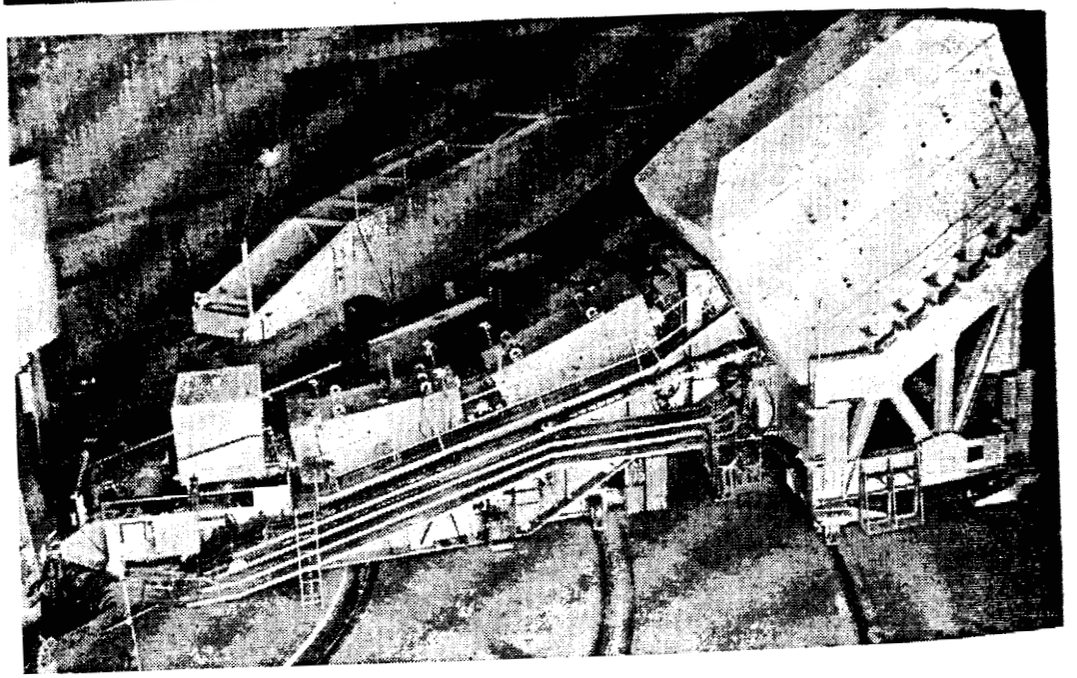
12-foot Liquid Hydrogen Bubble Chamber

A 12-foot liquid hydrogen bubble chamber facility now under construction at Argonne National Laboratory is a part of the major additions to the Zero Gradient Synchrotron (ZGS) facility for high energy physics research. Also included are a second external proton beam, and





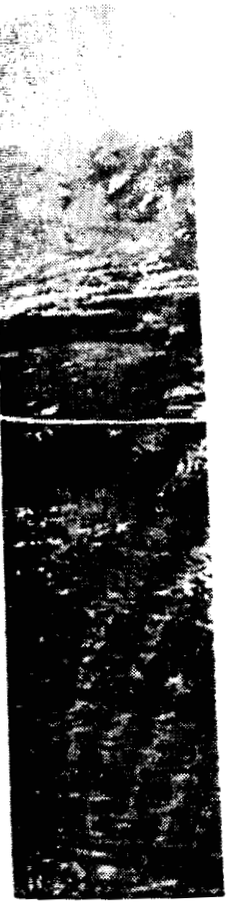
Stanford Linear Accelerator. A 40-inch hydrogen bubble chamber (*above*) went into use at the new Stanford Linear Accelerator during mid-1967, and an 82-inch chamber is under construction. The 2-mile-long, 20-Bev. linear accelerator (at *left*) on the Stanford University campus was dedicated on September 9, 1967. Photo *below* is an interior view of End Station "A" (largest building at bottom of photo on *left*) showing the 1,700-ton, 20-Bev. spectrometer. The electronic counters that detect the particles traversing the spectrometer are housed in the large concrete shielding pods so as to reduce accidental counts from cosmic-rays and stray radiations



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Site preparation

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a new proton experimental area which will greatly enchance the research capability of the ZGS.

The bubble chamber, 12 feet in diameter by 6 feet high, will contain over 825 cubic feet (26,500 liters) of liquid hydrogen. The large volume of the Argonne chamber will permit many experiments which were not previously possible. These include experiments requiring the detection of particles with very low interaction rates, such as neutrinos and those requiring the complete identification of the neutral reaction products (gamma rays and neutrons). The chamber can be filled with either hydrogen, dueterium, or hydrogen-neon mixtures. Metal plates for conversion of gamma rays can be installed as required.

Los Alamos Meson Physics Facility

Preliminary site preparation has started for the planned Los Alamos Meson Physics Facility (LAMPF) at the Los Alamos Scientific Laboratory, N. Mex. The AEC received authorization for construction



of the facility in July 1967. The heart of the facility will be a linear accelerator capable of producing a proton beam of 1 microampere at 800 million electron volts (Mev.). When such an intense beam bombards a suitable target, secondary meson beams thousands of times more intense than currently available will be produced. Thus this medium-energy, high current proton accelerator will open up important areas of nuclear and meson physics as well as important biological and medical studies. It will permit expanded studies on the structure of the atomic nucleus and the nature of nuclear forces. The accelerator will also offer a number of practical applications, one of which will be the use of negative pi mesons to treat inoperable tumors.

Scyllac Facility Authorized

The AEC was authorized, during July, to build a new controlled thermonuclear research facility (to be known as Scyllac) at the Los Alamos Scientific Laboratory (LASL). Its construction is in response to general agreement that theta-pinch pulsed systems provide a very important method of studying the behavior of thermonuclear plasmas or very hot gases. The first successful demonstration of a controlled fusion reaction was achieved in 1959 in a theta-pinch apparatus known as Scylla I at LASL. Since that time, there have been four powerful theta-pinch devices developed at LASL. The largest one, Scylla IV, has operated since 1963. The basic limitation of Scylla IV and other short linear theta-pinch devices is the loss of plasma out of the ends of the coil. The proposed new Scyllac experiment will attempt to reduce these end losses significantly. It will permit more meaningful studies on controlling the instabilities of plasmas. The objective of the AEC's controlled thermonuclear program is to attain a sustained fusion reaction which, like atomic fission reaction, can produce heat to generate electricity.

Proposed National Accelerator Laboratory

The proposed National Accelerator Laboratory, to be located at Weston, Ill., will have the world's largest accelerator capable of producing the highest energy particles. The accelerator is being designed by a group of accelerator specialists employed by the Universities Research Association, Inc. (URA), a prime contractor for the AEC. A highly ingenious and economical design has evolved in which the functions of bending the proton beam around the circular orbit and focusing it to confine it within the vacuum chamber are carried out by separate types of magnets. This type of accelerator makes it possible

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to reduce the cross-section and weight of the magnets substantially below those required for conventional "combined-function" accelerators. Thus, it may be possible for this accelerator to go beyond its design energy of 200 Bev. to 400 Bev. or more, if provided with more power. Plans for experimental use are centered around the idea of extracting the circulating proton beam and transporting it in a straight line away from the accelerator to adjacent target areas.

BIOLOGY AND MEDICINE

There is an urgent requirement for better understanding of the principles, mechanisms, and implications of the interaction of radiation with biological systems. Further, scientific guidance for control of exposure to radiation can be extended and refined if the basic data are at hand. Finally, important life science problems are being resolved through the use of radiation and byproduct materials (radioisotopes). The AEC's biomedical research program is directed toward these three main objectives.

The AEC's biological, medical, and environmental sciences research is conducted under more than 650 contracts. These contracts support work at nearly 250 universities, colleges, other nonprofit research institutions, commercial research organizations, and other Federal agencies. A good portion of the work is centered in major AEC installations, such as Argonne National Laboratory and Argonne Cancer Research Hospital, Chicago, Ill.; Brookhaven National Laboratory, Long Island, N.Y.; Lawrence Radiation Laboratory, Berkeley and Livermore, Calif.; Los Alamos Scientific Laboratory, Los Alamos, N. Mex.; Oak Ridge National Laboratory, Oak Ridge Associated Universities, and the University of Tennessee-AEC Agricultural Research Laboratory, at Oak Ridge, Tenn.; and Pacific Northwest Laboratory, Richland, Wash.

RECENT ADVANCEMENTS

The AEC's biomedical research is unique in that much of it must concern evolving elementary information about the life processes themselves before the radiation effects studies can begin. Thus, these AEC-sponsored studies are providing new information that may not necessarily be associated with the nuclear energy field. A number of the recent, interesting findings made recently under AEC sponsorship are included here in "highlight" form; these, and other, findings are more fully described in the supplemental report, "Fundamental Nu-

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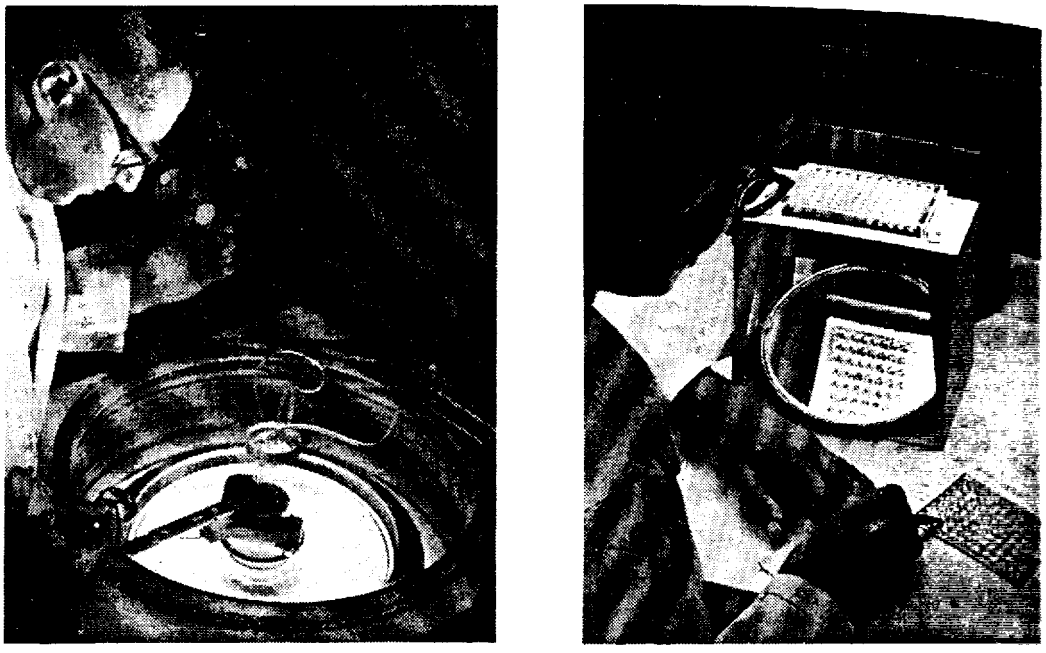
clear Energy Research—1967." [3] The report also includes two feature sections, one on AEC-sponsored studies related to the atmospheric sciences, and the other on the applications of semiconductor detectors in the field of medicine.

Selected Beneficial Applications

● Techniques have been perfected to synthesize human insulin for the first time. The perfection of such techniques is an important event in efforts to understand body processes and opens new avenues for research on diabetes.

● Technetium-99^{m} a radioisotope, has been shown to be as useful as radioactive iodine-131 in the diagnosis of abnormal conditions of the thyroid gland. Retention of technetium-99^{m} in the kidney has also

[3] See footnote 1, p. 251.



Zonal Centrifuge Research. Research in the use of the centrifuge in developing purified vaccines is being conducted at the AEC's Oak Ridge National Laboratory (ORNL) in a joint effort with the National Institutes of Health. Vaccines purified by centrifuge can give improved protection against diseases by eliminating many side effects and permitting multiple vaccines to be given in a single inoculation. Photo at *left* shows an ORNL scientist operating a centrifuge containing a new experimental centrophoresis rotor. Centrifugal force stabilizes the gradient while an electrical current fractionates serum into its component proteins. In *right* photo a technician records the results of a complement fixation test used to locate tumor antigens which were isolated by zonal centrifuge techniques. The uses of zonal centrifuges for medical research is an outgrowth of earlier work done at the AEC's Oak Ridge Gaseous Diffusion Plant on the use of centrifuges to separate uranium isotopes.

proved to be a useful characteristic for making good scans without unduly high radiation dose to the kidneys.

• Recent work with okra plant seedlings has shown that lower doses of radiation from neutrons are required to reduce growth comparable to the reductions induced by higher doses of gamma rays.

Instrumentation

• A newly developed scanning electron microscope has achieved a series of highly magnified photographs of living flour beetles. This appears to be one of the first times that living organisms have been visualized by electron microscopy.

Radiological Physics

• Measurements of energy deposition in sample targets which simulate living tissue (ten-millionths of a centimeter thick) indicate that a maximum of 100 to 110 thousand electron volts of energy can be deposited by energetic protons in a cell one ten-thousandth of a centimeter in diameter. This is about 20 percent more than previous estimates.

Cancer Research

• Implants of radioactive chromium wire introduced into cancer patients by means of a special injection "gun" have had results promising enough to deserve more attention.

• Needles containing californium-252 show some promise of becoming a new method for treating cancer. Dose rate measurements are now underway before biological studies begin. Patients will not be treated until preliminary trials in animals show this to be a safe technique.

Somatic Effects of Radiation

• In tests with germ-free mice, investigators have found that the absence of detectable micro-organisms does not increase the maximum length of life, but does increase the number of mice reaching "old age." This suggests that aging cannot be prevented by exclusion of micro-organisms from the environment.

• A bovine herd is under a lifetime study to observe the effects of radiation on: (*a*) fertility; (*b*) growth and viability of the calves;

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(*c*) pathological response in the cows; and (*d*) performance of the offspring by sire groups. Information acquired to date does not demonstrate that whole-body irradiation at levels of 200, 300, 400, and 600 roentgens has had an effect on the total reproductive performance of this herd.

Toxicity of Radioelements

● The biological effects of daily ingestion of various levels of strontium-90 in miniature swine have been under investigation since 1958. To date, 53 cases of lymphopoietic (lymph-forming tissue) or hematopoietic (blood-forming tissue) neoplasms have been observed in animals ingesting 250 to 625 microcuries of strontium-90 a day. Four of these swine had multiple bone tumors in addition to indications of leukemia. Most cases occurred in animals ingesting 125 microcuries a day. This amount is more than 100 times greater than the limits set for workers in atomic energy industries.

● Whole-body counters are being studied for their usefulness in determining deposition of plutonium-238 in the human lung. At one laboratory, it was concluded that the detection of a lung burden of plutonium-238 (0.016 nanocuries or 16 billionths of a curie) could be detected with existing equipment and that with some refinements in equipment, one-half this amount could be detected.

Combating Radiation's Detrimental Effects

● In tests of three chemicals for reduction in dose factors, MEA (mercaptoethylamine) was superior to the others in protecting mice from lethal irradiation of the head region while the rest of the body was protected by a lead shield.

Radiation Genetics

● Better synchronization of stages in a cell's cycle during periods of pre- and post-deoxyribonucleic acid (DNA) synthesis has been attained in cell cultures. With these refinements, it has been noted that most responses to X-ray vary greatly depending on the stage of the cycle at which the cell is irradiated.

● Work with plants has shown that a direct proportionality exists between the radiosensitivity of herbaceous plants and the volume of the chromosomes at the interphase stage of division in the cells of such plants. Continuing work extended to other forms of life, ranging from viruses and bacteria to the higher animals, has now shown that



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Radiobiology Studies. In Brookhaven National Laboratory's plant radiology laboratory (*above*) the effects of varying doses of radiation on plant materials are studied both on the macroscopic and microscopic scales. Such studies are leading to an increase of knowledge of plant genetics and the mechanisms of mutation production. The controlled environment facilities in the new laboratory wing include a number of "reach-in" growth chambers (*below*). The chambers shown here are located in the non-radiation control area where plants may be grown under various controlled environmental conditions including temperature, light, day length, and relative humidity. Minimizing the fluctuations of the growth environment permits more precise measurement of plant responses to genetic and physiological stresses. Various plants or other organisms may be irradiated, treated with chemical mutagens, etc. and then grown under the desired conditions during extended observation periods; or control plants may be grown under conditions identical to those for plants under continuous irradiation in a chamber in one of the shielded radiation rooms. Intricate alarm systems have been designed to bring immediate attention to any chamber malfunctions.



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(*a*) similar relationships between chromosome volume and radio-sensitivity exist; and (*b*) that these relationships can be used to classify all the forms studied thus far in seven distinct groups.

Molecular and Cellular Level Studies

● In studies of the synthesis of deoxyribonucleic acid (DNA) in cultured human cells, a new technique has shown that after irradiation, synthesis of DNA occurs in a manner completely different from that in normal unirradiated cells. This synthesis after irradiation may be a part of a repair process that eliminates some of the radiation-induced damage to the cells' genetic material. This is the first evidence to come to light for the repair of genetic damage by human cells.

● A study has shown that the removal of the nucleus from a developing egg (frog embryo) has no effect on the rate of protein synthesis. A conclusion is that although the nucleus must provide the ultimate control of growth and synthesis, the expression of the genetic characteristics coded in the nucleus does not necessarily occur as a simple, timed sequence of events.

● Ultracentrifuge rotors are being used to obtain large amounts of purified viruses for use in new vaccines. Several common cold viruses, as well as influenza virus, *Rauscher* and *Moloney* leukemia viruses, and bacteriophages have been obtained in a highly purified state using the ultracentrifuge.

Environmental Radiation Studies

● Translocation and accumulation of DDT labeled with a radioactive isotope have been studied in a freshwater marsh. Results have shown that DDT is rapidly translocated through the marsh ecosystems and is rapidly accumulated by many organisms of which aquatic plants are the greatest accumulators—taking up, within 3 days, 3,000 times the concentration applied initially.

● Radioactive labeling of ticks has been achieved and the method is giving promise of being a useful technique for studying the transfer of a number of diseases that plague mankind.

Atmospheric Radioactivity and Fallout

● A new high altitude rocket sampling system designed and developed by the AEC and the Department of Defense marks a significant increase in the altitude range over that attainable by balloon

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mpling for atmospheric radioactivity. An option in sampling itudes allows selection of one of three essentially equal altitude rements between 150,000 and 250,000 feet or an integral sample ken over this entire range.

• Iron-55 has increased from a minor fraction of fallout to the st abundant of all fallout isotopes since the 1961–62 nuclear tests. he study of the transfer of iron-55 and its concentration in the sphere is of interest because iron is an essential element to many ganisms and it is easily measured in almost all living organisms. he weak radiation associated with the iron-55 decay produces an ly small radiation exposure as compared even with the normal

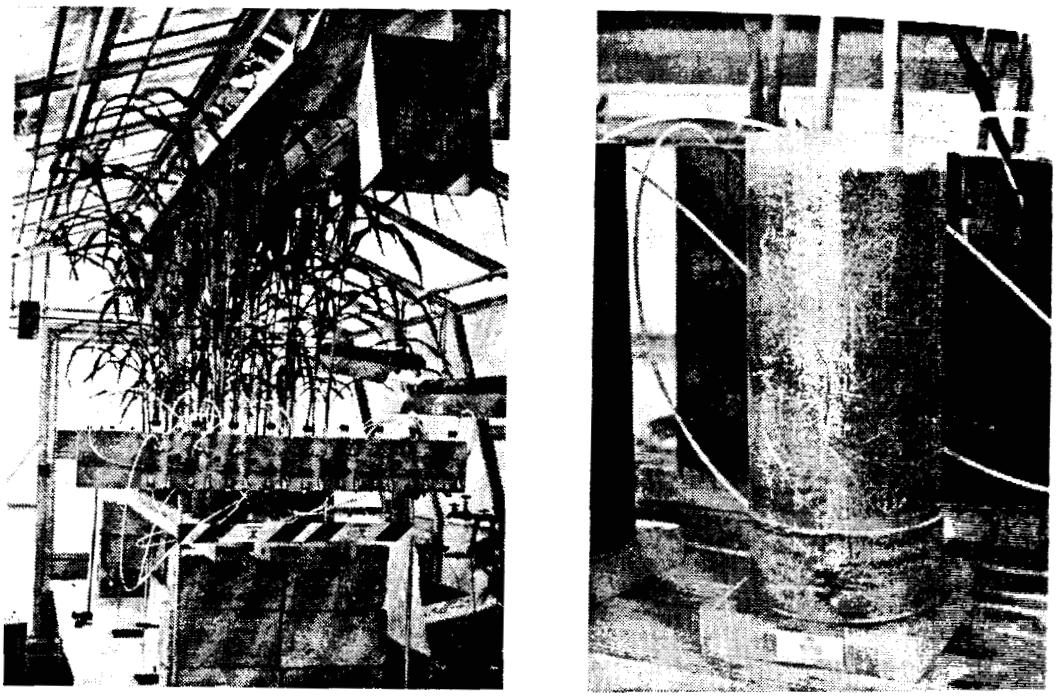
NEW BIOMEDICAL RESEARCH FACILITIES

Construction was completed on three new Government-owned biomedical research facilities during the year.

Virus Control Laboratory at ORNL

A virus control laboratory was completed at Oak Ridge National Laboratory (ORNL) at a cost of $1,360,000. The single-story building houses specialized animal rooms along with inter-related virology, immunology, pathology, clinical chemistry, and bacteriology laboratories. Each animal unit and the X-ray room has an ultraviolet air lock at each end to act as a barrier to contamination. Special doors within the critical area of the building are airtight.

It has become increasingly evident that bacteria, viruses, fungi, and parasites can complicate the value of large-scale mammalian research programs. Difficulties encountered include: (*a*) uncontrolled variation in behavior of experimental animals resulting from fluctuations in the numbers of microbes, and (*b*) disease resulting from the introduc-



Sorghum Plant Study. The relationship of moisture in soil to the uptake of radioactive cesium-137 is being determined at Oak Ridge National Laboratory in experiments with sorghum plants. A series of tensionmeters (center left, of *left* photo) are used to measure the moisture content of the soil surrounding the plant roots. Plants are embedded in soil containers (*right* photo) divided into two chambers separated by a thin wax membrane. The membrane is impermeable to water but easily penetrated by roots into cesium-tagged vermiculite and sand. At specified intervals, samples of the plants are counted for cesium uptake.

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ion or activation of disease-causing micro-organisms. Laboratories and isolation facilities adequately designed for containment of disease organisms (pathogens) are now available for testing of animals received from outside vendors as well as those raised at ORNL. Isolation facilities are also available for anaylsis and control of unexpected animal health problems as they arise. The new facilities will help to control complicating nutritional, toxicological, metabolic, and microbiological factors. It will now be possible to investigate diseases occurring within the present animal facilities effectively separated from other areas containing laboratory animals which are involved in long- and short-term experiments.

Addition to Co-Carcinogenesis Laboratory

An approximately $500,000 addition to the co-carcinogenesis [4] laboratory at ORNL is nearly complete. It has been designed to receive, isolate and control mammalian species for use in research on the causes of cancer. Since these animals must be free of specific disease-causing organisms, they are delivered in controlled environment containers and enter the building through an air lock in a receiving cell. When received, the new animals will spend a quarantine period in a holding cage.

Such pathogen-free mice are extensively used in co-carcinogenesis research and in other radiobiological research programs. This removes the threat to the experiment which might result from the development of disease during its course. Disease would mask or distort the experiment's results. Pathogen-free animals are used to assure that any observed deviations from normal are the results of the experiments. This is particularly important when the experiment is expected to produce only minor changes in the mice.

Variable Dose-Rate Irradiation Facility

A variable dose-rate irradiation facility has been completed at a cost of $193,000 at the University of Tennessee-AEC Agricultural Research Laboratory at Oak Ridge, to provide a means to irradiate animals under controlled conditions.

The facility consists of three areas: an irradiation room, an entrance maze, and a control room. The irradiation room houses six cobalt-60 sources with their operating mechanisms for use in variable dose-rate irradiation studies. The maze provides radiation shielding

[4] A study of the interaction of viruses, radiation, and chemicals in causing cancer in mice. This program is supported jointly by the National Cancer Institute of the National Institutes of Health and the AEC.

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and a means of access to the irradiation room from the outside. The control room houses the instrumentation and control mechanisms for the operation of the facility.

Dose-rate has been established as a significant factor in early and late mortality of laboratory animals exposed to gamma and X-irradiations. Irradiation of animals similar to, or larger than, man have been limited because of expense. The need, therefore, is to learn more about the effect of dose-rate in such species.

Dose-rate has also been established to be a significant factor in causing mutations, changes in genetic material, embryonic malformations, and lowered fertility or sterility of both sexes in small animals. Limited studies with large animals indicate that the dose-rate contributes to the effect of radiation on the biological defects noted above. The degree and sequence of effect, in some respects, do not appear to coincide with those of small animals.

This new facility should contribute to the flexibility of research projects in obtaining data on large species of mammals which would have application in the field of human radiobiology.

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Chapter 16

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Chapter 16

INDUSTRIAL PARTICIPATION ASPECTS

A policy set forth in the Atomic Energy Act is that the development, use, and control of atomic energy will "be directed so as to make the maximum contribution to the general welfare" and "strengthen free competition in private enterprise." Accordingly, the development of a strong, competitive, commercial, nuclear industry has been a major objective of the AEC, particularly since passage of the Atomic Energy Act of 1954 which permitted private ownership of facilities such as reactors.

NUCLEAR INDUSTRY GROWTH

During 1967, the nuclear industry took important additional steps toward maturity as orders for nuclear-electric generating equipment were placed at an even faster pace than in precedent-setting 1966 when, for the first time, orders for nuclear units approximately equalled orders for fossil-fired units.[1]

GROWTH INDICATORS

The surge to nuclear power for electric generation led to a series of actions by industry designed to meet the rapidly expanding demands. Four major growth indicators were:

1) The major producers of nuclear steam supply systems who have been successful in selling to electric utilities on a competitive basis, announced plans for substantial expansions of their nuclear production facilities.

[1] For a complete report on the private atomic energy industry, see "The Nuclear Industry—1967," prepared by the AEC's Division of Industrial Participation and available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $1.00.

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(*2*) Exploration for uranium ore by private firms expanded to a level in excess of that reached in the most active prior year, 1957, and new facilities for most steps in the uranium fuel cycle were announced by the private nuclear industry.

(*3*) Orders placed for fuel for power reactors will make for a smooth transition from a Government-dominated market to a largely private market without an extended "uranium depression" period after 1970 when Government procurement contracts expire, that at one time had been projected.

(*4*) The impact of nuclear power on the Nation's energy pattern was emphasized with the entry of major petroleum companies into the nuclear field during the year. Atlantic Richfield Co.—having acquired Nuclear Materials and Equipment Corp. (NUMEC) of Apollo, Pa.—obtained the AEC contract for the operation of chemical separation facilities at the Hanford Works, Richland, Wash., and expressed its intention of becoming a major commercial reprocessor of nuclear fuel on the West Coast. Gulf Oil Co. acquired the General Atomic Division of General Dynamics to become an important contender in the supply of power reactors and the production of reactor fuels. Both these companies and a substantial number of other major oil companies have shown interest in developing new uranium reserves.



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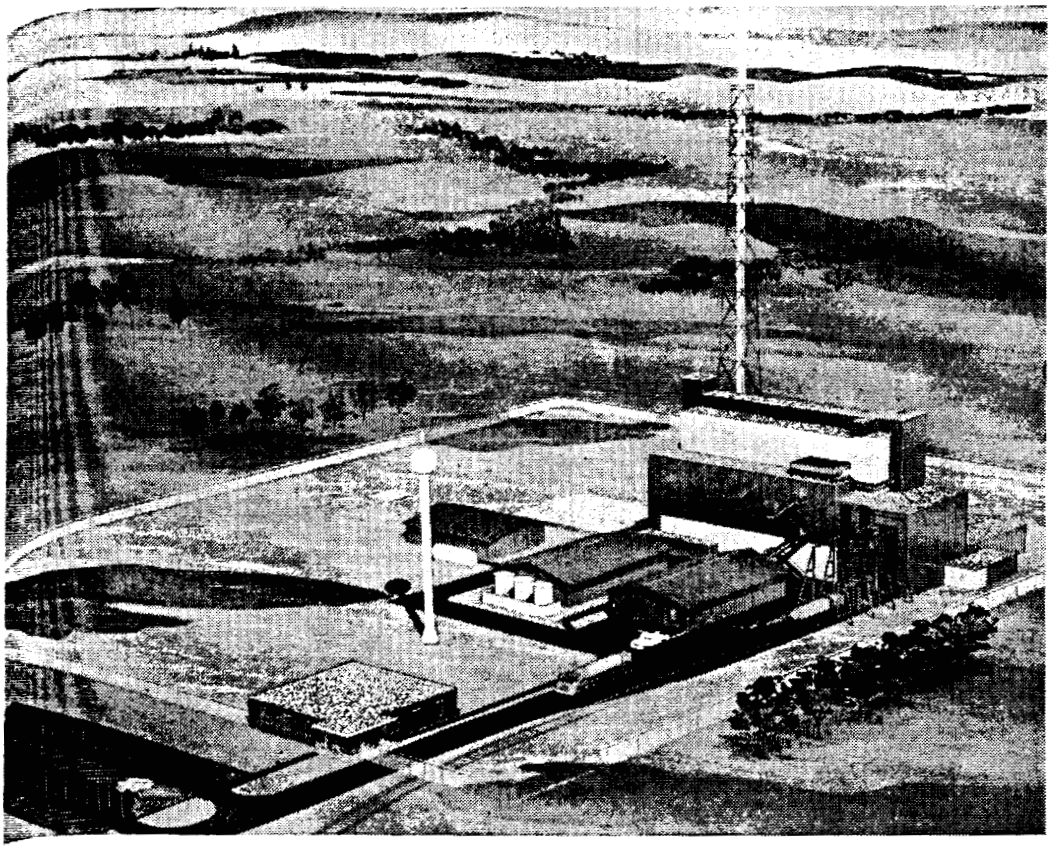


Competition in the Nuclear Industry

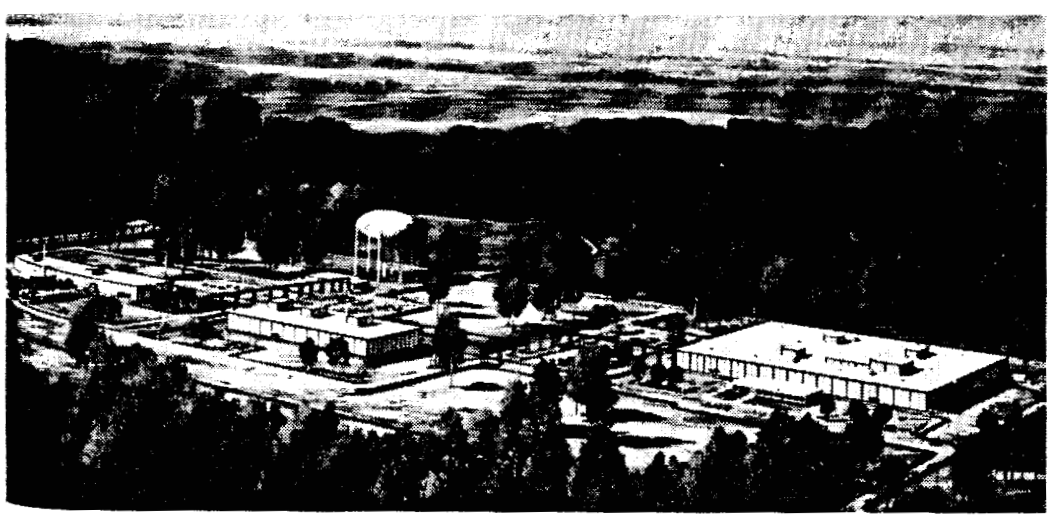
In developing policies governing the furnishing of nuclear-associated services to the public and in the execution of its regulatory responsibilities under the Atomic Energy Act of 1954, as amended, the AEC performs functions which have a profound effect on the status of the nuclear power industry. It is also clear from provisions of the Act, that the AEC is expected to carry out all of its activities in a manner consistent with the antitrust laws as administered by the Department of Justice.

Industry Study. To assist the Commissioners and the Department of Justice in fulfilling their responsibilities under the Atomic Energy Act and antitrust legislation, the two agencies are working on a joint project of examining all aspects of competition in the new and developing nuclear industry. Under an AEC contract, A. D. Little, Inc., of Cambridge, Mass., is making a study of competition in the nuclear industry to assist the project. For the purpose of the study, the nuclear power supply industry is deemed to consist of those firms engaged in the business of supplying reactors, reactor components, nuclear fuel, or other products and services associated with the design.

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New Facilities. The *above* is an artist's concept of the General Electric Co.'s proposed Midwest Fuel Recovery Plant which will be located adjacent to the Commonwealth Edison Co.'s Dresden Nuclear Power Stations near Morris, Ill. Construction is expected to start in 1968 with test operation planned for 1969, and commercial operation following in 1970. *Below* is an artist's drawing of General Electric's second atomic power equipment production site now under construction near Wilmington, N.C. The multimillion-dollar plant will initially have three major facilities totaling more than 500,000 square feet of manufacturing floor space. It will be producing nuclear powerplant equipment and nuclear fuel for General Electric's boiling water reactor nuclear systems by early 1969 to meet the needs of rapidly growing nuclear power industry. This will more than triple present production capacity of the GE Atomic Power Equipment Production Department's plant in San Jose, Calif.



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construction and operation of nuclear-electric plants including the entire fuel cycle. It is possible that the study will provide the basis for preparation and consideration of guidelines for the healthy development of competition in the emerging nuclear industry.

Broadening Competition Indicators

Some indications of broadening competition in the nuclear industry are given in the following paragraphs.

Power Reactors. Although the larger part of reactor orders continue to go to General Electric and Westinghouse, the portion of the market secured by Babcock & Wilcox and Combustion Engineering rose from zero in 1965 and 23 percent in 1966 to about 30 percent in 1967 (see also Appendix 5—Central Station Nuclear Powerplants). In addition, the Gulf General Atomic Co. and Atomics International Division of North American Rockwell Corp. continue to be prospective suppliers of advanced converter and breeder reactors.

Feed-Material Conversion. Kerr-McGee, one of the larger suppliers of uranium concentrate (U_3O_8) for reactor fuel, has announced plans to build a new facility near Sallisaw in eastern Oklahoma to convert U_3O_8 to uranium hexafloride (UF_6), the feed material for the gaseous-diffusion plants which enrich uranium in the fissionable uranium-235 (U^{235}) isotope. The new facility will provide competition for the only existing private plant of this type, at Metropolis, Ill., owned by Allied Chemical.

Reactor Vessels. Chicago Bridge and Iron Co. (CB&I) announced plans to enlarge a plant it is constructing at Memphis, Tenn., to provide for shop fabrication of reactor vessels. CB&I which is currently field fabricating a reactor pressure vessel near the Monticello, Minn., nuclear plant site will become the third shop fabricator. Babcock & Wilcox and Combustion Engineering were the first shop fabricators of these vessels which range in size up to more than 70 feet high and 20 feet in diameter with walls more than 12 inches thick and weighing over 600 tons.

Zirconium Tubing. Fuel for light water nuclear power reactors is usually in the form of uranium oxide (UO_2) pellets encased in zircaloy tubing. Amax Specialty Metals, Harvey Aluminum, Reactive Metals, Superior Tube, and Wolverine Tube are the current suppliers of zirconium tubing. During 1967, Sandvik Special Metals Corp. (a jointly owned subsidiary of Sandvik Steel and United Nuclear) started construction of a new zirconium tubing mill near Kennewick, Wash. Westinghouse announced plans to construct a similar mill at Blairsville, Pa., and General Electric is building a comparable facility at its new nuclear fuel fabricating plant near Wilmington, N.C.

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Reactor Fuel Processing. Future competition in the processing of ...ent fuels appears assured. One private processing plant (Nuclear ...uel Services at West Valley, N.Y.) is in operation, and five others (General Electric, Allied Chemical, National Lead, Atlantic Richfield, ...d Gulf Oil) are planning or considering similar facilities. (See "Fuel ...rocessing" section in Chapter 1—Source and Special Nuclear Ma...erials.)

COOPERATION WITH INDUSTRY

In working toward a strong, viable, commercial nuclear industry ...ood communications between government and industry, between the ...ederal and State Governments, and within the industrial community ...ave been essential.

INDUSTRY ASSOCIATIONS

The AEC has maintained good channels of communication with ...dustry through frequent meetings with leaders of industry associa...ons that have active interests in the nuclear field. For instance, the ...ommissioners meet frequently with the Board of the Atomic Indus...ial Forum (AIF). Forum committees meet with the AEC staff. ...hese meetings provide for a free and informal exchange of views on ...atters of mutual interest and cover a wide range of subjects including ...e AEC's research and development and regulatory activities.

Other associations provide important, though more specialized ...annels of communication between the AEC and industry. These ...clude the Edison Electric Institute, Chamber of Commerce of the ...S., Manufacturing Chemists' Assn., and American Public Power ...ssn.

...uclear Instrument Manufacturers

After more than a year of organizational effort, the Association ...Nuclear Instrument Manufacturers (ANIM) came into full oper...ion in January 1967. ANIM member companies produce nuclear ...struments and related equipment for application in the physical ...ences, biological and medical sciences and industry. The objectives ...ANIM are to stimulate the growth and profitability of the industry ...ough improved relations with the Government and the public, ...e development of industry statistics and standards and the promo...n of international trade. Twenty companies representing approxi-

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mately 75 percent of the industry have joined the ANIM. The AEC staff is working closely with ANIM in identifying and resolving potential industry problems.

Science Information Exchange

The Science Information Exchange (SIE) of the Smithsonian Institution, Washington, D.C., is a national registry of research in progress and maintains a computerized system of providing current information on all reported research. Under the SIE system, which includes data on AEC programs, research is registered and cataloged at the time it is initiated rather than appearing as reports one or more years later in journals, libraries, and documentation centers. The SIE staff scientists and engineers analyze and index data on each project.

During 1967, the AEC instituted a program under which private industry was urged to register with SIE current and planned research and development in the fields of isotopes and radiation. The SIE, working with the AEC and its Advisory Committee on Isotopes and Radiation, developed a category-reporting system believed to be sufficiently informative without revealing proprietary information concerning work in specific companies. The aim is effective coordination, with a minimum of overlapping, of an overall isotope and radiation development program.

REGIONAL SUPPORT ACTIVITIES

Interstate compacts provide a means of coordinating regional efforts in the nuclear field permitting activities on a regional scale that could be difficult for an individual State to support.

Southern Interstate Nuclear Board

The Southern Interstate Nuclear Board [2] (SINB) coordinates the efforts of 17 Southern States in nuclear and aerospace activities and serves as an important communications link between the AEC and the southern community. One of the important activities of the SINB has been the sponsoring of seminars in cooperation with the AEC for the purpose of informing southern leaders on various nuclear matters. Two seminars were held in 1967: one on food irradiation at

[2] Composed of member States of the Southern Governors' Conference: Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

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Oak Ridge, Tenn., in February, and one on fuel reprocessing in Augusta, Ga., in May.

The objectives of the SINB have been to help foster the sound development of nuclear energy in the South, to help the States meet the growing influence of nuclear energy in new fields as well as in traditional areas of State responsibility, and to develop a balance of authority and responsibility between the States and the Federal establishment.

Other Interstate Compacts

The Midwestern Governors' Conference,[3] and the Western Governors Conference [4] have taken initial steps toward forming nuclear compacts. In general these are modeled after the Southern Interstate Nuclear Compact under which the SINB was formed.

A Midwest compact was endorsed by the Midwestern Governors in 1966, and enabling legislation has since been introduced in three State legislatures. A western compact was endorsed by the Western Governors at their annual conference in June 1967, and a final draft of the compact is now ready for appropriate action by the individual States.

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[3] Representing: Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

[4] Representing: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming, Guam, and American Samoa.

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Chapter 17

ADMINISTRATIVE AND MANAGEMENT MATTERS

Surveys showed a continuing increase in the number of people employed in the atomic energy industry. Efforts to strengthen the economic base of communities dependent upon local AEC operations continued during the year. Two production facilities no longer needed by the AEC were turned over to other Federal agencies with a minimum of disruption to local employment. Transfer of the Los Alamos community and sale of government-owned real estate neared completion. AEC sought public comment on the establishment of a standard records and reports system for radiation workers. During 1967, and for the sixth consecutive year, more than 43 percent of the AEC's subcontracts went to small business concerns.

EMPLOYMENT DATA

During the past few years, significant program changes and technical developments have affected employment in the atomic energy field not only on AEC contract operations but also in private industry activities. Each year the U.S. Bureau of Labor Statistics conducts a survey of industrial establishments for the AEC of employment in the atomic energy field. The 1967 survey showed:

1) Atomic energy employment among 498 reporting units of Government and private and some nonprofit establishments totaled 137,750 as of March 1967, compared to 136,929 in March 1966.
2) Employment in 69 Government-owned facilities totaled 102,293, a decrease of 0.8 percent below the March 1966 employment figure.
3) Atomic energy employment in 429 units of private industry and nonprofit establishments totaled 35,457, an increase of 4.7 percent over March 1966.

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1967 Lawrence Awardees. Six young U.S. nuclear scientists, including one who was unable to attend the presentation ceremonies in 1966, received the 1967 E. O. Lawrence Memorial Award from the Atomic Energy Commission on April 27. Each of the scientists received a check for $5,000, a citation, and a gold medal. The AEC presents the award upon the recommendation of its General Advisory Committee and with the approval of the President. Those receiving the 1967 award and their citations were, *left to right: Dr. Allan F. Henry*, Manager of Reactor Theory, Bettis Atomic Power Laboratory, Westinghouse, Pittsburgh, Pa.—"for his many original and important contributions to the physics of water reactors and the theory of reactor kinetics, and their application to the development of pressurized water reactors for naval and land-based nuclear power systems." *Dr. Murray Gell-Mann*, Professor of Physics, California Institute of Technology, Pasadena, Calif., who was unable to attend the 1966 presentation—"for his contributions of the highest significance to the theory of elementary particles and for the exceptional stimulus he has provided to experimental and theoretical work in the field of physics." *Dr. Robert N. Thorn*, Group Leader in the Theoretical Division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.—"for his eminent role in initiating and conducting theoretical studies of thermonuclear weapon design, for his outstanding performance in adapting results of theoretical studies to practical device designs, and for his investigations of the effects and particular requirements of our defensive nuclear weapons." *Dr. John O. Rasmussen*, Senior Staff Member, Lawrence Radiation Laboratory, Professor at University of California, Berkeley—"for his outstanding contributions to the better understanding of nuclear structure by his imaginative experimental and theoretical studies." *Dr. Mortimer M. Elkind*, National Cancer Institute, National Institutes of Health, Bethesda, Md.—"for his outstanding contributions to radiobiology and the understanding of cellular recovery from radiation injury." *Dr. John M. Googin*, Technical Assistant to the Y-12 Plant Superintendent, Union Carbide Nuclear Division, Oak Ridge, Tenn.—"for his outstanding contributions in the technological developments of processes for hafnium-zirconium and lithium isotope separations."

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Table 1 shows a distribution of employees by segments of the atomic energy field for Government owned and privately owned establishments in March 1967. Appendix 10 summarizes the 1967 survey by detailed occupational employment, the first such detailed collection since 1962.

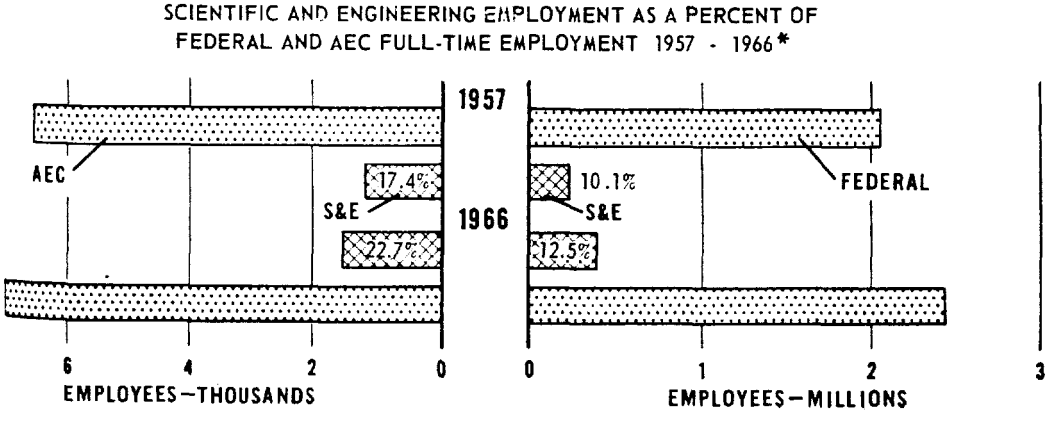
TABLE 1.—DISTRIBUTION OF EMPLOYEES IN ATOMIC ENERGY WORK BY ECONOMIC SEGMENT AND BY OCCUPATIONAL CATEGORY—MARCH 1967

Segment	Number units	Total employment	Engineers	Science and mathematics	Technology	All other
Uranium milling	15	1,962	128	90	134	1,610
Feed materials production	11	7,480	570	481	926	5,503
Production of special materials for use in reactors	20	1,350	114	45	244	947
Fuel element fabrication and recovery activities	15	3,883	475	158	559	2,691
Reactor and reactor components, design and manufacturing	44	14,238	4,385	978	2,596	6,279
Design and engineering of nuclear facilities	43	6,037	2,497	118	1,501	1,921
Power reactor operation and maintenance	18	1,026	182	18	208	618
Radioactive waste disposal	7	34	1	6	6	21
Nuclear instrument manufacturing	71	5,615	794	291	1,740	2,790
Processing and packaging radioisotopes	30	824	42	240	287	255
Particle accelerator manufacturing	10	1,018	152	44	227	595
Private research laboratories [1]	52	2,074	529	630	647	268
Commission laboratories and research facilities	26	51,670	8,160	8,326	10,470	24,714
Atomic energy defense production facilities	17	31,063	2,697	1,399	3,051	23,916
Industrial radiography	43	559	53	3	434	69
Miscellaneous	76	8,917	932	310	766	6,909
Total	498	137,750	21,711	13,137	23,796	79,106

[1] Includes nonprofit establishments.

AEC CONTRACTOR EMPLOYMENT

In November 1967, 40 AEC prime contractors who operate facilities owned by the Government employed a total of 106,623 persons. This total is comprised of 40.9 percent production and related employees;



*LATEST AVAILABLE FIGURES

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23.4 percent clerical and related employees; 19.5 percent non-supervisory scientists and engineers; and 16.2 percent executive, administrative, and other professional personnel including supervisory scientists and engineers.

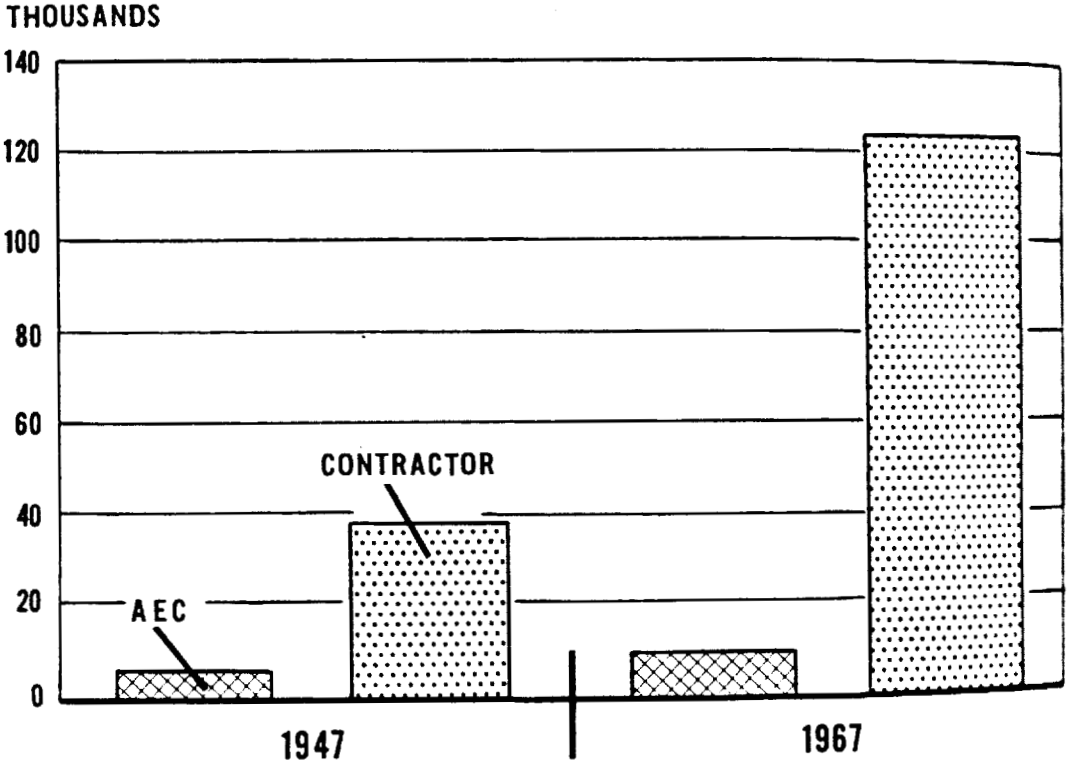
Earnings Increase

A 5-year trend of earnings for employees of the 40 AEC prime cost-type contractors shows that average hourly earnings for production and related employees have increased at a rate of 2.7 percent a year, and for clerical and related employees at a rate of 3.0 percent. Base monthly earnings (over 4 years) for scientists and engineers have increased at a rate of 3.9 percent yearly and for executives, administrators, and other professionals at an annual rate of 3.7 percent.

Youth Opportunity Campaign

Reports from participating prime contractors at AEC-owned facilities show that 860 young people were employed under President Johnson's Youth Opportunity Campaign during the summer of 1967.

COMPARISON OF TOTAL PAID AEC AND CONTRACTOR EMPLOYMENT



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Of the 860, about 22 percent were "rehires" from the 1966 program. Approximately 46 percent were in minority groups and 29 percent were Negroes. College students made up 55 percent of the employees, 35 percent were high school graduates, 9 percent were high school students, and 2 percent were high school "drop outs."

About 69 percent of the total were males, and 43 percent of all were between the ages of 16 to 18, and 57 percent were 19 to 22.

Equal Employment Opportunity

AEC on-site compliance reviews of Government contractor facilities, under Executive Order 11246, continued at a rate of approximately 600 a year. In addition, reviews were made at most of the large multi-facility corporations assigned to AEC.

The contractor compliance program continued to emphasize use of specialized sources of minority group job seekers, including the Job Corps, Office of Economic Opportunity community action programs and Department of Labor training programs. In-plant training activities, including apprenticeships, were expanded. Hiring and promotion standards, particularly educational requirements and tests, are being examined to determine validity and need for modification.

Special efforts were initiated with State officials, contractor groups, labor organizations, and community leaders, to lay the groundwork for an effective affirmative equal employment opportunity program in connection with the proposed construction and operation of the National Accelerator Laboratory at Weston, Ill.

LABOR RELATIONS

Of the 106,623 employees of the 40 prime contractors at government-owned facilities, approximately 29,500, or 27.6 percent are represented by labor unions:

Union organization	Approximate representation	Percent
Metal Trades Council (AFL–CIO)	9,740	33.1
International Association of Machinists (AFL–CIO)	5,840	19.8
Oil, Chemical & Atomic Workers Intl. Union (AFL–CIO)	3,365	11.4
Office Employees International Union (AFL–CIO)	1,875	6.4
Miscellaneous guards unions (independents)	1,485	5.0
Miscellaneous unions (excluding guards)	7,163	24.3
Total	29,468	100.0

COLLECTIVE BARGAINING

The Atomic Energy Labor-Management Relations Panel intervened in three instances in 1967:

(1) A wage dispute involving Pan American World Airways, Inc. and the Transport Workers Union at the Nevada Test Site (NTS) on January 30, 1967.

(2) A May 20 dispute between Reynolds Electrical and Engineering Co., Inc. (REECO) and the Operating Engineers involving drilling at NTS.

(3) An impasse in contract renewal negotiations between REECO and the Culinary Workers in September.

Supplemental Test Site in Nevada

A project construction agreement was negotiated during the year between Holmes & Narver, Inc., and 11 construction trades unions[1] at the proposed new supplemental test site in central Nevada (see Chapter 3—Nuclear Defense Effort). This agreement, similar to the one negotiated by the construction trades unions with REECO and Catalytic Construction Co. (CATCO), at the Nevada Test Site in 1966, is for a period of 4 years, from March 1, 1967 to March 1, 1971. The agreement contains a no-strike clause; grievance and arbitration procedures; arrangements for shift work; and other features comparable to the NTS agreement.

Contract Renewals and Work Stoppages

As of mid-December 1967, negotiations involving labor agreement renewals or reopening provisions had been completed by AEC operating contractors for 43 organized units. Of these negotiations, 39 were concluded without work stoppages.

About 182,000 man-hours were lost in operations and in construction during the January to mid-December period. Most of the time lost involved:

(1) A 37-day strike (23,272 man-hours) at the Nevada Test Site involving drilling crews of Reynolds Electrical and Engineering Co. who are represented by the International Union of Operating Engineers;

[1] The unions signatory to the project agreement are: Teamsters, Ironworkers, Cement Masons, Carpenters, Laborers, Operating Engineers, Pipefitters, Electricians, Painters, Sheet Metal Workers, and Roofers.

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(2) A strike of about 18 days (21,183 man-hours) by bus drivers of the Amalgamated Transit Union who are employed by Idaho Nuclear Corp. at the National Reactor Testing Station, Idaho;

(3) A strike involving the Building Service Employees International Union at Argonne National Laboratory lasted about a week (19,960 man-hours);

(4) A strike against Douglas United Nuclear, by the Hanford Atomic Metal Trades Council, which began on September 1 and continued through December 12, accounted for 104,969 man-hours of lost time. The dispute affected Hanford's "N" reactor.

DIVERSIFICATION AND TRANSFER

During the year, the economy of the tri-cities area of Richland, Pasco, and Kennewick, Wash., continued to grow and to diversify through the cooperative assistance of the AEC and its contractors. New diversification plans were announced, and a major AEC project, the construction of the Fast Flux Test Facility, was announced for the area. The AEC's diversification program began in 1964 [2] when the AEC announced plans to change its Hanford Works operation from a single-contractor to a multiple-contractor basis and to assist the three cities in establishing an economic base that is less-dependent on the AEC's Hanford facilities. In selecting new operating contractors, consideration has been given to private activities which the contractor proposed to bring into the area.

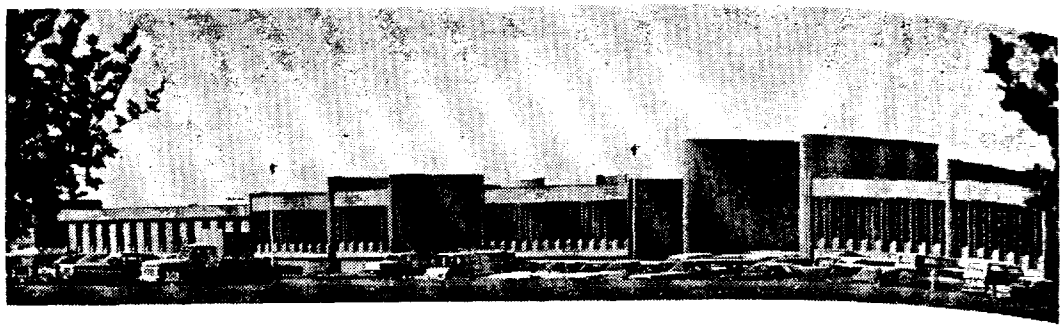
New Contractor and New Diversification Plans

On July 5, 1967, the AEC announced selection of Atlantic Richfield Co. for operation of the chemical processing facilities at the Hanford Plant in place of the joint venture firm, Isochem Inc., which had been selected in 1965.[3] It was mutually agreed to by both the company and the AEC to conclude the contract. The diversification activities of Atlantic Richfield include construction of a resort and convention facility and a meat-packing and cattle feedlot operation in the Richland area, establishment of a local investment company, and financial support of an annual seminar program at Richland's Center for Graduate Study and investigation of the potential for commercial nuclear business in the tri-cities area. Atlantic Richfield formed a new

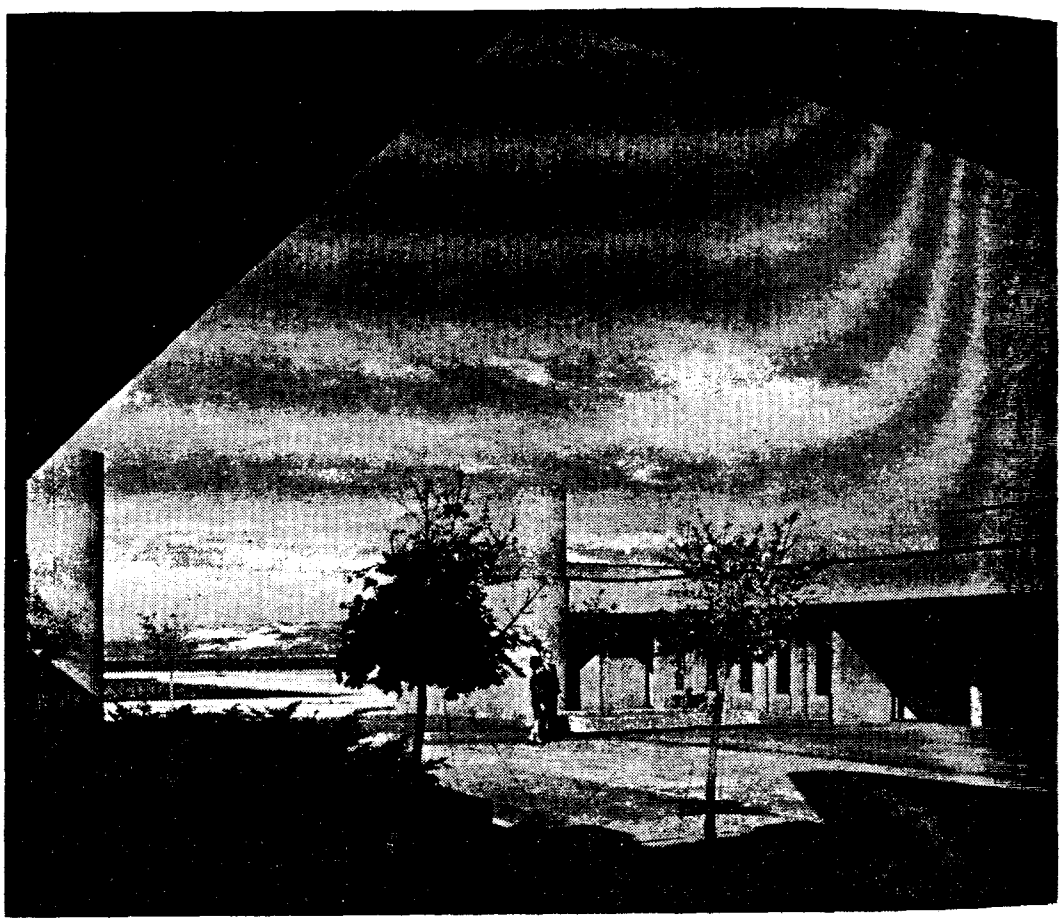
[2] See p. 107, "Annual Report to Congress for 1966."
[3] See pp. 27–28, and p. 81, "Annual Report to Congress for 1965."

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subsidiary, Atlantic Richfield Hanford Co. (ARHCO) for the venture, and took over operation of the chemical processing facilities on September 4, 1967.



New Research Center. The first phase of the Battelle-Northwest laboratory complex near the AEC's Hanford Works was dedicated October 27. The first four buildings (*above*) cost $4.3 million. Battelle, which operates the AEC's Pacific Northwest Laboratory at Hanford, has announced it will spend $20 million over a 10-year period on its private research laboratory complex which is the Battelle diversification project for the Richland, Wash., area. An atrium or central court leads to the entrance (*below*) of the Research and Operations Building and the Mathematics Building of the new Battelle-Northwest research complex.



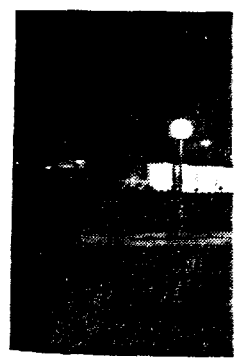
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New Facilities

Dedication of three new diversification commitment facilities took place in 1967 in the tri-cities area. Battelle-Northwest dedicated the first phase of its planned $20 million laboratory complex, Douglas Aircraft dedicated its new Donald W. Douglas Laboratories, and the International Telephone and Telegraph Co. will dedicate the first portion of a $1.9 million electronic component assembly plant early in 1968.

In September 1967, Douglas United Nuclear, Inc. (DUN), jointly owned by McDonnell Douglas Corp., and United Nuclear Corp., announced that they would expand the existing capability of the



New Buildings in Richland. One of the considerations given to awarding new operating contracts for the AEC's Hanford Works has been how the new contractor will aid in diversifying the economic base of the local communities by developing new private sources for employment. ITT-Richland is part of the International Telephone and Telegraph Corp. diversification program in the Hanford area. The new plant's 105 employees manufacture thermostats, heating, ventilating, and air conditioning control units for both residential and industrial users. The plant (shown *above*) also produces electrical coils for assembly into other products. ITT-Richland operates the Hanford Works support facilities. Production work in this new building began on September 11, 1967. *Below* is a night view of Donald W. Douglas Laboratories which were dedicated March 29, 1967, by Douglas Aircraft Co.

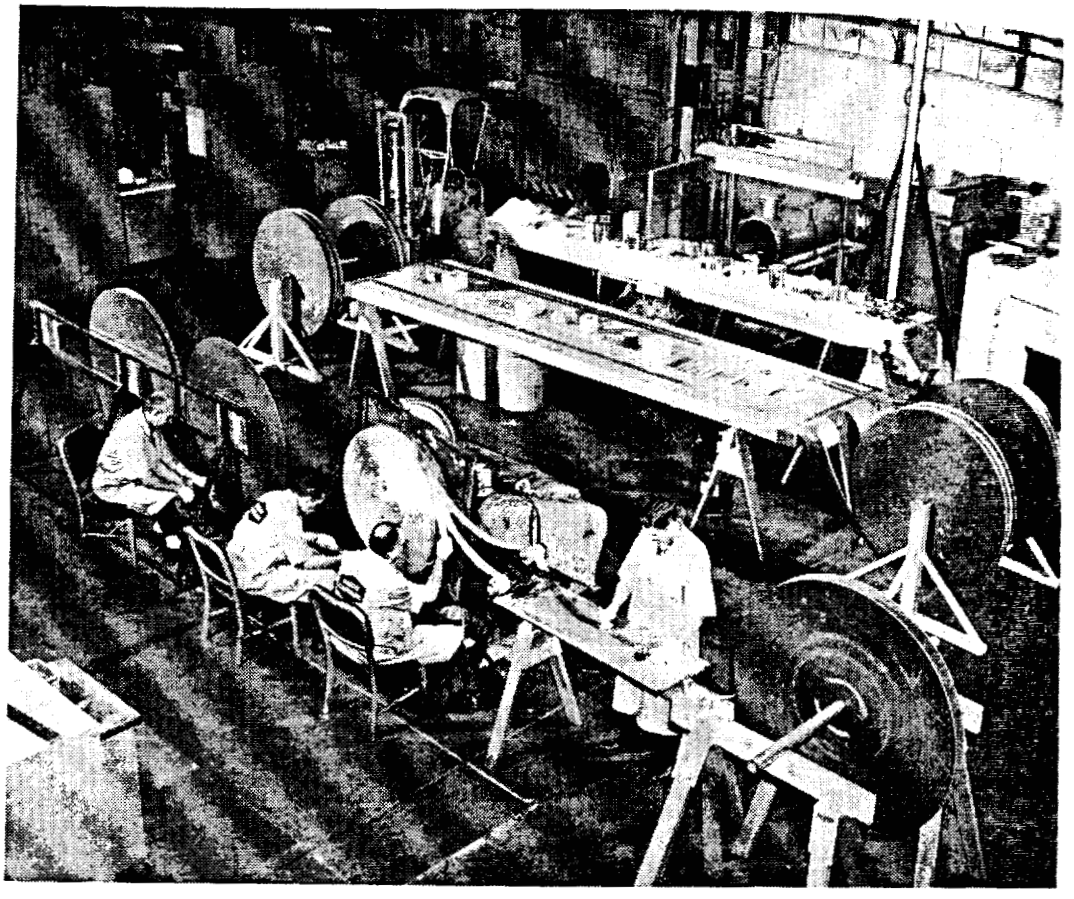


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Donald W. Douglas Laboratories at Richland to increase the investment from $2 million to $4 million. United Nuclear Corp. at the same time, announced plans to expand the capacity of its zirconium tube facility from $1,900,000 to possibly as much as $4,400,000 by 1970. Construction of the zirconium plant was started in April 1967.

AEC "Know-How" Used in Other Federal Work

AEC technical capabilities at Oak Ridge, Tenn.; Paducah, Ky.; and Evendale, Ohio, continue to be used by other Federal agencies at a net savings to the Government. Highly qualified scientists and technicians, as well as specialized tools and equipment at the three installations, have been engaged in performing work for 11 Federal departments and independent agencies during 1967.



Work for Others. The technical skill and manpower of the AEC's Gaseous Diffusion Plant at Paducah, Ky., is being used to support research being conducted at the NASA Lewis Research Center, Cleveland, Ohio, in a study of magnetic fields of large volume and high field intensity. Fabrication support at the Union Carbide-operated facility includes the manufacture of cryogenically cooled and superconducting electromagnets wound from high purity aluminum. Some magnets have produced steady-state fields as large as 200 kilogauss.

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[4] See p. 124, "Ann

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DISPOSAL OF FACILITIES

Two plants were declared excess to the AEC's needs during the year and were tranferred to other Federal agencies.

South Albuquerque Works

As a result of an economic study to determine the facilities needed to meet continuing weapons production requirements, a plan had been announced in December 1966 [4] for the reduction and possible phase-out of the South Albuquerque (N. Mex.) Works. At that time, a program to minimize the economic impact of this decision was initiated. AEC and General Services Administration (GSA) representatives visited Albuquerque in January and met with public, civic, and union officials to discuss possible uses and disposal of the plant which had been contractor-operated by ACF Industries (ACFI) for the AEC. Unclassified briefings and tours were conducted to familiarize interested individuals and groups with the plant. Arrangements also were made for other AEC contractors to hold interviews at the facility as a measure of job insurance for ACFI employees.

In April 1967, the Air Force announced its interest in acquiring the ACFI plant for the production by the General Electric (GE) Co. of jet engine parts. Subsequently, the Air Force, AEC, GE, and ACF Industries, worked closely to develop a plan whereby Air Force/GE work could be brought into the plant to be worked on by ACF employees. This was designed to ease the transition, reduce layoffs, and provide GE with a fully effective work force at the time of its actual takeover.

Many ACF employees who had been working at the plant, on projects in support of other AEC programs under the Sandia or Los Alamos laboratories, were employed by other contractors in the Albuquerque area.

On December 1, the Air Force assumed control of the major portion of the plant and Dow Chemical Co. assumed the small remaining AEC workload which is being transferred to AEC's Dow-operated Rocky Flats Plant near Denver, Colo.

Weldon Spring Feed Materials Plant

On June 9, 1967, the AEC advised the General Services Administration that the Weldon Spring Plant, Weldon Spring, Mo., was no longer needed for AEC programs. At that time, expressions of interest

[4] See p. 124, "Annual Report to Congress for 1966."

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in commercial use of the plant, which AEC had requested from industry, were provided to GSA. On July 11, 1967, GSA was advised that the Army Corps of Engineers had a possible requirement for the plant. On October 13, the Army requested that transfer arrangements be made and the Army Engineers took custody of the site as of midnight December 31.

Substantially all of the 500 employees of the Mallinckrodt Chemical Works, which had operated the Weldon Spring Plant for the AEC, secured other jobs, principally in the St. Louis area. Placement of most of the affected employees was accomplished through a special office established by Mallinckrodt soon after the AEC's April 1966 announcement that the plant would be shut down. Some workers were transferred to Mallinckrodt's St. Louis office. A smaller number gained employment outside of the St. Louis area.

Middlesex Storage Site

The decontamination of the Middlesex Storage Site was completed in 1967 to enable unrestricted disposal by GSA. The site, located near New Brunswick, N.J., was previously used for uranium ore storage and sampling.

Los Alamos Community Disposal

Significant steps were taken during 1967 toward ending AEC ownership and management of the community at Los Alamos, N. Mex., as authorized by legislation approved September 28, 1962.

Sale of Real Property

All single family and duplex houses were sold as of December 31, 1967. Proposed legislation covering the policies and procedures to be followed in the sale of the remaining apartment units was the subject of a public hearing conducted at Los Alamos on August 11, 1967, by the Subcommitte on Communities of the Congressional Joint Committee on Atomic Energy. Appraisal and sale of commercial real estate, residential lots, unimproved property, and church and nonprofit properties, by the U.S. Department of Housing and Urban Development, is progressing and will continue until all are sold.

Community Operation

On July 1, 1967, municipal and utility functions and facilities (except fire protection) were transferred to Los Alamos County. The Government's interest in the community telephone system was sold to Mountain States Telephone and Telegraph Co., on July 1, 1967.

The AEC is authorized to make annual assistance payments of just and reasonable sums to the county, the hospital and the schools for a 10-year period from the date of transfer to private operation. The AEC will also be responsible for the operation and maintenance of unsold Government-owned property remaining in the community, and of utilities and other facilities in the technical areas and in the other portions of Los Alamos County that are not subject to disposal.

Financial Aid to Other Communities

In addition to the payments now being made at Los Alamos, the AEC has been providing similar assistance to Oak Ridge, Tenn., and Richland, Wash.

Fiscal 1969 (ending June 30, 1969) is the final year of the 10-year period of authority to make assistance payments to the cities of Oak Ridge and Richland, and to the Richland School District. Although the nature of the assistance varies, all three entities require additional aid before this special AEC assistance can be terminated. The results of a study of this situation were reported to the Joint Committee on Atomic Energy on July 28, 1967; and a hearing was held by the committee to determine the need for additional legislation to extend the authority. Authorizing legislation was subsequently enacted.

Under this authority, the AEC plans to continue to make annual assistance payments to Oak Ridge and certain one-time payments at Richland to assure that the school and civic buildings are adequate before ending AEC assistance.

WORKERS RECORDS SYSTEM

During the year, the AEC continued its efforts to develop a cooperative employer-State-Federal records and reports system for radiation workers.[5] The need for a records system for radiation workers was highlighted in 1967 during hearings before the JCAE on radiation exposures to uranium miners. The system proposed by AEC would include such workers.

In an attempt to resolve a number of questions expressed during hearings before the JCAE in September 1966, Commission staff have participated in numerous meetings with representatives of industry, labor and other interested public and private organizations. Based upon these discussions and upon the specific recommendations of the

[5] See pp. 379–381, "Annual Report to Congress for 1966."

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Commission's Labor-Management Advisory Committee, the system, as modified in September 1966, was further revised to limit annual reporting of exposure data to the central repository as follows:

1. Reports of individuals whose quarterly external exposure exceeds those levels beyond which personnel monitoring is required under existing criteria;
2. Reports of individuals' internal exposure which exceeds applicable exposure limits (overexposures); and
3. Identification information for those individuals required to be monitored under 10 CFR Part 20 for external or internal exposure whose exposure does not exceed the levels or limits under 1 and 2 above.

The Commission, after considering various alternatives for implementing the system and in order to gain experience in the operation of a central repository, proposed, subject to public comment, implementation of the system with its contractors and licensees.

On November 16, 1967, the Commission published in the "Federal Register," vol. 32, No. 222, page 15762, for comment, proposed changes to 10 CFR Part 20. These amendments, if adopted, would require AEC licensees to report annually to a central repository to be maintained by AEC the identification and radiation exposure information described above. The proposed changes, however, would not involve any major departure from the monitoring and record keeping practices presently required of AEC licensees under existing regulations. Similar amendments applicable to our AEC contractors are under review by AEC field offices and contractors.

Other Activities

The AEC has continued its cooperative relationship with the States in matters involving the improvement in State workmen's compensation laws for radiation workers. To this end, 47 of the 51 jurisdictions, including Puerto Rico, have completed an analysis of their State workmen's compensation laws. The remaining four studies are in progress.

The studies were undertaken to determine the adequacy of such laws in meeting the 11 workmen's compensation standards adopted by the Commission in 1965.[7] In addition, 46 States and Puerto Rico have agreed to furnish AEC with copies of radiation related medical treatment or lost time reports filed by employers, copies of claims filed by employees alleging radiation injury, and analyses of settled or adjudicated claims involving radiation.

[7] See pp. 49–51, "Annual Report to Congress for 1965."

Legislation was introduced in 23 States, in 1967, covering one or more of the recommended 11 standards. Sixteen of these legislative proposals were enacted into law. Results of the State studies, and available information in the absence of completed studies, indicate the need of further action. The number of States meeting each of the AEC's 11 standards are:

AEC standard on:	Number of States meeting standards
Compulsory law	30
No numerical exemption	26
Extraterritoriality	42
Waivers prohibited	38
Broad second injury fund	21
Adequate time limit	36
Radiation injury coverage	46
Full medical and physical rehabilitation coverage	33
Vocational rehabilitation	22
Authority to review medical care	34
Review of lump-sum settlements	51*

*50 States plus Puerto Rico.

CONTRACTING POLICY

In response to President Johnson's directive of September 16, 1966, to cut Federal expenditures by improving procurement and management of property, the AEC and its prime contractors: (*a*) eliminated 43,920 line items from inventory; (*b*) utilized $22.8 million worth of excess property; (*c*) redistributed $5.4 million worth of property for use in lieu of new procurement; (*d*) returned $22.0 million worth of equipment stock and to AEC pools for further use; (*e*) declared $7.0 million worth of equipment to be in excess of needs; (*f*) canceled items on outstanding orders valued at $2.7 million; and (*g*) reduced items (not including "f") on outstanding orders by $3.1 million.

AEC Subcontracting to Small Business

The AEC continues to encourage and assist small business participation in its prime contracts and subcontracts. During fiscal 1967, for the sixth consecutive year, AEC prime contractors awarded over 43 percent of the subcontracts to small business concerns; $280.0 million of $643.5 million, or 43.5 percent. The average percentage of subcontract awards to small business during the period of 1951–1967 was 39 percent.

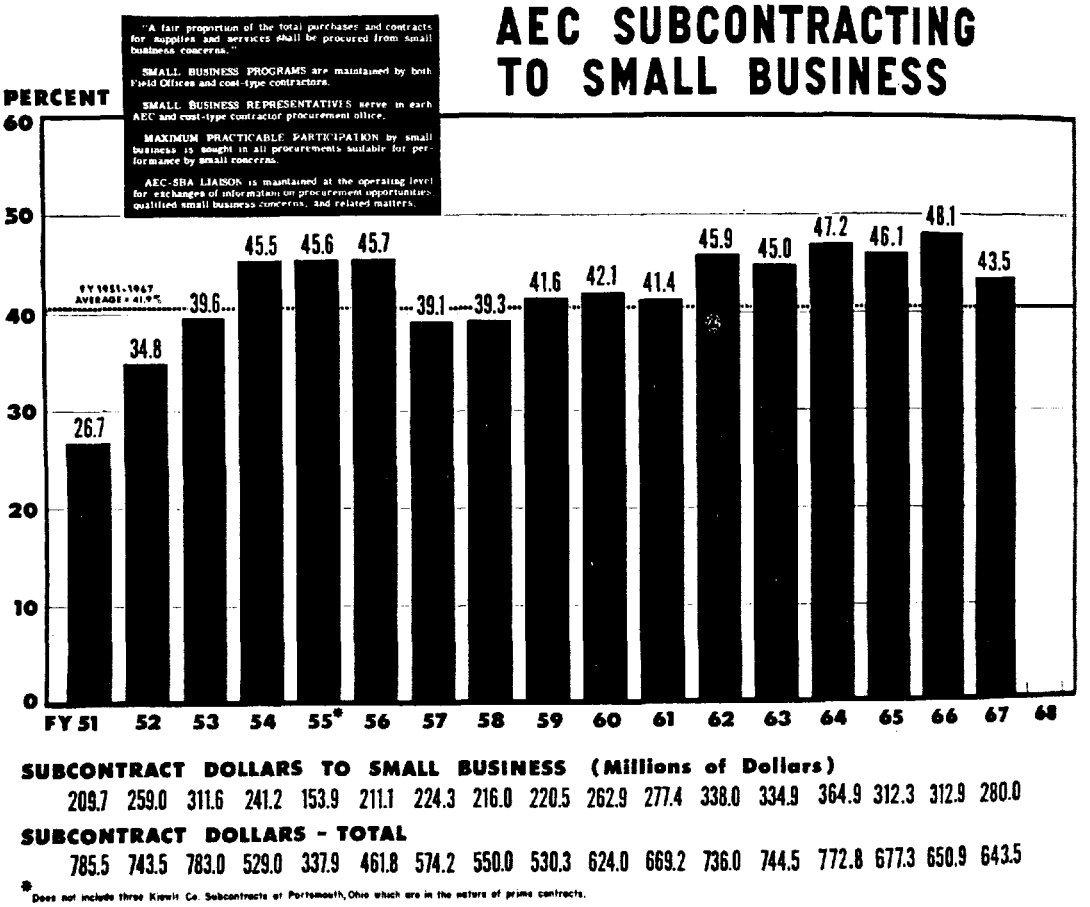
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Changes in University Research Contracts

The AEC has revised its method of contracting for basic research with educational institutions by adopting a "special research support agreement" as a replacement for the former "fixed price" contract. The new research support agreement provides that the AEC will reimburse the institution for a specified percentage of actual costs incurred in performance of the research, up to a ceiling amount. A limited number of specific approval requirements regarding changes in the ways and means of performing the work are spelled out in the contract, thus eliminating the need for approval of all "substantial deviations" from the scope of work. This allows the university to exercise greater freedom of imagination in doing the research.

Procurement Procedures Study Group

A seven-man group has been formed to study AEC procurement processes and to prepare a comprehensive report. The group has been asked to evaluate: (*a*) the AEC's controls on the contractors' procurement practices, (*b*) the AEC's decentralized approach to contract administration, (*c*) the influence of the AEC's program administration techniques, (*d*) the effect of after-the-fact reviews of contractor pro-



urement, (*e*) the feasibility of removing some restrictions on small subcontracts, and (*f*) the necessity of each step in the procurement process.

The study[8] is aimed at assuring that the AEC continues to get quality performance of its programs through the use of quality contracting.

Board of Contract Appeals

During the 3-year period of its existence, the Board of Contract Appeals has docketed 50 appeals and one special proceeding. The Board Chairman and staff also have participated in Government-wide studies of similar boards and in the above described studies of AEC procurement processes. All appeals on the docket at the beginning of 1967, have been disposed of by the Board.

Special Proceeding

A dispute between United Nuclear Corp. (UNC) and the AEC concerning the Quinta Property in New Mexico was docketed by the Board on October 24, 1966. At issue was the number of pounds of uranium concentrate (U_3O_8) which could have been profitably produced and delivered from the Quinta property between April 1, 1963 and December 31, 1966.

A special board panel, acting as an arbitrator, determined that UNC profitably could have produced and delivered to AEC 3,393,780 pounds of uranium concentrate out of a total of 3,460,303 pounds which had been claimed. This resulted in the AEC having to purchase from UNC 3,393,780 pounds of uranium concentrate at $8.00 per pound.

Disposition by Agreement

The board policy of active participation with the parties in disposing of disputes by agreement continues as an important means of resolving disputes even though the number of disputes resolved by

[8] Chairman of the study group is Wallace B. Reynolds, former managing engineer and business manager of the Lawrence Radiation Laboratory, Berkeley. Other members of the study group are: William J. Catacosinos, assistant director of the AEC's Brookhaven National Laboratory, operated by Associated Universities, Inc. (New York); Paul H. Gantt, chairman of the AEC Board of Contract Appeals; David Saxe, vice president for administration of Atomics International, Div. of North American Rockwell Corp.; Arthur Schoenhaut, deputy controller of the AEC; Kenneth S. Spoon, former director of procurement and traffic for the Sandia Corp.; and Alden B. Greninger, general manager of the Nuclear Technology Department of General Electric's Vallecitos Atomic Laboratory in Pleasanton, Calif.

agreement of the parties declined in 1967. A salutary effect of this policy, which has been noted by the Board, is that stronger efforts are being exerted by contracting officers to dispose of disputes by agreement without the necessity of appeal proceedings.

The proper use of pretrial conference techniques developed by the Board is primarily responsible for the disposition by agreement of appealed disputes. The conference purpose, as set down in the Board's rules (10 CFR Part 3), is "to bring the parties together informally to consider the possibility of disposing of the appeal by agreement." The conference has proved useful to the Board in achieving this result.

Accelerated Procedure and Small Business

The consideration and disposition of appeals without regard to their normal position on the docket continues to successfully resolve those appeals in which the procedure is used. The accelerated procedure may be used when the amount in dispute does not exceed $10,000 or for other good causes shown.[9]

In 1967, to avoid hardships which administrative proceedings may cause small businesses, the Board as it has in earlier years made every effort to accommodate small businesses in granting promptly the accelerated procedure and in holding conferences and hearings at or near the location of the small business.

OFFICE OF HEARING EXAMINERS

The hearing examiners' staff is responsible to the Commission for the conduct of hearings and the issuance of orders and decisions in licensing proceedings, including certain patent licensing matters, and in controversies involving the availability of Federal funds under Title VI of the Civil Rights Act of 1964.[10]

Year's Activities

During 1967, the hearing examiners served as chairmen of six atomic safety and licensing boards which adjudicate facility licensing cases under the Atomic Energy Act and the Administrative Procedure Act.

[9] The BCA is the only Board which by specific rule may apply this procedure to disputes involving up to $10,000. In addition, the Board has liberally construed this rule to apply the accelerated procedure where the need arises regardless of amount.

[10] 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.

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Atomic reactor licensing actions for construction permits by boards presided over by the hearing examiners in 1967 included: Duke Power Co., Florida Power & Light Co., Tennessee Valley Authority, Wisconsin Michigan Power Co., and Commonwealth Edison Co. One other construction permit hearing was conducted for General Electric's Midwest Fuel Recovery Plant. (See discussion of these cases in Chapter 6—Licensing and Regulating the Atom.)

In addition, one of the hearing examiners served as chairman for the informal review board on an operating permit for a small (10 kwt.) research reactor at the National Bureau of Standards, Gaithersburg, Md.

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APPENDIX 1

ORGANIZATION AND PRINCIPAL STAFF OF U.S. ATOMIC ENERGY COMMISSION

COMMISSIONERS

...mic Energy Commission	GLENN T. SEABORG, *Chairman* ARNOLD R. FRITSCH, *Special Assistant* JAMES T. RAMEY JOHN C. RYAN, *Special Assistant* GERALD F. TAPE JACK ROSEN, *Special Assistant* WILFRID E. JOHNSON GERARD F. HELFRICH, *Technical Assistant* VACANCY [1]
...retary to the Commission	W. B. MCCOOL
...troller	JOHN P. ABBADESSA
...eral Counsel	JOSEPH F. HENNESSEY
...ector, Division of Inspection	CURTIS A. NELSON
...f. Hearing Examiner	SAMUEL W. JENSCH
...irman, AEC Board of Contract Appeals	PAUL H. GANTT
...irman, Atomic Safety and Licensing Board Panel	ALGIE A. WELLS

OPERATING AND PROMOTIONAL FUNCTIONS

...eral Manager	ROBERT E. HOLLINGSWORTH
Executive Assistant to the General Manager	DONALD C. KULL
Assistant to the General Manager	HARRY S. TRAYNOR
Assistant to the General Manager for Program Analysis	ROGER W. A. LEGASSIE
...ty General Manager	EDWARD J. BLOCH
...stant General Manager	HOWARD C. BROWN, Jr.
Director, Division of Industrial Participation	ERNEST B. TREMMEL
Director, Division of Intelligence	C. H. REICHARDT
Director, Division of Public Information	JOHN A. HARRIS
Director, Office of Congressional Relations	ROBERT D. O'NEILL
Special Assistant for Disarmament	ALAN M. LABOWITZ
...stant General Manager for Operations	JOHN A. ERLEWINE
Assistant for Economic and Community Affairs	GEORGE J. KETO
Assistant for Workmen's Compensation and Radiation Records	CHARLES F. EASON
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	MARTIN B. BILES

[1] Dr. Samuel M. Nabrit resigned as a member of the Atomic Energy Commission effective ...ust 1, 1967, to become Executive Director of the Southern Fellowship Fund with head...ters in Atlanta, Ga.

Assistant General Manager for Research and Development	SPOFFORD G. ENGLISH
Director, Division of Biology and Medicine	JOHN R. TOTTER
Director, Division of Isotopes Development	E. EUGENE FOWLER
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	MILTON KLEIN
Assistant General Manager for International Activities	MYRON B. KRATZER
Director, Division of International Affairs	MYRON B. KRATZER
Assistant General Manager for Administration	JOHN V. VINCIGUERRA
Director, Division of Classification	C. L. MARSHALL
Director, Division of Headquarters Services	EDWARD H. GLADE
Director, Division of Personnel	DONALD E. BOSTOCK
Director, Division of Security	WILLIAM T. RILEY
Director, Division of Technical Information	EDWARD J. BRUNENKANT
Assistant General Manager for Military Application [2]	BRIG. GEN. EDWARD B. GILLER, USAF
Controller, Office of the Controller	JOHN P. ABBADESSA
General Counsel, Office of the General Counsel	JOSEPH F. HENNESSEY
Director, Division of Inspection	CURTIS A. NELSON
Director, Office of Safeguards and Materials Management	BRIG. GEN. DELMAR L. CROWSON, USAF (retired)

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	HERMAN E. ROSER
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
200 Bev. Accelerator Facility	LAWRENCE C. MOHR
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
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	J. PERRY MORGAN

[2] P.L. 90–190 (December 14, 1967) amended the Atomic Energy Act of 1954, as amended, by, among other things, changing the title of the Director, Division of Military Application, to that of Assistant General Manager for Military Application.

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...sburgh (Pa.) Naval Reactors Office	LAWTON D. GEIGER
...land (Wash.) Operations Office	DONALD G. WILLIAMS
... Francisco (Calif.) Operations Office	ELLISON C. SHUTE
Canoga Park (Calif.) Area	JOEL V. LEVY
Palo Alto (Calif.) Area	HOWARD C. HOOPER
...annah River (Aiken, S.C.) Operations Office	NATHANIEL STETSON
...nectady (N.Y.) Naval Reactors Office	STANLEY W. NITZMAN

AEC Scientific Representatives Abroad

... De Janeiro, Brazil	ROBERT H. WILCOX
...ssels, Belgium	DIXON B. HOYLE, *Senior Representative*
...enos Aires, Argentina	ROBERT H. GOECKERMANN
...alk River, Ontario, Canada	ROBERT W. RAMSEY, Jr.
...ndon, England	CARL E. MALMSTROM
...ris, France	JOSEPH J. DINUNNO
...kyo, Japan	WHITTIE J. MCCOOL

LICENSING AND REGULATORY FUNCTIONS

...rector of Regulation	HAROLD L. PRICE
...puty Director	CLIFFORD K. BECK
...sistant Director for Reactors	M. M. MANN
...sistant Director for Administration	C. L. HENDERSON
Director, Division of Compliance	LAWRENCE D. LOW
Director, Division of Reactor Licensing	PETER A. MORRIS
Director, Division of Reactor Standards	EDSON G. CASE
Director, Division of Radiation Protection Standards	FORREST WESTERN
Director, Division of Materials Licensing	JOHN A. MCBRIDE
Director, Division of State and Licensee Relations	EBER R. PRICE
Director, Division of Nuclear Materials Safeguards	RUSSELL P. WISCHOW

Directors of Compliance Regional Offices

...gion I (New York)	ROBERT W. KIRKMAN
...gion II (Atlanta)	JOHN G. DAVIS
...gion III (Chicago)	BOYCE H. GRIER
...gion IV (Denver)	DONALD I. WALKER
...gion V (San Francisco)	RICHARD W. SMITH

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APPENDIX 2

MEMBERSHIP OF COMMITTEES DURING 1967

STATUTORY COMMITTEES AND BOARDS

Joint Committee on Atomic Energy—90th Congress (First Session)

The committee was established by the Atomic Energy Act of 1946, and continued under section 201 of 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 1967, the committee was composed of:

Senator JOHN O. PASTORE (Rhode Island), *Chairman*
Representative CHET HOLIFIELD (California), *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 THOMAS G. MORRIS (New Mexico)
Representative JOHN YOUNG (Texas)
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 (*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

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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. CARL WALSKE, *Chairman*
Maj. Gen. OTTO J. GLASSER, United States Air Force
Maj. Gen. RICHARD H. ELLIS, United States Air Force
RAdm. SAMUEL R. BROWN, Jr., United States Navy
Brig. Gen. KENNETH F. DAWALT, United States Army
Brig. Gen. JAMES A. HEBBELER, United States Army
Capt. JAMES G. WHITEAKER, United States Navy

General Advisory Committee

This committee was established by the Atomic Energy Act of 1946, and is continued by Section 26 of the Atomic Energy Act of 1954. The nine civilian members are appointed by the President to advise the Commission on scientific and technical matters relating to materials, production, and research and development. The committee meets at least four times in every calendar year and annually designates one of its own members as chairman.

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, retired (formerly Director, Puerto Rico Nuclear Center, San Juan, P.R.)
Dr. EDWIN L. GOLDWASSER, Professor of Physics, University of Illinois, Urbana, Ill.
Dr. JANE H. HALL, Assistant Director, Los Alamos Scientific Laboratory, Los Alamos, 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, retired, formerly Vice President, Standard Oil Co. of California, San Francisco, Calif.
WILLIAM WEBSTER, Chairman, New England Electric System, Boston, Mass.
DUANE C. SEWELL, *Scientific Officer;* Lawrence Radiation Laboratory, Livermore, Calif.
ANTHONY A. TOMEI, *Secretary;* U.S. Atomic Energy Commission, Washington, D.C.

The committee met four times in 1967: during February at Richland, Wash.; during May in Washington, D.C.; during August at Los Alamos, N. Mex.; and during November in Washington, D.C.

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, patent attorney, Toledo, Ohio
HERMAN I. HERSH, firm of McDougall, Hersh, Scott, & Ladd, Chicago, Ill.
LAWRENCE C. KINGSLAND, firm of Kingsland, Rogers, Ezell, Eilers & Robbins, St. Louis, Mo.

The board met three times during 1967: in Washington D.C., on March 16, May 23–25, and December 13.

Advisory Committee on Reactor Safeguards

The committee, established under Section 29 of the Atomic Energy Act of 1954, as amended, reviews safety studies and facility license applications referred to it and makes reports thereon, advises the Commission with regard to the hazards of proposed or

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isting reactor facilities and the adequacy of proposed reactor safety standards, and forms such other duties as the Commission may request. The committee's reports on plications for facility licenses become a part of the record of the application and ailable to the public, except for security material. Members are appointed by the mmission for a term of four years each, and one member is designated by the committee as its chairman. This committee was established as a statutory body in 1957.

NUNZIO J. PALLADINO, *Chairman;* Dean, College of Engineering, The Pennsylvania State University, University Park, Pa.

Dr. CARROLL W. ZABEL, *Vice Chairman;* Director of Research and Associate Dean of the Graduate School, University of Houston, Houston, Tex.

Dr. SPENCER H. BUSH, Consultant to the Director (Metallurgy), Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, Wash.

HAROLD ETHERINGTON, Consulting Engineer (Mechanical Reactor Engineering), Jupiter, Fla.

Dr. WILLIAM L. FAITH, Consultant (Air Pollution Control), San Marino, Calif.

Dr. FRANKLIN A. GIFFORD, Jr., Director, Atmospheric Turbulence and Diffusion Laboratory, Environmental Science Services Administration, Oak Ridge, Tenn.

Dr. STEPHEN H. HANAUER, Professor of Nuclear Engineering, University of Tennessee, Knoxville, Tenn.

Dr. JOSEPH M. HENDRIE, Physicist, Brookhaven National Laboratory, Upton, N.Y.

Dr. HERBERT S. ISBIN, Professor of Chemical Engineering, University of Minnesota, Minneapolis, Minn.

HAROLD G. MANGELSDORF, Chairman of the Board, Crown Central Petroleum Corp., Short Hills, N.J.

Dr. JACK E. MCKEE, Professor of Environmental Health Engineering, California Institute of Technology, Pasadena, Calif.

Dr. HARRY O. MONSON, Senior Engineer, Laboratory Director's Office, Argonne National Laboratory, Argonne, Ill.

Dr. ARLIE A. O'KELLY, Consultant (Chemical Engineering), Littleton, Colo.

Dr. DAVID OKRENT, Senior Physicist, Laboratory Director's Office, Argonne National Laboratory, Argonne, Ill.

Dr. WILLIAM R. STRATTON, Physicist, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

R. F. FRALEY, *Executive Secretary;* U.S. Atomic Energy Commission, Washington, D.C.

ring 1967, the committee met 13 times: January 12–14, February 9–11, February 28, rch 9–11, April 6–8, May 11–13, June 8–10, July 6–8, August 10–12, September 7–9, tober 5–7, November 2–3, and December 7–9.

omic Safety and Licensing Board Panel

Section 191 of the Atomic Energy Act of 1954 authorizes, in addition to other matters, e Commission to establish one or more atomic safety and licensing boards, each to be mposed of three members, two of whom are to be technically qualified and one of whom to be qualified in the conduct of administrative proceedings. Technically qualified alternates may be appointed to atomic safety and licensing boards, to serve in the event that board member should become unavailable before the start of a hearing. 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 anel to serve on atomic safety and licensing boards as assigned.

A. A. WELLS, *Panel Chairman,* U.S. Atomic Energy Commission, Washington, D.C.

WARREN E. NYER, *Vice Chairman,* Aerojet General Corp., Idaho Falls, Idaho.

J. D. BOND, Hearing Examiner, U.S. Atomic Energy Commission, Washington, D.C.

R. B. BRIGGS, Director, Molten Salt Reactor Program, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. JOHN HENRY BUCK, Vice President and General Manager, Instruments Div., The Budd Co., Phoenixville, Pa.

Dr. A. DIXON CALLIHAN, Oak Ridge National Laboratory, Oak Ridge, Tenn.

JACK M. CAMPBELL, Partner in law firm of Stephenson, Campbell & Olmsted, Santa Fe, N. Mex.

VALENTINE B. DEALE, Attorney-at-law, Washington, D.C.

Dr. MILTON C. EDLUND, AEC Combined Operations Planning, Union Carbide Corp., Oak Ridge, Tenn.

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Dr. STUART GORDON FORBES, Assistant Manager, Technology, Atomic Energy Div., Phillips Petroleum Co., Idaho Falls, Idaho.
Dr. JOHN C. GEYER, Chairman, Department of Sanitary Engineering and Water Resources, The Johns Hopkins University, Baltimore, Md.
JAMES P. GLEASON, Attorney-at-law, Washington, D.C.
Dr. CLARK GOODMAN, Professor of Physics and Department Chairman, University of Houston, Houston, Tex.
Dr. EUGENE GREULING, Professor of Physics, Duke University, Durham, N.C.
Dr. DAVID B. HALL, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. JOHN P. HOWE, The Institute for Defense Analyses, Arlington, Va.
SAMUEL W. JENSCH, Chief Hearing Examiner, U.S. Atomic Energy Commission, Washington, D.C.
ARTHUR W. MURPHY, Columbia University School of Law, New York City.
Dr. HUGH PAXTON, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. TOMAS 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. CLARKE WILLIAMS, Research Administrator, Regional Marine Resources Council, Nassau-Suffolk Regional Planning Board, Hauppauge, Long Island, N.Y.
Dr. CHARLES E. WINTERS, Parma Research Center, Union Carbide Corp., Cleveland, Ohio.
Dr. ABEL WOLMAN, The Johns Hopkins University, Baltimore, Md.
HOOD WORTHINGTON, retired, Wilmington, Del.

Eleven new boards were drawn from the panel in 1967 for regulatory proceedings. Two meetings of the entire panel were held during the year: one at the National Reactor Testing Station, Idaho Falls, Idaho, on September 19–21, and the other at the AEC's Headquarters in Washington, D.C., on December 5–6.

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 board, in addition, conducts hearings and finally decides debarment cases in which a hearing has been held. 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.

PAUL H. GANTT, *Chairman;* U.S. Atomic Energy Commission, Washington, D.C.
JOHN G. ROBERTS, *Vice Chairman;* U.S. Atomic Energy Commission, Washington, D.C.
CARMINE S. BELLINO, Certified Public Accountant, 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.
JOHN T. FEY, President of the National Life Insurance Co., Montpelier, Vt.
Dr. G. KENNETH GREEN, Chairman, Accelerator Department, Brookhaven National Laboratory, Upton, 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.
JOHN A. MCINTIRE, Consulting Attorney, Office of Judge Advocate General, U.S. Navy, Washington, D.C.
RALPH C. NASH, Jr., Associate Dean for Graduate Studies, Research and Projects of National Law Center, George Washington University, Washington, D.C.
THOMAS J. O'TOOLE, Dean, Northeastern School of Law, Boston, Mass.
HAROLD C. PETROWITZ, Professor of Law, Washington College of Law, American University, Washington, D.C.
CHARLES G. SONNEN, Assistant to the Director, Division of Construction, U.S. Atomic Energy Commission, Washington, D.C.

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JOHN M. STOY, Certified Public Accountant, Stoy, Malone & Co., Washington, D.C.
ARLENE TUCK ULMAN, Attorney at Law, Washington, D.C.
ROBERT M. UNDERHILL, Vice President and Treasurer Emeritus, University of California, Berkeley, Calif.
Capt. DANIEL B. VENTRES, Consulting Engineer, Haddam, Conn.
JOHN W. WHELAN, Professor of Law, University of California at Davis School of Law, Davis, Calif.

The full board met once during 1967, on November 29, in Washington, D.C. Numerous meetings of the individual panels designated to hear, consider, and decide appeals were also held.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Atomic Energy Labor-Management Advisory Committee

This committee was established in March 1962 to bring 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.
H. ROY CHOPE, Executive Vice President for Development and Engineering, Industrial Nucleonics Corp., Columbus, Ohio
HAROLD A. FIDLER, Associate Director, Lawrence Radiation Laboratory, Berkeley, Calif.
GORDON M. FREEMAN, International President, International Brotherhood of Electrical Workers, Washington, D.C.
CHARLES D. HARRINGTON, President, Douglas United Nuclear, Inc., Richland, Wash.
CHARLES H. KEENAN, Vice President, Yankee Atomic Electric Co., Boston, Mass.
HOWARD K. NASON, President, Monsanto Research Corp., St. Louis, Mo.
P. L. SIEMILLER, International President, International Association of Machinists and Aerospace Workers, Washington, D.C.
PETER T. SCHOEMANN, General President, United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada, Washington, D.C.
ELWOOD D. SWISHER, Vice President, Oil, Chemical and Atomic Workers International Union, Denver, Colo.

The committee met twice during 1967: at Washington, D.C., on May 18, and in Haddam Neck, Conn., on October 5.

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. EARL L. GREEN, *Chairman;* Director, The Jackson Laboratory, Bar Harbor, Maine
Dr. PHILIP P. COHEN, *Vice Chairman;* Professor and Chairman, Department of Physiological Chemistry, University of Wisconsin School of Medicine, Madison, Wis.
Dr. WILLIAM F. BALE, Professor, Radiation Biology, Department of Radiation Biology and Biophysics; and Atomic Energy Project, University of Rochester, School of Medicine and Dentistry, Rochester, N.Y.
Dr. ARIE J. HAAGEN-SMIT, Professor, Division of Biology, California Institute of Technology, Pasadena, Calif.
Dr. ROBERT D. MOSELEY, Jr., Chairman of Department of Radiology, University of Chicago, Chicago, Ill.
Dr. LEMUEL C. MCGEE, Medical Director, Hercules, Inc., Wilmington, Del.
Dr. MORELL B. RUSSELL, Director, Agricultural Experiment Station, University of Illinois, Urbana, Ill.

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Dr. JAMES B. WYNGAARDEN, Chairman, Department of Medicine, Duke University Medical Center, Durham, N.C.

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 met six times during 1967: January 13–14, Washington, D.C.; March 9–11, Berkeley, Calif.; May 12–13, Rochester, N.Y.; June 8–9, Washington, D.C.; September 7–8, Washington, D.C.; and November 9–10, Oak Ridge, Tenn.

Historical Advisory Committee

The Historical Advisory Committee was established by the Commission in February 1955 to advise the Commission and its historical staff on matters relating to the preparation of the history of the Atomic Energy Commission.

Dr. GEORGE E. MOWRY, *Chairman;* Professor of History, University of North Carolina, Chapel Hill, N.C.

Dr. JAMES L. CATE, Professor of History, University of Chicago, Chicago, Ill.

Dr. A. HUNTER DUPREE, Professor of History, University of California, Berkeley, Calif.

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. ISADORE PERLMAN, Associate Director, Lawrence Radiation Laboratory, Berkeley, Calif.

Dr. DON K. PRICE, Jr., Dean, John Fitzgerald Kennedy School of Government, Harvard University, Cambridge, Mass.

Dr. ROBERT R. WILSON, Director, National Accelerator Laboratory, Weston, Ill.

Dr. RICHARD G. HEWLETT, AEC representative, Chief Historian, U.S. Atomic Energy Commission, Washington, D.C.

The committee met once during 1967, on July 31–August 1, at Argonne National Laboratory, Ill.

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. CHARLES ARTANDI, Director of Research, Suture Products, Ethicon, Inc., Somerville, N.J.

Dr. JOHN C. BRANTLEY, Vice President, International Chemical and Nuclear Corp., Pittsburgh, Pa.

Dr. MILTON BURTON, Director of Radiation Laboratory, University of Notre Dame, Notre Dame, Ind.

Cmdr. SCOTT CARPENTER, U.S. Navy Dept., Washington, D.C.

H. ROY CHOPE, Executive Vice-President, Industrial Nucleonics Corp., Columbus, Ohio.

Dr. BERNARD FRIES, Senior Research Associate, Chevron Research Co., Richmond, Calif.

Dr. DAVID E. HARMER, Head, Gamma Radiation Section, Radiochemistry Research Laboratory, Dow Chemical Co., Midland, Mich.

Dr. THOMAS E. HICKS, Professor of Engineering, University of California at Los Angeles, Los Angeles, Calif.

Dr. GEORGE M. KAVANAGH, Assistant General Manager for Reactors, U.S. Atomic Energy Commission, Washington, D.C.

Dr. WILFRED R. KONNEKER, General Manager, Mallinckrodt/Nuclear, St. Louis, Mo.

Dr. JAMES R. MAXFIELD, Jr., Maxfield Clinic-Hospital, Dallas, Tex.

HOWARD K. NASON, President, Monsanto Research Corp., St. Louis, Mo.

Dr. DONALD W. PRITCHARD, Director, Chesapeake Bay Institute, and Chairman, Department of Oceanography, Johns Hopkins University, Baltimore, Md.

Dr. RODMAN A. SHARP, President, Sharp Laboratories Div., Beckman Instruments, Inc., La Jolla, Calif.

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Dr. VIVIAN T. STANNETT, Professor of Chemical Engineering, School of Engineering, North Carolina State University, Raleigh, N.C.

Dr. PAUL M. STIER, Program Manager—Corporation Research, Union Carbide Corp., Tarrytown, N.Y.

committee met twice during 1967: at Oak Ridge National Laboratory on April 6–7, at Washington, D.C., on October 12–13.

visory Committee on Medical Uses of Isotopes

committee was established in 1958 and replaced the Subcommittee on Human Appli-ions of the Advisory Committee on Isotope Distribution. The committee advises the mmission on policies and standards for the regulation and licensing of medical uses of dioisotopes 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 and Head, Department of Biochemistry, University of Minnesota Medical School, Minneapolis, Minn.

Dr. JOHN E. CHRISTIAN, Head of Bionucleonics, Purdue University, Lafayette, Ind.

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. DAVID E. KUHL, Associate Professor of Radiology, University of Pennsylvania, School of Medicine, Philadelphia, Pa.

Dr. GEORGE V. LEROY, Medical Director, Metropolitan Hospital, Detroit, Mich.

Dr. RULON W. RAWSON, Dean of Medicine and Vice President, New Jersey College of Medicine and Dentistry, Jersey City, N.J.

Dr. HARALD ROSSI, Professor of Radiology, College of Physicians and Surgeons, Columbia University, New York, N.Y.

Dr. ROBERT J. SHALEK, Head, Department of Physics, M.D. Anderson Hospital and Tumor Institute, University of Texas, Houston, Tex.

Dr. CHARLES D. WEST, Associate Research Professor of Biology, University of Utah, College of Medicine, Salt Lake City, Utah.

committee met twice during 1967: on January 21 in Washington, D.C., and August 10 East Lansing, Mich.

wshare Advisory Committee

The Plowshare Advisory Committee was established in September 1959. The committee's ction is to advise the Commission and the General Manager on selecting and carrying particular Plowshare projects, developing and making available various applications Plowshare and determining the general orientation and policies of the Plowshare gram.

Dr. SPOFFORD G. ENGLISH, *Chairman,* Assistant General Manager for Research and Development, U.S. Atomic Energy Commission, Washington, D.C.

Mr. WILLARD BASCOM, President, Ocean Science and Engineering, Inc., Washington, D.C.

Lt. Gen. JAMES H. DOOLITTLE, Los Angeles, Calif.

Dr. LOUIS H. HEMPELMANN, University of Rochester, Rochester, N.Y.

Dr. RICHARD LATTER, The Rand Corp., Santa Monica, Calif.

Dr. WILLARD F. LIBBY, University of California at Los Angeles, Calif.

Dr. DONALD H. MCLAUGHLIN, Chairman of the Board, Homestake Mining Co., San Francisco, Calif.

Mr. JOHN G. PALFREY, School of Law, Columbia University, New York City.

Dr. PHILIP C. RUTLEDGE, Partner, Mueser, Rutledge, Wentworth & Johnson, New York, N.Y.

Dr. PAUL B. SEARS, Yale University, New Haven, Conn.

Dr. HYMER L. FRIEDELL, Western Reserve University, Cleveland, Ohio

Lt. Gen. ALFRED D. STARBIRD, Director, Defense Communications Agency, Arlington, Va.

JOHN S. KELLY, *Secretary,* Director, Division of Peaceful Nuclear Explosives, U.S. Atomic Energy Commission, Washington, D.C.

committee met once during 1967: on October 10–11, at Sandia Laboratory, Albuquerque, Mex.

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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.
Dr. ROBERT BAYARD, Westinghouse Electric Corp., Bettis Atomic Power Div., Pittsburgh, Pa.
JACK CHERNICK, Associate Head, Reactor Physics Division, Brookhaven National Laboratory, Upton, N.Y.
Dr. E. RICHARD COHEN, Associate Director, North American Aviation Science Center, Thousand Oaks, Calif.
Dr. FRANK G. DAWSON, Jr., Manager, Reactor Physics Dept., Pacific Northwest Laboratory, Richland, Wash.
Dr. GERHARD DESSAUER, Director, Physics Section, Savannah River Laboratory, Aiken, S.C.
Dr. RICHARD EHRLICH, Manager, Advanced Development Activity, Knolls Atomic Power Laboratory, Schenectady, N.Y.
Dr. REX FLUHARTY, Manager, Nuclear Physics Branch, Idaho Nuclear Corp., Idaho Falls, Idaho
Dr. E. R. GAERTTNER, Director, Linac Project, Rensselaer Polytechnic Institute, Troy, N.Y.
Dr. GORDON HANSEN, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. W. B. LOEWENSTEIN, LMFBR Program Office, Argonne National Laboratory, Argonne, Ill.
Dr. F. C. MAIENSCHEIN, Associate Director, Neutron Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.
Dr. LOTHAR W. NORDHEIM, Chairman, Theoretical Physics Department, General Atomic, San Diego, Calif.
Dr. THOMA M. SNYDER, Atomic Products Division, General Electric Co., Pleasanton, Calif.
Dr. ALVIN RADKOWSKY, *Secretary;* Division of Naval Reactors, U.S. Atomic Energy Commission, Washington, D.C.

The Committee met once during 1967, on May 4–5, at the National Bureau of Standards, Gaithersburg, Md.

Advisory Committee on Nuclear Materials Safeguards

The committee was established August 29, 1967, to assist the Atomic Energy Commission in carrying out more effectively its responsibilities for safeguarding special nuclear materials under the Atomic Energy Act. The committee will advise the Commission in the development of: policy regarding safeguards against the diversion of special nuclear materials; safeguards standards and criteria; safeguards procedures; safeguards research and development; methods of measurement and other procedures; and standard reference materials. On request, the advisory committee will provide technical advice relating to safeguards standards and criteria regarding specific problems involving licensee or contractor operations and on other matters that may be pertinent.

JOHN PALFREY, *Chairman;* Professor of Law, Columbia University, New York City (Mr. Palfrey served as a member of the Atomic Energy Commission, 1962–1966)
Brig. Gen. DELMAR L. CROWSON (USAF, Ret.), *Vice Chairman;* Director, Office of Safeguards and Materials Management, U.S. Atomic Energy Commission, Washington, D.C.
Dr. RUSSELL P. WISCHOW, *Vice Chairman;* Director, Division of Nuclear Materials Safeguards, U.S. Atomic Energy Commission, Washington, D.C.
ROGER E. BATZEL, Associate Director, Lawrence Radiation Laboratory, Livermore, Calif.

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FRANCIS P. COTTER, Vice President, Westinghouse Electric Corp., Washington, D.C.
PAUL GRADY, consultant to accounting firm of Price-Waterhouse Co., New York City
Dr. JANE HALL, Associate Director, Los Alamos (N. Mex.) Scientific Laboratory
Dr. RALPH F. LUMB, Director, Western New York Nuclear Research Center, Buffalo, N.Y.
Dr. HORACE W. NORTON, III, Professor, University of Illinois, Urbana, Ill.
CLEMENT J. RODDEN, Manager, AEC's New Brunswick (N.J.) Area Office and Director of the New Brunswick Laboratory
LOUIS H. RODDIS, Jr., Chairman of the Board, Pennsylvania Electric Co., and Director of Nuclear Power Activities for General Public Utilities Corp., of New York City
WALTON A. RODGER, past Associate Director, Chemical Engineering Division, Argonne (Ill.) National Laboratory and now on the staff of Nuclear Safety Associates in Bethesda, Md.
LOMBARD SQUIRES, Manager, Atomic Energy Div., Evplosives Department, E. I. du Pont de Nemours and Co., Inc., Wilmington, Del.
CHARLES D. W. THORNTON, Executive Vice President, Cleveland (Ohio) Container Corp.
Dr. FRED H. TINGEY, Manager of Operations Analysis, Idaho Nuclear Corp., Idaho Falls, Idaho
FRANCIS O. WILCOX, Dean, School of Advanced International Studies, Johns Hopkins University, Baltimore, Md.
J. ERNEST WILKINS, Jr., Assistant Director, Gulf General Atomics, Inc., San Diego, Calif.

The committee met once during 1967, September 28–29 in Washington, D.C.

Advisory Committee of State Officials

This committee was established by the Commission in September 1955 as a means of obtaining the views and advice of State regulatory agencies in connection with the Atomic Energy Commission's regulatory activities in the field of public health and safety. 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, Washington State Department of Public Health, Olympia, Wash.
Dr. R. L. CLEERE, Director of Public Health, Colorado 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.
C. W. KLASSEN, Chief Sanitary Engineer, Illinois Department of Public Health, Springfield, Ill.
Dr. MORRIS KLEINFELD, Director, Division of Industrial Hygiene, New York, State 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.
Dr. JAMES E. PEAVY, Commissioner of Health, Texas 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, New York State Office of Atomic and Space Development, New York, N.Y.

The Committee did not meet in 1967.

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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, Chairman; Director, Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C.
CARROLL G. BOWEN, Director, the M.I.T. Press, Massachusetts Institute of Technology, Cambridge, Mass.
JOHN E. DOBBIN, Project Director, Educational Testing Service, Princeton, N.J.
JAMES L. GAYLORD, Senior Partner of James L. Gaylord Associates, Pacific Palisades, Calif.
Dr. ALLEN G. GRAY, Editor, "Metals Progress," American Society for Metals, Metals Park, Ohio.
FRED P. PETERS, Executive Vice President, Reinhold Publishing Corp., 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, New York State Atomic and Space Development Authority, New York, N.Y.
JOHN W. WRIGHT, Vice President for Marketing, McGraw-Hill Book Co., Inc., New York, N.Y.

The committee did not meet in 1967.

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.

EDMARD J. BRUENKANT, Chairman; Director, Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C.
BREWER F. BOARDMAN, Director, Technical Information, Idaho Nuclear Corp., Idaho Falls, Idaho.
CLARENCE T. BROCKETT, Head, Technical Informaton Department, Lawrence Radiation Laboratory, Livermore, Calif.
JOHN E. DAVIS, Senior Administrative Assistant, Department of Materials Engineering, Battelle Memorial Institute, Columbus, Ohio.
W. E. DREESZEN, Head, Information and Security, Ames Laboratory, Ames, Iowa.
DOROTHY M. DUKE, Technical Librarian, Atomic Energy Division, the Babcock & Wilcox Co., Lynchburg, Va.
DOUGLAS DUPEN, Technical Information Department, Stanford Linear Accelerator Center, Stanford University, Palo Alto, Calif.
W. L. HARWELL, Senior Legal Advisor, 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 of Information, 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., West Mifflin, 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.
A. D. PEPMUELLER, Manager, Technical Information Department, Sandia Corp., Livermore, Calif.
DENNIS PULESTON, Head, Information Division, Brookhaven National Laboratory, Upton, N.Y.
HELEN F. REDMAN, Librarian, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
FRANK D. SHEARIN, Technical Editor, Monsanto Research Corp., Mound Laboratory, Miamisburg, Ohio

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C. G. STEVENSON, Technical Information Section Manager, Pacific Northwest Laboratory, Richland, Wash.

Dr. STUART STURGES, Manager, Technical Information, Knolls Atomic Power Laboratory, Schenectady, N.Y.

CHARLES D. TABOR, Assistant Manager, Technical Division, Goodyear Atomic Corp., Piketon, Ohio

JOSEPH W. VOTAW, Assistant to Technical Director, National Lead Co. of Ohio, Cincinnati, Ohio

Dr. RAYMOND K. WAKERLING, Chief, 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 twice in 1967, January 16–18 in Oak Ridge, Tenn. and October 19–20 in Washington, D.C.

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 classification rules and guides for the control of scientific and technical information.

Dr. WARREN C. JOHNSON, *Chairman;* retired Vice President for Special Scientific Programs, University of Chicago, Chicago, Ill.

Dr. EUGENE EYSTER, Alternate GMX Division Leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. FRANK C. HOYT, Consultant to Theoretical Division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

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.

ROBERT W. HENDERSON, Vice President, Sandia Corp., Albuquerque, N. Mex.

The committee met three times during 1967: February 6–7 at Berkeley, Calif., March 29 at Livermore, Calif., and December 19–21 at Albuquerque, N. Mex.

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. MARIO L. JUNCOSA, *Chairman;* The Rand Corp., Santa Monica, Calif.

Dr. BENGT G. CARLSON, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Prof. GERALD ESTRIN, Department of Engineering, University of California at Los Angeles, Calif.

Dr. SIDNEY FERNBACH, Computation Division, Lawrence Radiation Laboratory, University of California, Livermore, Calif.

Dr. J. WALLACE GIVENS, Jr., Applied Mathematics Division, Argonne National Laboratory, Argonne, Ill.

Dr. ALSTON S. HOUSEHOLDER, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. CHARLES V. L. SMITH, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.

Dr. YOSHIO SHAIMAMOTO, *Secretary;* Brookhaven National Laboratory, Upton, N.Y.

The committee met twice during 1967: on September 1 at Washington, D.C., and September 2 at Brookhaven National Laboratory.

Nuclear Cross Sections Advisory Committee

This committee 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 AEC.

Dr. HENRY T. MOTZ, *Chairman;* Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. HARRY ALTER, Atomics International, Canoga Park, Calif.

Dr. R. S. CASWELL, National Bureau of Standards, Washington, D.C.

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Dr. R. E. CHRIEN, Brookhaven National Laboratory, Upton, N.Y.
Prof. HERBERT GOLDSTEIN, Columbia University, New York, N.Y.
Dr. EUGENE HADDAD, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.
Prof. HENRY W. NEWSON, Duke University, Durham, N.C.
Prof. GERALD C. PHILLIPS, Rice University, Houston, Tex.
Prof. ERWIN F. SHRADER, Case-Western Reserve University, Cleveland, Ohio.
Dr. PAUL H. STELSON, Oak Ridge National Laboratory, Oak Ridge, Tenn.
Dr. N. F. WIKNER, Defense Atomic Support Agency, Department of Defense, Washington, D.C.
Dr. IRA F. ZARTMAN, Division of Reactor Development and Technology, U.S. Atomic Energy Commission, Washington, D.C.
Dr. MICHAEL S. MOORE, *Secretary;* Idaho Nuclear Corp., Idaho Falls, Idaho.

During 1967, the committee met on April 13–14 at Brookhaven National Laboratory, and October 17–18 at Idaho Falls, Idaho.

High Energy Physics Advisory Panel

This advisory panel was established in November 1966 pursuant to the provisions of Section 161a of the Atomic Energy Act, to review on a continuing basis, the High Energy Physics Research Program and to provide advice and recommendations to the Division of Research with respect to this program.

Prof. VICTOR F. WEISSKOPF, *Chairman;* Massachusetts Institute of Technology, Cambridge, Mass.
Dr. RODNEY L. COOL, Brookhaven National Laboratory, Upton, N.Y.
Prof. EARLE C. FOWLER, Duke University, Durham, N.C.
Prof. LEON LEDERMAN, Nevis Laboratories, Columbia University, Irvington, N.Y.
Dr. EDWARD J. LOFGREN, Lawrence Radiation Laboratory, Berkeley, Calif.
Dr. GEORGE E. PAKE, Washington University, St. Louis, Mo.
Prof. W. K. H. PANOFSKY, Stanford Linear Accelerator Center, Stanford University, Stanford, Calif.
Prof. ROBERT G. SACHS, Argonne National Laboratory, Argonne, Ill.
Prof. KEITH R. SYMON, University of Wisconsin, Madison, Wis.
Prof. ROBERT L. WALKER, California Institute of Technology, Pasadena, Calif.
Prof. ROBERT R. WILSON, National Accelerator Laboratory, Oak Brook, Ill.
Prof. C. N. YANG, State University of New York, Stony Brook, N.Y.
Dr. BERNARD HILDEBRAND, *Executive Secretary;* Division of Research, U.S. Atomic Energy Commission, Washington, D.C.

The committee met seven times during 1967: January 29, February 10, and March 23–24 at Cambridge, Mass.; May 28–29 at Lawrence Radiation Laboratory, Berkeley, Calif.; September 15–16 at Washington, D.C.; October 26 at Oak Brook, Ill.; and December 8–9 at Argonne National Laboratory, Argonne, Ill.

Standing Committee for Controlled Thermonuclear Research

The Commission established on June 21, 1966, a Standing Committee for Controlled Thermonuclear Research. This committee reviews, on a continuing basis, the AEC's controlled thermonuclear program and provides advice and recommendations to the Division of Research and the Commission relative to the program. The committee was established to ensure closer cooperative effort within the program and to provide guidance on implementing major program decisions. The committee has four members who are directors of the controlled thermonuclear research in their respective laboratories, and four members from the scientific community outside of the AEC and its major laboratories.

Dr. AMASA S. BISHOP, *Chairman;* Assistant Director for Controlled Thermonuclear Research, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.
Dr. LEWIS M. BRANSCOMB, Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder, Colo.
Dr. SOLOMON J. BUCHSBAUM, Bell Telephone Laboratories, Holmdell, N.J.
Dr. WILLIAM A. FOWLER, California Institute of Technology, Pasadena, Calif.
Dr. MELVIN B. GOTTLIEB, Princeton Plasma Physics Laboratory, Princeton, N.J.
Dr. ARTHUR H. SNELL, Oak Ridge National Laboratory, Oak Ridge, Tenn.
Dr. RICHARD F. TASCHEK, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. CHESTER VAN ATTA, Lawrence Radiation Laboratory, Livermore, Calif.

Dr. HAROLD
Calif.

The committee met fi
and September 7–8 at
tory, Livermore, Calif.

Personnel Security Revi

This board was app
cases which arise un
recommendations con
Commission on the b
for determining eligib

JOHN J. WILSON,
LOUIS A. TURNER,
VACANCY

The board reviewed
during 1967.

DR. HAROLD W. LEWIS, University of California at Santa Barbara, Santa Barbara, Calif.

The committee met five times during 1967: February 3–4 at Oak Ridge, Tenn.; April 28–29 and September 7–8 at Washington, D.C.; October 30–31 at the Lawrence Radiation Laboratory, Livermore, Calif., and December 14–15 at Princeton, N.J.

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. This 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.

JOHN J. WILSON, *Chairman*, Washington, D.C.
LOUIS A. TURNER, Princeton, N.J.
VACANCY

The board reviewed and made a recommendation to the General Manager on one case during 1967.

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APPENDIX 3

MAJOR AEC-OWNED, CONTRACTOR-OPERATED INSTALLATIONS*

AMES LABORATORY (Iowa State University of Science and Technology, contractor), Ames, Iowa

Director	Dr. FRANK H. SPEDDING
Deputy Director	Dr. MORTON SMUTZ
Assistant Director	Dr. ADOLPH F. VOIGT

ARGONNE NATIONAL LABORATORY (University of Chicago and Argonne Universities Association, contractors), Argonne, Ill.

Director	Dr. ROBERT B. DUFFIELD
Associate Director	Dr. WINSTON M. MANNING
Associate Director	Dr. STEPHEN LAWROSKI
Associate Director	Dr. ROBERT G. SACHS
Assistant Director	Dr. RICHARD M. ADAMS

University of Chicago

President	Dr. GEORGE W. BEADLE
Vice President, Special Projects	W. B. HARRELL

Argonne Universities Association

Chairman, Board of Trustees	Dr. HOWARD BOWEN
President	Dr. PHILIP N. POWERS

The participating institutions in the Argonne Universities Association are:

Carnegie-Mellon University	University of Arizona
Case-Western Reserve University	University of Chicago
Illinois Institute of Technology	University of Cincinnati
Indiana University	University of Illinois
Iowa State University	University of Iowa
Kansas State University	University of Kansas
Loyola University	University of Michigan
Marquette University	University of Minnesota
Michigan State University	University of Missouri
Northwestern University	University of Notre Dame
Ohio State University	University of Wisconsin
Purdue University	Washington University (St. Louis)
St. Louis University	Wayne State University

BETTIS ATOMIC POWER LABORATORY (Westinghouse Electric Corp., contractor), Pittsburgh, Pa.

General Manager	N. A. BELDECOS
Manager, Operations	A. P. ZECHELLA
Controller	W. C. BULETTE, Jr.

BROOKHAVEN NATIONAL LABORATORY (Associated Universities, Inc., contractor), Upton, N.Y.

Laboratory Director	Dr. MAURICE GOLDHABER
Deputy Director	Dr. GEORGE VINEYARD
Associate Director	Dr. VICTOR P. BOND
Associate Director	Dr. RODNEY L. COOL

Associated Universities, Inc.

Chairman, Board of Trustees	Dr. ERNEST F. JOHNSON
President	Dr. T. KEITH GLENNAN

*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—1967."

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The participating institutions in Associated Universities, Inc., are:

Columbia University	Princeton University
Cornell University	University of Pennsylvania
Harvard University	University of Rochester
The Johns Hopkins University	Yale University
Massachusetts Institute of Technology	

BURLINGTON AEC PLANT (Mason & Hanger-Silas Mason Co., Inc., contractor), Burlington, Iowa

Contract Manager (Vice President)	R. B. JEWELL
Plant Manager	D. E. HEFFELBOWER
Administration & Services Division Manager	R. S. RAMSEY
Engineering Division Manager	C. R. POOLE
Manufacturing, Division A Manager	F. J. BRODSKY
Manufacturing, Division B Manager	P. D. HOLLIDAY

CAMBRIDGE ELECTRON ACCELERATOR (Massachusetts Institute of Technology and Harvard University, contractors), Cambridge, Mass.

Director	Dr. CARL STRAUCH
Assistant Director	ROBERT E. CUMMINGS
Assistant Director	Dr. THOMAS L. COLLINS
Assistant Director	Dr. GUSTAV A. VOSS
Business Manager	WILLIAM B. BALCH

FEED MATERIALS PRODUCTION CENTER (National Lead Co. of Ohio, contractor), Fernald, Ohio

Vice President	A. STEWART, Jr.
Manager	JAMES H. NOYES
Assistant Manager	M. S. NELSON

HANFORD FACILITIES (six contractors—Atlantic Richfield, Battelle-Northwest, Computer Sciences Corp., Douglas United Nuclear, Hanford Environmental Health Foundation, ITT Federal Support Services), Richland, Wash.

Atlantic Richfield Hanford Co., Richland, Wash.

President	L. M. RICHARDS
Vice President, Operations	R. P. CORLEW
Vice President, Business Management	J. M. SCHULTZ

Computer Sciences Corp., Northwest Operations, Richland, Wash.

Director	C. D. THIMSEN
Executive Assistant	Z. E. CAREY
Manager, Finance and Administration	J. W. HALVERSON

Douglas United Nuclear, Inc., Richland, Wash.

President and General Manager	C. D. HARRINGTON
Vice President and Deputy Gen. Manager	RAYMON W. HALLET, Jr.
Vice President and Asst. Gen. Manager for Operation Division	O. C. SCHROEDER
Vice President and Asst. Gen. Manager for Technical Division	C. W. KUHLMAN
Vice President and Asst. Gen. Manager for Finance and Administration Division	S. KOEPCKE

Hanford Environmental Health Foundation, Richland, Wash.

Medical Director	P. A. FUQUA, M.D.
Asst. Medical Director	G. H. CROOK, M.D.
Manager, Finance and Contract Administration	A. R. ADELINE
Manager, Environment Sciences Department	FRANK ADLEY

ITT Federal Support Services, Richland, Wash.

Executive Vice President and General Manager	T. P. LEDDY
Manager, Purchasing and Stores	W. M. HUNT
Manager, Transportation and Maintenance	M. F. RICE
Manager, Plant Protection, Services, and Utilities	C. W. WEEKS

Pacific Northwest Laboratory (Battelle-Northwest Division of Battelle Memorial Institute, Columbus, Ohio, contractor), Richland, Wash.

Director	Dr. F. W. ALBAUGH

Deputy Director	Dr. R. S. PAUL
Staff Manager, Finance Dept.	W. SALE
Staff Manager, Legal Dept. (includes contracts)	P. T. SANTILLI

United States Testing Co., Inc., Richland, Wash.

General Manager	D. B. WILCOX
Manager, Dosimetry Services	R. L. PIERCE
Manager, Radiochemistry	D. P. ARGYLE
Manager, Engineering Services	N. W. HAAGENSON

ANSAS CITY PLANT (The Bendix Corp., Kansas City Division, contractor), Kansas City, Mo.

eneral Manager	R. J. QUIRK
istant General Manager	V. L. RITTER
rector, Manufacturing	F. J. TAYLOR
rector, Engineering	D. J. NIGG

OLLS ATOMIC POWER LABORATORY (General Electric Co., contractor), Schenectady, N.Y.

neral Manager	K. A. KESSELRING
nager, S5G Project	H. E. STONE
nager, A1G Project	C. S. HOFMANN
nager, NR–1 Project	A. W. BEDFORD

O. LAWRENCE RADIATION LABORATORY (University of California, contractor), Berkeley and Livermore, Calif.

rector	Dr. EDWIN M. MCMILLAN
rector, Livermore Laboratory	Dr. MICHAEL M. MAY
siness Manager	RICHARD P. CONNELL
puty Business Manager	WILLIAM B. HARFORD

ociate Directors, Berkeley:

uner Laboratory of Medical Physics, Director	Dr. JOHN H. LAWRENCE
rganic Materials Research Division	Dr. LEO BREWER
boratory of Chemical Biodynamics, Director	Dr. MELVIN CALVIN
clear Chemistry Division	Dr. ISADORE PERLMAN
ysics Division	Dr. DAVID L. JUDD
ogram and Planning	Dr. ROBERT L. THORNTON
ministration	Dr. HAROLD A. FIDLER
pport	Dr. ELMER L. KELLY

ociate Directors, Livermore:

anced Studies	Dr. ARTHUR T. BIEHL
medical Research	Dr. JOHN W. GOFMAN
emistry and Space Reactors	Dr. ROGER E. BATZEL
itary Applications	A. CARL HAUSSMANN
clear Design	Dr. JACK ROSENGREN
clear Testing	Dr. HARRY L. REYNOLDS
ysics	Dr. EDWARD TELLER
owshare	Dr. GLENN C. WERTH
erwood	Dr. CHESTER M. VAN ATTA
pport	DUANE C. SEWELL

S ALAMOS SCIENTIFIC LABORATORY (University of California, contractor), Los Alamos, N. Mex.

rector	Dr. NORRIS E. BRADBURY
chnical Associate Director	Dr. RAEMER E. SCHREIBER
sistant Director	Dr. JANE H. HALL
sistant Director, Production	Dr. MAX F. ROY
sistant Director, Classification and Security	PHILLIP F. BELCHER
sistant Director, Financial Planning	LESLIE G. HAWKINS
sistant Director, Administration	HENRY R. HOYT

OUND LABORATORY (Monsanto Research Corp., contractor), Miamisburg, Ohio

oject Director (President, Monsanto Research Corp.)	H. K. NASON
ant Manager (Vice President, Monsanto Research Corp.)	DAVID L. SCOTT
rector, Nuclear Operations	G. RICHARD GROVE
rector, Explosives Operations	J. E. BRADLEY

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NATIONAL REACTOR TESTING STATION (NRTS) (five contractors—Argonne National Laboratory, General Electric, Idaho Nuclear, Phillips, and Westinghouse), Idaho Falls, Idaho

Argonne National Laboratory (the University of Chicago and Argonne Universities Assn., contractors), the Idaho Division, Idaho Falls

Director	M. NOVICK
Associate Director	F. W. THALGOTT

General Electric Co. (Idaho Test Station, Nuclear Materials and Propulsion Operation, Atomic Products Division), Idaho Falls

Manager	Dr. J. W. MORFITT

General Electric Co. (Knolls Atomic Power Laboratory, S5G Test Plant Site), Idaho Falls

Manager	E. R. SCHOCH

Idaho Nuclear Corp., Idaho Falls (jointly owned subsidiary of Aerojet General Corp. and Allied Chemical Corp.)

President and Manager	Dr. J. B. PHILIPSON
Vice President and Deputy Manager	F. H. ANDERSON
Manager, Operations Division	F. H. ANDERSON (acting)
Manager, Nuclear and Chemical Technology Div	D. R. DEBOISBLANC
Manager, Engineering Div	L. J. WEBER
Manager, Administration Div	R. TRIPP

Phillips Petroleum Co., Atomic Energy Division, Idaho Falls

Manager	J. P. LYON
Assistant Manager, Technical Division	S. G. FORBES
Assistant Manager, Administration	L. L. LEEDY

Westinghouse Electric Corp., Idaho Falls

Manager, Naval Reactors Facility	R. C. MAIRSON

NEVADA TEST SITE (Reynolds Electrical & Engineering Co., contractor), Mercury, Nev.

General Manager	J. R. CROCKETT
Deputy General Manager	R. W. KIEHN
Administration Division	R. E. GILLETT
Program Control Division	W. A. STEVENS
Operations Division	R. D. CUNNINGHAM
Site Facilities Division	R. A. SMITH

NUCLEAR ROCKET DEVELOPMENT STATION (Los Alamos Scientific Laboratory, Pan American World Airways, Inc., Westinghouse Electric Corp., contractors), Jackass Flats, Nev.

OAK RIDGE RESEARCH AND DEVELOPMENT AND PRODUCTION FACILITIES (Union Carbide Corp., Nuclear Division, contractor), Oak Ridge, Tenn., and Paducah, Ky.

President, Union Carbide Corp., Nuclear Division	Dr. C. E. LARSON

Oak Ridge Production Facilities

Vice President—Production, Union Carbide Corp., Nuclear Division	R. F. HIBBS*
Superintendent, Y–12 Plant	R. F. HIBBS*
Deputy Superintendent, Y–12 Plant	J. M. CASE
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 Corp., Nuclear Division)	Dr. ALVIN M. WEINBERG
Deputy Director	Dr. H. G. MACPHERSON

PANTEX PLANT (Mason & Hanger-Silas Mason Co., contractor), Amarillo, Tex.

Contract Manager (Vice President)	R. B. JEWELL
Plant Manager	JOHN C. DRUMMOND
Division Manager, Engineering	MARION L. OTT
Division Manager, Manufacturing	ROBERT B. CARROLL

*Dual capacity.

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PRINCETON-PENNSYLVANIA ACCELERATOR (Princeton University and University of Pennsylvania, contractors), James Forrestal Research Center, Princeton, N.J.

Director	Dr. MILTON G. WHITE
Assistant Director	Dr. AARON LEMONICK
Assistant Director	Dr. ALFRED K. MANN

PRINCETON PLASMA PHYSICS LABORATORY (Princeton University, contractor), James Forrestal Research Center, Princeton, N.J.

Director	Dr. MELVIN B. GOTTLIEB
Associate Director	Dr. EDWARD A. FRIEMAN
Assistant Director	Dr. E. C. TANNER
Head, Experimental Division	Dr. TOM STIX
Head, Engineering and Development Division	Dr. ROBERT MILLS
Head, Theoretical Division	Dr. J. M. DAWSON
Head, Administrative Division	ROBERT VON VERDO

PORTSMOUTH GASEOUS DIFFUSION PLANT (Goodyear Atomic Corp., contractor), Piketon, Ohio

General Manager	C. H. REYNOLDS
Deputy General Manager	CHARLES TABOR

ROCKY FLATS PLANT (Dow Chemical Co., contractor), Rocky Flats, Colo.

General Manager	Dr. LLOYD M. JOSHEL
Facilities Manager	DOYLE M. BASSLER
Quality Manager	HERBERT E. BOWMAN
Manufacturing Manager	JOHN G. EPP
Industrial Relations Manager	CHARLES M. LOVE
Director of Research and Development	Dr. LORNE A. MATHESON
Division Services Manager	EDWARD J. WALKO
Albuquerque Plant Manager	WILLIAM H. LEE

SANDIA LABORATORY (Sandia Corp., contractor), facilities at Sandia Base, Albuquerque, N. Mex.; Livermore, Calif.; and Tonopah, Nev.

President	J. A. HORNBECK
Vice President	W. J. HOWARD
Vice President	R. W. HENDERSON
Vice President	R. B. POWELL
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Vice President	G. A. FOWLER

SAVANNAH RIVER LABORATORY (E. I. du Pont de Nemours & Co., contractor), Aiken, S.C.

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Assistant Director	C. H. ICE
Section Director—Physics Section	G. DESSAUER
Section Director—Nuclear Engineering and Materials Section	J. W. MORRIS
Section Director—Separations Chemistry and Engineering Section	L. H. MEYER

SAVANNAH RIVER PLANT (E. I. du Pont de Nemours & Co., contractor), Aiken, S.C.

Plant Manager	J. A. MONIER, Jr.
Assistant Plant Manager	K. W. FRENCH
General Superintendent, Works Technical Dept	W. P. BEBBINGTON
General Superintendent, Production	J. K. LOWER

STANFORD LINEAR ACCELERATOR CENTER (Stanford University, contractor), Palo Alto, Calif.

Director	WOLFGANG K. H. PANOFSKY
Deputy Director	MATTHEW L. SANDS
Associate Director, Technical Division	RICHARD B. NEAL
Associate Director, Research Division	JOSEPH BALLAM
Associate Director, Business Services Division	FREDERICK V. L. PINDAR
Associate Director, Administrative Services Division	ROBERT H. MOULTON, Jr.

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APPENDIX 4

ANNOUNCED DEFENSE-RELATED UNDERGROUND NUCLEAR DETONATIONS, 1967 [1]

Name	*Date*	*Yield* [2]
Latchkey Series (January–June 1967)		
Nash	January 19	Low Intermediate
Bourbon	January 20	Low Intermediate
Ward	February 8	Low
Persimmon	February 23	Low
Agile	February 23	Low Intermediate
Rivet	March 2	Low
Fawn	April 7	Low
Chocolate	April 21	Low
Effendi	April 27	Low
Mickey	May 10	Low Intermediate
Commodore	May 20	Intermediate
Scotch [3]	May 23	Intermediate
Knickerbocker [3]	May 26	Low Intermediate
Midi Mist [4]	June 26	Low
Umber	June 29	Low
Crosstie Series (July–December 1967)		
Stanley	July 27	Low Intermediate
Washer	August 10	Low
Bordeaux	August 18	Low
Door Mist [4]	August 31	Low
Yard	September 7	Low Intermediate
Zaza	September 27	Low Intermediate
Lanpher	October 18	Intermediate
Sazerac	October 25	Low
Cobbler	November 8	Low
Stilt	December 15	Low

[1] Plowshare (peaceful uses) program detonations are not included here (see Chapter 11).

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

[3] Conducted in the Pahute Mesa area of the NTS.

[4] Department of Defense event conducted with AEC laboratory assistance.

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APPENDIX 5
U.S. CENTRAL STATION NUCLEAR POWER
Table 1.—PLANTS OPERABLE

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Authorized or licensed for: (a) Construction (b) Provisional operation (c) Full-term license	Operational milestones: (a) Initial criticality (b) First electricity (c) Design power attained	1967 highlights
CALIFORNIA				
Humboldt Bay Power Plant, Unit 3 (Pacific Gas & Electric Co.), Eureka, Calif.	(a) 69 (b) BWR (c) GE (d) 2/58	(a) 11/60 (b) 8/62 (c)	(a) 2/63 (b) 4/63 (c) 5/63	Power generation was limited by licensee to control the reactor's off-gas release rate. Attained 90% of design power in Nov. following partial refueling.
San Onofre Nuclear Generating Station [3] (Southern California Edison and San Diego Gas & Electric Co.), San Clemente, Calif.	(a) 430 (b) PWR (c) West. (d) 2/63	(a) 3/64 (b) 3/67 (c)	(a) 6/67 (b) 7/67 (c)	Step-by-step increases to full power delayed by troubles with non-nuclear components, 405-Mwe. level reached in Oct., 250-hour demonstration run at 405-Mwe. began in Nov. after scheduled 10-day shutdown and completed Dec. 26.
CONNECTICUT				
Connecticut Yankee Atomic Power Plant [3] (Connecticut Yankee Atomic Power Co.), Haddam Neck, Conn.	(a) 462 (b) PWR (c) West. (d) 12/62	(a) 5/64 (b) 6/67 (c)	(a) 7/67 (b) 8/67 (c) 12/67	Test program at 125-Mwe. level completed in Oct.; 400-Mwe. level attained mid-Nov.; 485-Mwe. (gross) power reached in Dec. after brief maintenance and testing shutdown.
ILLINOIS				
Dresden Nuclear Power Station, Unit 1 (Commonwealth Edison Co.), Morris, Ill.	(a) 200 (b) BWR (c) GE (d) 7/55	(a) 5/56 (b) 9/59 (c) 10/60	(a) 10/59 (b) 4/60 (c) 6/60	After partial core refueling, resumed full power in June. Shutdown for maintenance and hydrostatic tests in Oct. was extended for repairs to 6-inch bypass line; operation resumed Nov. 6.

See footnotes at end of tables.

U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 1.—PLANTS OPERABLE—Continued

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Authorized or licensed for: (a) Construction (b) Provisional operation (c) Full-term license	Operational milestones: (a) Initial criticality (b) First electricity (c) Design power attained	1967 highlights
MASSACHUSETTS				
Yankee Nuclear Power Station [3] (Yankee Atomic Electric Co.), Rowe, Mass.	(a) 175 (b) PWR (c) West. (d) 6/56	(a) 11/57 (b) 7/60 (c) 6/61	(a) 8/60 (b) 11/60 (c) 1/61	Full-power operation continued until Nov. 15, when available reactivity became insufficient for full power. At end of year, power level was down to 160 Mwe. (gross); refueling is scheduled for March 1968.
MICHIGAN				
Enrico Fermi Atomic Plant [3] (Power Reactor Development Co.), Lagoona Beach, Mich.	(a) 61 (b) FBR (c) PRDC (d) 3/57	(a) 8/56 (b) 5/63 (c)	(a) 8/63 (b) 8/66 (c)	Remained shut down during 1967 to determine cause of fuel failure. Unidentified object large enough to block sodium flow to several fuel subassemblies found; efforts started to remove it.
Big Rock Point Nuclear Power Plant [3] (Consumers Power Co.), Big Rock Point, Mich.	(a) 70 (b) BWR (c) GE (d) 12/59	(a) 5/60 (b) 8/62 (c) 5/64	(a) 9/62 (b) 12/62 (c) 3/63	Full power operation resumed June 30, following refueling and satisfactory core internal inspection outage that began on May 19.
MINNESOTA				
Elk River Reactor [3] (AEC and Rural Coop. Power Assoc.), Elk River, Minn.	(a) 22 (b) BWR (c) A-C (d) 6/58	(a) 1/60 (b) 11/62 (c) 6/65	(a) 11/62 (b) 8/63 (c) 2/64	Reactor shut down April 28 for refueling, scheduled maintenance, and minor modifications; full power operations resumed July 1.
NEW YORK				
Indian Point Station, Unit 1 (Consolidated Edison Co. of New York, Inc.), Indian Point, N.Y.	(a) 265 (b) PWR (c) B&W (d) 2/55	(a) 5/56 (b) 3/62 (c)	(a) 8/62 (b) 9/62 (c) 1/63	Full power operation on Core B satisfactory through Sept. First refueling of Core B done in Oct.-Nov. Full power operation resumed Dec. 13.

NEW YORK				
Indian Point Station, Unit 1 (Consolidated Edison Co. of New York, Inc.), Indian Point, N.Y.	(a) 265 (b) PWR (c) B&W (d) 2/55	(a) 5/56 (b) 3/62 (c)	(a) 8/62 (b) 9/62 (c) 1/63	Full power operation on Core B satisfactory through Sept. First refueling of Core B done in Oct.-Nov. Full power operation resumed Dec. 13.
OHIO				
Piqua Nuclear Power Facility [3] (AEC and City of Piqua), Piqua, Ohio	(a) 11 (b) OMR (c) AI (d) 6/59	(a) 1/60 (b) 8/62 (c) 8/64	(a) 6/63 (b) 11/63 (c) 1/64	Plant inoperative during 1967 to remove cokelike fouling materials from internals of the reactor system. AEC announced termination of operating contract on Dec. 13.
PENNSYLVANIA				
Shippingport Atomic Power Station (AEC and Duquesne Light Co.), Shippingport, Pa.	(a) 90 (b) PWR (c) West. (d) 7/53	(a) (4) (b) (4) (c) (4)	(a) 12/57 (b) 12/57 (c) 12/57	Reactor continued to operate satisfactorily on second core which had been installed April 30, 1965.
Peach Bottom Atomic Power Station, Unit 1 [3] (Philadelphia Electric Co.), Peach Bottom, Pa.	(a) 40 (b) HTGR (c) GA (d) 11/58	(a) 2/62 (b) 1/66 (c)	(a) 3/66 (b) 1/67 (c) 5/67	Full-power operation authorized Jan. 12; ascension delayed by construction-type fire and cooling system modification; licensed power level reached May 25.
PUERTO RICO (Territory of)				
Boiling Nuclear Superheat Power Station [3] (AEC and Puerto Rico Water Resources Authority), Punta Higuera, P.R.	(a) 17 (b) BWR (c) Comb. Eng. (d) 1/60	(a) 7/60 (b) 4/64 (c) 7/66	(a) 4/64 (b) 8/64 (c) 9/65	Shut down July 24 for inspection of turbine shafts. Resumed operation in Aug., then shut down to investigate core flow reduction; crud formation found in fuel flow channels. At year's end, plant was still shut down for investigation of problems.
SOUTH CAROLINA				
(See footnote 5.)				

See footnotes at end of tables.

U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 1.—PLANTS OPERABLE—Continued

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Authorized or licensed for: (a) Construction (b) Provisional operation (c) Full-term license	Operational milestones: (a) Initial criticality (b) First electricity (c) Design power attained	1967 highlights
SOUTH DAKOTA				
Pathfinder Atomic Power Plant [3] (Northern States Power Co.), Sioux Falls, S. Dak.	(a) 59 (b) BWR (c) A-C (d) 5/57	(a) 5/60 (b) 3/64 (c)	(a) 3/64 (b) 7/66 (c) 9/67	Minor operating difficulties interrupted ascension to full power. Achieved full licensed power on Sept. 12. At year's end, plant had been shut down since Oct. when it was found that vanes in the steam separator discharge nozzles had broken.
WASHINGTON				
"N" Reactor (Steam take-off for power) [6] (Washington Public Power Supply System), Hanford Works, Wash.	(a) 800 (b) Graphite (c) GE	(a) NA (b) NA (c) NA	(a) 12/63 (b) 4/66 (c) 12/66	Power generation held to 400 Mwe. during replacement of transmission system transformers; WPPSS generation plant returned to 800 Mwe. output in May.
WISCONSIN				
LaCrosse Boiling Water Reactor [3] (AEC and Dairyland Power Cooperative), Genoa, Wis.	(a) 50 (b) BWR (c) A-C (d) 6/62	(a) 3/63 (b) 7/67 (c)	(a) 7/67 (b) 12/67 (c)	Nov. license amendment permitted operation above 1 Mwt. At year's end, plant had been operated at power levels up to 12.5-Mwt. Completion of start up tests and warranty run scheduled for March 1968.

U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 2.—PLANTS UNDER CONSTRUCTION

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Construction: (a) Application received (b) Permit issued	Projected date of operation	End of 1967 status

Table 2.—PLANTS UNDER CONSTRUCTION

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Construction: (a) Application received (b) Permit issued	Projected date of operation	End of 1967 status
ALABAMA				
Browns Ferry Nuclear Power Plant, Unit 1 (Tennessee Valley Authority), Decatur, Ala.	(a) 1,065 (b) BWR (c) GE (d) 6/66	(a) 7/66 (b) 5/67	1970	Provisional construction permit issued after public hearing April 25-26 by ASLB [7] and its May 9 initial decision. Construction was 10% complete as of Nov. 15.
Browns Ferry Nuclear Power Plant, Unit 2 (Tennessee Valley Authority), Decatur, Ala.	(a) 1,065 (b) BWR (c) GE (d) 6/66	(a) 7/66 (b) 5/67	1971	(Same as above.) Construction 5% complete as of Nov. 15.
CONNECTICUT				
Millstone Nuclear Power Station, Unit 1 (Conn. Light & Power Co., Hartford Electric Light Co., and Western Mass. Electric Co.), Waterford, Conn.	(a) 549 (b) BWR (c) GE (d) 9/65	(a) 11/65 (b) 5/66	1969	Construction was 37% complete as of Nov. 1.
FLORIDA				
Turkey Point, Unit 3 (Florida Power & Light Co.), Turkey Point, Fla.	(a) 652 (b) PWR (c) West. (d) 11/65	(a) 3/66 (b) 4/67	1970	Provisional construction permit issued after ASLB public hearing Feb 28–March 3 and its April 26 initial decision. Construction was 7% complete as of Nov. 1.
Turkey Point, Unit 4 (Florida Power & Light Co.), Turkey Point, Fla.	(a) 652 (b) PWR (c) West. (d) 4/67	(a) 3/66 (b) 4/67	1971	(Same as Turkey Point, Unit 3.) Construction was 3% complete as of Nov. 1.

See footnotes at end of tables.

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U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 2.—PLANTS UNDER CONSTRUCTION—Continued

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Construction: (a) Application received (b) Permit issued	Projected date of operation	End of 1967 status
ILLINOIS				
Dresden Nuclear Power Station, Unit 2 (Commonwealth Edison Co.), Morris, Ill.	(a) 809 (b) BWR (c) GE (d) 2/65	(a) 4/65 (b) 1/66	1969	On Nov. 17, licensee requested provisional license for operation of Units 2 and 3 at ultimate 809-Mwe. design power level (previously planned for 715 Mwe.) and appropriate construction permit amendment. Construction was 59% complete as of Nov. 15.
Dresden Nuclear Power Station, Unit 3 (Commonwealth Edison Co.), Morris, Ill.	(a) 809 (b) BWR (c) GE (d) 1/66	(a) 2/66 (b) 10/66	1970	(Same as above.) Construction was 39% complete as of Nov. 15.
Quad-Cities Station, Unit 1 (Commonwealth Edison Co. and Iowa-Illinois Gas & Electric Co.), Cordova, Ill.	(a) 715 (b) BWR (c) GE (d) 4/66	(a) 5/66 (b) 2/67	1970	Provisional construction permit issued following ASLB [7] public hearing Jan. 24 and Feb. 14 initial decision. Construction was 20% complete as of Nov. 1.
Quad-Cities Station, Unit 2 (Commonwealth Edison Co. and Iowa-Illinois Gas & Electric Co.), Cordova, Ill.	(a) 715 (b) BWR (c) GE (d) 7/66	(a) 8/66 (b) 2/67	1971	(Same as above.) Construction was 10% complete as of Nov. 1.
MICHIGAN				
Palisades Nuclear Power Station (Consumers Power Co. of Michigan), Palisades Park, Mich.	(a) 700 (b) PWR (c) Comb. Eng. (d) 1/66	(a) 6/66 (b) 3/67	1970	Provisional construction permit issued following ASLB [7] public hearing Feb. 23-24 and its March 13, initial decision. Construction was 20% complete as of Nov. 1.
MINNESOTA				
Monticello Nuclear Generating Plant (Northern States Power Co.), Monticello, Minn.	(a) 472 (b) BWR (c) GE (d) 4/66	(a) 8/66 (b) 6/67	1970	Provisional construction permit issued after ASLB public hearing held May 25-26 and its June 19 initial decision. Field fabrication of pressure vessel began in Nov. Construction was 16% complete as of Nov. 1
NEW JERSEY				

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MINNESOTA				
Monticello Nuclear Generating Plant (Northern States Power Co.), Monticello, Minn.	(a) 472 (b) BWR (c) GE (d) 4/66	(a) 8/66 (b) 6/67	1970	Provisional construction permit issued after ASLB public hearing held May 25-26 and its June 19 initial decision. Field fabrication of pressure vessel began in Nov. Construction was 16% complete as of Nov. 1.
NEW JERSEY				
Oyster Creek Nuclear Power Plant, Unit 1 (Jersey Central Power & Light Co.), Toms River, N.J.	(a) 515 (b) BWR (c) GE (d) 12/63	(a) 3/64 (b) 12/64	1968	Application for provisional operating license received Jan. 25. In Oct. and Nov. cracks were found in control rod stub tubes and flaws in field welding of control rod guide tubes to stub tubes. Investigations of cause underway.
NEW YORK				
Nine Mile Point Nuclear Station (Niagara Mohawk Power Corp.), Scriba, N.Y.	(a) 500 (b) BWR (c) GE (d) 10/63	(a) 4/64 (b) 4/65	1968	Utility applied for provisional operating license June 1. At applicant's request, latest construction completion date was extended to Aug. 1, 1968 (originally Dec. 1, 1967) because of delays caused by shortage of construction workers and other factors. Construction was 65% complete as of Nov. 1.
Robert Emmett Ginna Nuclear Power Plant (formerly called "Brookwood"), (Rochester Gas & Electric Co.), Ontario, N.Y.	(a) 420 (b) PWR (c) West. (d) 8/65	(a) 11/65 (b) 4/66	1969	Construction was 40% complete as of Nov. 1.
Indian Point Station, Unit 2 (Consolidated Edison Co. of New York), Indian Point, N.Y.	(a) 873 (b) PWR (c) West. (d) 11/65	(a) 12/65 (b) 10/66	1969	Construction was 27% complete as of Nov. 1.
SOUTH CAROLINA				
H. B. Robinson S. E. Plant, Unit 2 (Carolina Power & Light Co.), Hartsville, S.C.	(a) 663 (b) PWR (c) West. (d) 1/66	(a) 7/66 (b) 4/67	1970	Provisional construction permit issued following ASLB ' public hearing March 28 and its April 12 initial decision. Construction was 10% complete as of Nov. 15.

See footnotes at end of tables.

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U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 2.—PLANTS UNDER CONSTRUCTION—Continued

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Construction: (a) Application received (b) Permit issued	Projected date of operation	End of 1967 status
SOUTH CAROLINA—Continued				
Oconee Nuclear Station, Unit 1 (Duke Power Co.), Lake Keowee, S.C.	(a) 839 (b) PWR (c) B&W (d) 7/66	(a) 12/66 (b) 11/67	1971	Provisional construction permit issued following ASLB [7] public hearing Aug. 29-30 and Sept. 12 and its initial decision of Nov. 3. Exceptions filed to ASLB decision by intervenors; matter before Commissioners for formal review at year's end.
Oconee Nuclear Station, Unit 2 (Duke Power Co.), Lake Keowee, S.C.	(a) 839 (b) PWR (c) B&W (d) 7/66	(a) 12/66 (b) 11/67	1972	(Same as Unit 1.)
Oconee Nuclear Station, Unit 3 (Duke Power Co.), Lake Keowee, S.C.	(a) 839 (b) PWR (c) B&W (d) 5/67	(a) 4/67 (b) 11/67	1973	(Same as Unit 1.)
VERMONT				
Vermont Yankee Generating Station (Vermont Yankee Nuclear Power Corp.), Vernon, Vt.	(a) 514 (b) BWR (c) GE (d) 8/66	(a) 12/66 (b) 12/67	1970	Provisional construction permit issued Dec. 11 following ASLB [7] public hearing held Aug. 1-2 and Sept. 6-7 and initial decision of Dec. 8. Exceptions filed by municipal group; matter before Commissioners for formal review at year's end.
WISCONSIN				
Point Beach Nuclear Plant, Unit 1 (Wisconsin Michigan Power Co.), Two Creeks, Wis.	(a) 455 (b) PWR (c) West. (d) 2/66	(a) 8/66 (b) 7/67	1970	Provisional construction permit was issued after ASLB public hearing June 28-29 and its initial decision of July 18. Construction was 10% complete as of Nov. 1.

Table 3.—APPLICATIONS UNDER REVIEW

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Date application received	Projected date of operation	End of 1967 status

Table 3.—APPLICATIONS UNDER REVIEW

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Date application received	Projected date of operation	End of 1967 status
ALABAMA				
Browns Ferry Nuclear Power Plant, Unit 3 (Tennessee Valley Authority), Decatur, Ala.	(a) 1,065 (b) BWR (c) GE (d) 6/67	7/67	1972	Site is in Limestone County, on north shore of Wheeler Dam Reservoir.
ARKANSAS				
Russellville Nuclear Unit (Arkansas Power & Light Co.), Russellville, Ark.	(a) 825 (b) PWR (c) B&W (d) 4/67	11/67	1972	Site is on a peninsula in Dardanelle Reservoir on Arkansas River, Pope County, Ark. Applicant, an operating subsidiary of Middle South Utilities, Inc., plans a Sept. 1968 construction start.
CALIFORNIA				
Bolsa Island Nuclear Power & Desalting Plant (Edison-San Diego Unit SCE, SDG&EC, (MWD) [3]), Huntington Beach, Calif.	(a) 900 [3] (b) (c) (d)	9/67	1973	On 8/30, California Gov. Reagan signed the bill granting site for man-made Bolsa Island to MWD. MWD has selected Bechtel Corp. to supervise this construction.
Bolsa Island Nuclear Power & Desalting Plant, (MWD) Unit [3] LADWP, Huntington Beach, Calif.	(a) 900 [3] (b) (c) (d)	9/67	1974	(Same as above.)
Diablo Canyon (Pacific Gas & Electric Co.), Diablo Canyon, Calif.	(a) 1,060 (b) PWR (c) West. (d) 11/66	1/67	1971	Site is on coast, about 150 miles N. of Los Angeles.

See footnotes at end of tables.

U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 3.—APPLICATIONS UNDER REVIEW—Continued

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Date application received	Projected date of operation	End of 1967 status
CALIFORNIA—Continued				
Malibu Nuclear Power Plant Unit 1 (Los Angeles Dept. of Water and Power), Corral Canyon, Calif.	(a) 462 (b) PWR (c) West. (d) 1/63	11/63	1971	Not currently being reviewed; Commission remanded case to ASLB [7] March 27 for further proceedings on application amendment concerning design against permanent ground displacement by earthquakes.
Rancho Seco Nuclear Generating Station, Unit No. 1 (Sacramento Municipal Utility District), Sacramento, Calif.	(a) 800 (b) PWR (c) B&W (d) 8/67	11/67	1973	Site is in Southeast corner of Sacramento County, about 25 miles SE. of City of Sacramento.
COLORADO				
Fort St. Vrain Power Station [8] (Public Service Co. of Colorado), Platteville, Colo.	(a) 330 (b) HTGR (c) GA (d) 3/65	10/66	1971	The Weld County site is 35 miles N. of Denver near the joining of the South Platte and St. Vrain Rivers.
FLORIDA				
Crystal River Plant, Unit 3 (Florida Power Corp.), Red Level, Fla.	(a) 825 (b) PWR (c) B&W (d) 2/67	8/67	1972	Site is on Gulf of Mexico near Crystal River, 70 miles north of Tampa.
Crystal River Plant, Unit 4 (Florida Power Corp.), Red Level, Fla.	(a) 825 (b) PWR (c) B&W (d)	8/67	1974	(Same as above.)
ILLINOIS				
Zion Station, Unit 1 (Commonwealth Edison Co.), Zion, Ill.	(a) 1,050 (b) PWR (c) West. (d) 2/67	7/67	1972	Lake County site is on west shore of Lake Michigan, about 40 miles N. of Chicago.
Zion Station, Unit 2 (Commonwealth Edison Co.)	(a) 1,050	8/67	1973	

ILLINOIS				
Zion Station, Unit 1 (Commonwealth Edison Co.), Zion, Ill.	(a) 1,050 (b) PWR (c) West. (d) 2/67	7/67	1972	Lake County site is on west shore of Lake Michigan. about 40 miles N. of Chicago.
Zion Station, Unit 2 (Commonwealth Edison Co.), Zion, Ill.	(a) 1,050 (b) PWR (c) West. (d) 7/67	8/67	1973	(Same as above.)
MAINE				
Maine Yankee Atomic Power Plant (Maine Yankee Atomic Power Corp.), Wiscasset, Maine.	(a) 790 (b) PWR (c) Comb. Eng. (d) 2/67	9/67	1972	Site is on west shore of Back River in Lincoln County. Site preparation began in Oct.
MASSACHUSETTS				
Pilgrim Station (Boston Edison Co.), Plymouth, Mass.	(a) 625 (b) BWR (c) GE (d) 8/65	6/67	1971	Site is on western shore of Cape Cod Bay, about 26 miles from Boston.
MICHIGAN				
Donald C. Cook Nuclear Plant, Unit 1 (Indiana & Michigan Electric Co.) Lake Township, Mich.	(a) 1,054 (b) PWR (c) West. (d) 7/67	12/67	1972	Site is located in Lake Township, Berrien County, Mich., about 11 miles from Benton Harbor, containment design includes Westinghouse's ice condenser concept as a heat sink.
Donald C. Cook Nuclear Plant, Unit 2 (Indiana & Michigan Electric Co.) Lake Township, Mich.	(a) 1,054 (b) PWR (c) West. (d) 7/67	12/67	1973	(Same as above.)

See footnotes at end of tables.

U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 3.—APPLICATIONS UNDER REVIEW—Continued

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Date application received	Projected date of operation	End of 1967 status
MINNESOTA				
Prairie Island Nuclear Plant, Unit 1 (Northern States Power Co.), Red Wing, Minn.	(a) 550 (b) PWR (c) West. (d) 2/67	4/67	1972	Site is on west bank of Mississippi River, about 28 miles SE. of Minneapolis-St. Paul metropolitan area.
Prairie Island Nuclear Plant, Unit 2 (Northern States Power Co.), Red Wing, Minn.	(a) 550 (b) PWR (c) West. (d) 6/67	8/67	1974	(Same as above.)
NEBRASKA				
Fort Calhoun Station, Unit 1 (Omaha Public Power District), Fort Calhoun, Nebr.	(a) 457 (b) PWR (c) Comb. Eng. (d) 10/66	4/67	1971	Washington County site is on Missouri River, about 19 miles NW. of Omaha.
Cooper Nuclear Station (Consumers Public Power District), Brownville, Nebr.	(a) 778 (b) BWR (c) GE (d) 4/67	7/67	1972	Site is in Nemaha County on Missouri River's west bank.
NEW JERSEY				
Unit 1 (formerly "Burlington Nuclear Generating Station") (Public Service Electric & Gas Co., PEC, ACEC, & DP&LC [10]) (Not known).	(a) 1,050 (b) PWR (c) West. (d) 8/66	12/66	1971	(Former site was about 17 miles NE. of Philadelphia.) Public Service Electric & Gas Co. withdrew its Burlington site in Aug. and plans submittal of amended application for new site.
Unit 2 (Public Service Electric & Gas Co., PEC, ACEC, & DP&LC [10]), (Not known).	(a) 1,050 (b) PWR (c) West. (d) 5/67	10/67	1973	Application of 12/13/66 was amended to include second unit; site is not known.
NEW YORK				
Indian Point Nuclear Power Station, Unit 3 (Consolidated Edison Co. of N.Y.), Indian Point, N.Y.	(a) 965 (b) PWR (c) West.	4/67	1971	Unit 3 to be next to Unit 1 on Hudson River's east bank at Buchanan in Westchester County, 24 miles N. of New York City.

	(c) West. (d) 5/67			
NEW YORK				
Indian Point Nuclear Power Station, Unit 3 (Consolidated Edison Co. of N.Y.), Indian Point, N.Y.	(a) 965 (b) PWR (c) West. (d) 4/67	4/67	1971	Unit 3 to be next to Unit 1 on Hudson River's east bank at Buchanan in Westchester County, 24 miles N. of New York City.
Easton Nuclear Station (Niagara Mohawk Power Corp.), Easton, N.Y.	(a) 766 (b) BWR (c) GE (d) 10/66	8/67	1971	Site is on Hudson River's east side in Washington County, about 15 miles N. of Troy.
PENNSYLVANIA				
Peach Bottom Atomic Power Station, Unit 2 (Philadelphia Electric Co., PSE&GC, ACEC, and DP&LC [10]), Peach Bottom, Pa.	(a) 1,065 (b) BWR (c) GE (d) 8/66	2/67	1971	Site is in York County near the prototype HTGR Unit 1. Hearing held by ASLB [7] Dec. 7 at Delta, Pa., and its initial decision was pending at year's end.
Peach Bottom Atomic Power Station, Unit 3 (Philadelphia Electric Co., PSE&GC, ACEC, and DP&LC [10]), Peach Bottom, Pa.	(a) 1,065 (b) BWR (c) GE (d) 8/66	2/67	1973	(Same as for Unit 2.)
Three Mile Island Nuclear Station (Metropolitan Edison Co.), Goldsboro, Pa.	(a) 831 (b) PWR (c) B&W (d) 11/66	5/67	1971	Site is Susquehanna River island above York Haven Dam in Dauphin County, about 10 miles SE. of Harrisburg.
VIRGINIA				
Surry Power Station, Unit 1 (Virginia Electric & Power Co.), Hog Island, Va.	(a) 783 (b) PWR (c) West. (d) 10/66	3/67	1971	Site is seven miles S. of Williamsburg next to James River in Surry County.
Surry Power Station, Unit 2 (Virginia Electric & Power Co.), Hog Island, Va.	(a) 783 (b) PWR (c) West. (d) 10/66	3/67	1972	(Same as above.)

See footnotes at end of tables.

U.S. CENTRAL STATION NUCLEAR POWER—Continued

Table 3.—APPLICATIONS UNDER REVIEW—Continued

Plant name, owner(s), location	Reactor: (a) Net Mwe capacity (b) Type [1] (c) Builder [2] (d) Contract awarded	Date application received	Projected date of operation	End of 1967 status
WISCONSIN				
Point Beach Nuclear Plant, Unit 2 (Wisconsin Electric Power Co. and Wisconsin Michigan Power Co.), Two Creeks, Wis.	(a) 455 (b) PWR (c) West. (d) 2/67	8/67	1971	The Manitowoc County site is same as for Unit 1 with construction start planned for first of year.
Kewaunee Nuclear Power Plant, Unit 1 (Wisconsin Group (WPSC, WP&LC, MG&EC)[11]).	(a) 527 (b) PWR (c) West. (d) 2/67	8/67	1972	Kewaunee County site is on west shore of Lake Michigan about 30 miles E. of Green Bay.

Table 4.—REACTORS ON ORDER; CONSTRUCTION APPLICATION TO AEC PENDING

Project, owner(s), location	Capacity (Mwe)	Type [1]	Builder [2]	Contract awarded	Operational year
GEORGIA					
Altamaha Nuclear Power Plant (Georgia Power Co.), on Altamaha River near Baxley, Ga..	800	BWR	GE	12/67	1973
INDIANA					
Bailly Generating Station (Northern Indiana Public Service Co.), Dune Acres, near Gary, Ind.	515	BWR	GE	1/67	1974
MARYLAND					
Calvert Cliffs Nuclear Power Plant Units No. 1 and 2 (Baltimore Gas & Electric), 60 miles SE. of Baltimore, Md (2 units).	766 each	PWR	Comb. Eng.	5/67	1973 1974
(Not named) (Jersey Central Power and Light Co.), (not announced)	800	PWR	B&W	2/67	1973
NEW YORK					
Shoreham Nuclear Power Station (Long Island Lighting Co.), near Shoreham, Long Island, N.Y.	540	BWR	GE	2/67	1973
Milliken Station (New York State Electric & Gas Corp.), near Binghamton, N.Y.	829	BWR	GE	6/67	1973
PENNSYLVANIA					

(Not named) (Jersey Central Power and Light Co.), (not announced)	800	PWR	West.	12/67	1974
NEW YORK					
Shoreham Nuclear Power Station (Long Island Lighting Co.), near Shoreham, Long Island, N.Y.	540	BWR	GE	2/67	1973
Milliken Station (New York State Electric & Gas Corp.), near Binghamton, N.Y.	829	BWR	GE	6/67	1973
PENNSYLVANIA					
Shippingport Atomic Power Station No. 2 (Duquesne Light Co. and Ohio Edison Co.), Shippingport, Pa.	800	PWR	West.	9/67	1973
(Not named) (Philadelphia Electric Co.), (not announced) (2 units)	1,065 each	BWR	GE	10/67	1975, 1977
VIRGINIA					
(Not named) (Virginia Electric Power Co.), (not announced)	800	PWR	West.	10/67	1974

[1] BWR—Boiling Water Reactor; FBR—Fast Breeder-type Reactor; HTGR—High-Temperature Gas-Cooled Reactor; OMR—Organic Moderated Reactor; PWR—Pressurized Water Reactor.

[2] A-C—Allis-Chalmers Mfg. Co.; AI—Atomics International, a division of North American Rockwell Corp.; B&W—The Babcock & Wilcox Co.; Comb. Eng.—Combustion Engineering, Inc.; GA—General Atomic (formerly a division of General Dynamics Corp., now Gulf General Atomic, Inc., a subsidiary of the Gulf Oil Corp.); GE—General Electric Co.; PRDC—Power Reactor Development Co.; West.—Westinghouse Electric Corp.

[3] Project under Power Reactor Demonstration Program (PRDP) in which the AEC and industry share the costs.

[4] Not applicable for licensing; this cooperative project of the AEC and Duquesne Light Co. was initiated prior to the Power Reactor Demonstration Program. The Shippingport Station is provided with a turbogenerator rated at 90 Mwe net. Use of a heat dissipation system permits operation at 150 Mwe gross equivalent on Core 2.

[5] The 17-Mwe, prototype heavy water-moderated Carolinas-Virginia Tube Reactor (CVTR) at Parr, S.C., was shut down in January 1967. By mutual agreement between the AEC and the Carolinas-Virginia Nuclear Power Associates, it was concluded that the pressure tube research objectives of this Power Reactor Demonstration Program plant, which had been in operation since 1963 had been achieved. The contract was terminated June 30. A proposal has been made to use the plant as a safety research facility.

[6] The "N" reactor is an AEC-owned plutonium production facility which also provides steam to the adjoining Washington Public Power Supply Systems (WPPSS) 800-Mwe generating station. Steam from the 4-year-old reactor was used for initial power generation on April 8, 1966, and the full-power level was reached on December 9, 1966. One day later, the failure of a high-voltage transformer in the interconnected Bonneville Power Administration's transmission system made it necessary to reduce the electricity output of the WPPSS plant to 400 megawatts. The "N" reactor-WPPSS hookup is the only such dual-purpose project in the U.S.

[7] ASLB—Atomic Safety and Licensing Board.

[8] LADWP—Los Angeles Department of Water and Power; MWD—Metropolitan Water District of Southern California; SCE—Southern California Edison Co.; SDG&EC, San Diego Gas & Electric Co.

[9] The twin reactors of the Bolsa Island project will produce 1,800 Mwe, gross; about 200 Mwe will be used by the adjoining desalting facility which will produce 50 million gallons of fresh water per day initially, with a 150 million gallon per day ultimate capacity.

[10] ACEC—Atlantic City Electric Co.; DP&LC—Delmarva Power & Light Co.; PEC—Philadelphia Electric Co.; PSE&GC—Public Service Electric & Gas Co.

[11] MG&EC—Madison Gas & Electric Co.; WP&LC—Wisconsin Power & Light Co.; WPSC—Wisconsin Public Service Co.

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APPENDIX 6

RULES AND REGULATIONS

The AEC'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 1967 are set forth below.

REGULATIONS AND AMENDMENTS PUT INTO EFFECT

Marine Navigational Instruments—Part 30

On January 24, 1967, an amendment of Part 30 ("Rules of General Applicability to Licensing of Byproduct Material") was published, effective February 23, 1967, which exempted from licensing requirements the possession and use of marine navigational instruments containing not more than 250 millicuries of tritium gas. The amendment also requires the tritium content of license exempt marine compasses to be in the physical form of gas.

Promethium-147 in Timepieces—Part 30

An amendment of Part 30 was published on October 6, 1967, effective upon publication, which exempted from licensing requirements the possession and use of watches and clocks with dials and hands containing small quantities of promethium-147. Importers of such timepieces, and persons who apply promethium-147 to timepieces, hands, and dials must be specifically licensed.

Promethium-147 in Spark Gap Tubes—Parts 30, 32

On April 26, 1967, an amendment of Part 30 was published, effective upon publication, which exempted from licensing requirements the possession and use of spark gap tubes containing not more than 30 microcuries of promethium-147. Part 32 ("Specific Licenses to Manufacture, Distribute or Import Exempted and Generally Licensed Items Containing Byproduct Material") was amended also so that such tubes would not be subject to the quality control requirement of visual inspections.

Scandium-46 in Labeled Resins—Parts 30, 32

On March 18, 1967, amendments of Parts 30 and 32 were published, effective April 17, 1967, which: (*a*) exempted from licensing requirements the possession and use of resins containing scandium-46 and designed for sand consolidation in oil wells and (*b*) set out requirements for issuance of specific licenses for the manufacture or import of such resins.

Tritium in Aircraft Safety Devices—Parts 31, 32

On May 16, 1967, amendments of Part 31 ("General Licenses for Certain Quantities of Byproduct Material and Byproduct Material Contained in Certain Items") and Part 32 were published, effective June 15, 1967, which increased the quantity limit of generally licensed tritium in any single luminous aircraft safety device from 4 curies to 10 curies.

Medical Licenses of Broad Scope—Part 35

An amendment to Part 35 ("Human Uses of Byproduct Material") was published on October 14, 1967, effective November 13, 1967, which permits the AEC to consider an application for a license for a diagnostic use of byproduct material as an application for a license for related uses of radioisotopes, and to issue a license for such related uses, additional to those requested by the applicant, if the applicant satisfies the licensing criteria for the group of related uses.

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Radioisotope Exports to Soviet-Bloc Countries—Part 36

An amendment of Part 36 ("Export and Import of Byproduct Material"), effective upon publication in the *Federal Register* on June 29, 1967, permits licensees to export certain radioisotopes (byproduct material) under a general license to several Soviet-bloc destinations. The general license covers radioisotopes having atomic numbers 3 to 83, inclusive, in labeled organic and inorganic compounds in quantities not exceeding one curie per shipment; and tritium with a specific activity of not more than 10 curies per gram of hydrogen in amounts not to exceed 10 curies per shipment as labeled organic compounds. It applies to Albania, Bulgaria, Czechoslovakia, Estonia, Hungary, Latvia, Lithuania, Outer Mongolia, and the Soviet Union, and also to Poland and Rumania, with regard to tritium. An existing general license in 36.21 of Part 36 permits the export to Poland and Rumania of byproduct material having an atomic number from 3 to 83, inclusive.

Expiration of Licenses—Part 40

On May 12, 1967, an amendment of Part 40 ("Licensing of Source Material") was published, effective upon publication, to eliminate the restriction, in § 40.42, of the terms of source material licenses to 3 years.

Aircraft Engine Parts Containing Nickel-Thoria Alloy—Part 40

On November 18, 1967, an amendment of Part 40 was published, effective December 18, 1967, which exempted from licensing requirements the possession and use of finished aircraft engine parts containing nickel-thoria alloy. In addition, the amendment provided a general license for export of such parts to countries other than Sino-Soviet bloc destinations and Southern Rhodesia.

Elimination of Statement of Reasons—Part 50

On February 21, 1967, an amendment of Part 50 ("Licensing of Production and Utilization Facilities") was published, effective upon publication, concerning applications for surrender of licenses. The amendment eliminated the requirement that a licensee provide a statement of reasons in an application to surrender the license, dismantle the facility, and dispose of its components.

SNM Control and Physical Inventory—Part 70

On February 3, 1967, an amendment of Part 70 ("Special Nuclear Material") was published, effective March 5, 1967, which required holders of licenses for special nuclear material (SNM) to adopt material control systems to better enable them to account for the special nuclear material which they are licensed to possess and to perform physical inventories of such material.

"Private Ownership" Amendments—Parts 50, 70, 115, and 140

On February 7, 1967, amendments of Parts 50, 70, 115 ("Procedures for Review of Certain Nuclear Reactors Exempted from Licensing Requirements") and 140 ("Financial Protection Requirements and Indemnity Agreements") in partial implementation of the "private ownership" amendments to the Atomic Energy Act, were published, effective March 9, 1967. They reflect the Commission's authority to issue licenses to receive title to, own, acquire, deliver, import, or export, under the terms of an agreement for cooperation arranged pursuant to section 123 of the Act, special nuclear material.

SNM Allocation and Distribution Procedures—Parts 50, 70

On March 15, 1967, amendments of Parts 50 and 70 were published, effective April 14, 1967, which discontinued the Commission's regulatory procedure for allocating and distributing special nuclear material to production and utilization facility licensees and to special nuclear material licensees.

Exclusion of Acts of War in Issuance of Facility License—Parts 50, 115

On September 26, 1967, amendments of Parts 50 and 115 were published, effective October 26, 1967. These changes codify the Commission's practice of not requiring applicants for facility licenses or authorizations to provide design features or other measures to protect specifically against effects of: (*a*) attacks and destructive acts, including sabotage, di-

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Miscellaneous Amend

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Criteria for the Use of

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(*b*) establish criter
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Reports of Exposures

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Promethium-147 in A

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License Fees—Parts 3

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ncreased Financial Protection Requirements—Part 140

An amendment to Part 140 to increase financial protection requirements for power and esting reactors of less than 100 Mwe. but more than one thermal megawatt was published on June 7, 1967, and became effective August 6, 1967.

Miscellaneous Amendments of Parts 2, 20, and 150

On July 15, 1967, amendments of Parts 2, 20, 150 were published, effective on publication, to reflect changes in the organization and functions of regulatory divisions and to make minor procedural changes. Part 2 concerns "Rules of Practice;" Part 20, "Standards for Protection Against Radiation;" Part 150, "Exemptions and Continued Regulatory Authority in Agreement States under Section 274."

PROPOSED REGULATIONS AND AMENDMENTS

Criteria for the Use of Respiratory Equipment—Part 20

On November 4, 1967, proposed amendments of Part 20 were published for comment which would: (*a*) permit use of respiratory protective equipment without prior AEC authorization in nonroutine operations where adequate limitation of the inhalation of radioactive materials by use of ventilation or other engineering controls is impractical; (*b*) establish criteria for respiratory protective equipment programs, and (*c*) make changes in § 20.103 concerning exposures of individuals to airborne concentrations.

Reports of Exposures to Radiation—Part 20

On November 16, 1967, the Commission published for public comment proposed amendments of Part 20 which would require annual reports to the AEC of certain identification and radiation exposure information and indicate more specifically the radiation exposure records required. The reported information would be maintained in a central repository which would provide an index of persons monitored for exposure to radiation. In addition, the system would accumulate information in one place for individuals who have worked for more than one employer or in more than one State.

Promethium-147 in Aircraft Safety Devices—Parts 31, 32

On September 21, 1967, proposed amendments of Parts 31 and 32 were published for public comment which would increase the quantity limit of generally licensed promethium-147 in any single luminous aircraft safety device from 100 millicuries to 300 millicuries.

License Fees—Parts 30, 40, 50, 70, and 170

On March 11, 1967, proposed amendments of Parts 30, 40, 50, and 70, and a new Part 170 were published which would establish fees for facility construction permits and operating licenses issued under Part 50, and for certain byproduct, source, and special nuclear materials licenses issued under Parts 30, 40, and 70. A 60-day comment period was provided, followed by a 60-day extension.

"Stretch Capacity" of Power Reactors—Part 50

A proposed amendment of Part 50 was published for public comment on February 14, 1967, which would require an applicant for a permit to construct a nuclear power reactor to submit with his application data pertinent to operation at the ultimate ("stretch") power level.

Financial Qualifications of Facility Applicants—Part 50

Proposed amendments to Part 50 to provide additional guidance on the kinds of information required to establish financial qualifications of applicants for licenses to construct and operate nuclear production and utilization facilities were published on June 13, 1967, for a 60-day comment period. On August 15, 1967, a notice was published extending the comment period for an additional 60 days.

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General Design Criteria for Nuclear Power Plants—Part 50

"General Design Criteria for Nuclear Power Plant Construction Permits" were published as a proposed amendment of Part 50 on July 11, 1967, for a 60-day comment period and interim guidance. The proposed criteria were a revision and expansion of similar criteria which were distributed with a press announcement on November 22, 1965.

Pile Driving Before Issuance of Construction Permit—Parts 50, 115

Proposed amendments of Parts 50 and 115 which would permit the driving of piles for foundation support of a nuclear reactor in advance of the issuance of a construction permit were published for comment on August 3, 1967.

Implementation of Regulatory Review Panel Recommendations—Parts 2, 50, and 115

On November 22, 1967, proposed amendments to Parts 2, 50, and 115 were published for 60-day comment to implement recommendations of the Second Regulatory Review Panel and make other changes in the Rules of Practice. The proposed amendments are intended to expedite the Commission's facility licensing procedures in contested cases and to clarify certain provisions in existing regulations.

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Bilateral

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Argentina
Australia
Austria
Brazil
Canada
China, Republic of
Colombia [1]
Denmark
Greece [2]
India
Indonesia
Iran
Ireland
Israel
Italy
Japan
Korea
Norway
Panama
Philippines
Portugal
South Africa
Spain
Sweden
Switzerland
Thailand
Turkey
United Kingdom
United Kingdom
Venezuela
Vietnam

Special arrangement:
U.S.-U.S.S.R.

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International Atomic
(IAEA).

APPENDIX 7

INTERNATIONAL AGREEMENTS

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	Research and Power	May 28, 1957	May 27, 1997
Austria	Research	Jan. 25, 1960	Jan. 24, 1970
Brazil	Research	Aug. 3, 1955	Aug. 2, 1975
Canada	Research and Power	July 21, 1955	July 13, 1980
China, Republic of	Research	July 18, 1955	July 17, 1974
Colombia [1]	Research	Mar. 29, 1963	Mar. 28, 1967
Denmark	Research	July 25, 1955	Sept. 7, 1968
Greece [2]	Research	Aug. 4, 1955	Aug. 3, 1974
India	Research and Power	Oct. 25, 1963	Oct. 24, 1993
Indonesia	Research	Sept. 21, 1960	Oct. 30, 1970
Iran	Research	Apr. 27, 1959	Apr. 26, 1969
Ireland	Research	July 9, 1958	July 8, 1968
Israel	Research	July 12, 1955	Apr. 11, 1975
Italy	Research and Power	Apr. 15, 1958	Apr. 14, 1978
Japan	Research and Power	Dec. 5, 1958	Dec. 4, 1968
Korea	Research	Feb. 3, 1956	Feb. 2, 1976
Norway	Research and Power	June 8, 1967	June 7, 1997
Panama	Research	June 27, 1963	June 26, 1968
Philippines	Research	July 27, 1955	July 26, 1968
Portugal	Research	July 21, 1955	July 20, 1969
South Africa	Research and Power	Aug. 22, 1957	Aug. 21, 1977
Spain	Research and Power	Feb. 12, 1958	Mar. 31, 1988
Sweden	Research and Power	Sept. 15, 1966	Sept. 14, 1996
Switzerland	Research and Power	Aug. 8, 1966	Aug. 7, 1996
Thailand	Research	Mar. 13, 1956	Mar. 12, 1975
Turkey	Research	June 10, 1955	June 9, 1971
United Kingdom	Research	July 21, 1955	July 20, 1976
United Kingdom	Power	July 15, 1966	July 14, 1976
Venezuela	Research and Power	Feb. 9, 1960	Feb. 8, 1970
Vietnam	Research and Power	July 1, 1959	June 20, 1974
Special arrangement:			
U.S.–U.S.S.R	Agreement on Cooperation in Desalination (Information and Personnel Exchange).	Nov. 18, 1964	Nov. 18, 1968

See footnotes at end of tables.

Agreements for Cooperation with International Organizations

Organization	Scope	Effective date	Termination date
European Atomic Energy Community (Euratom).	Joint Nuclear Power Program	Feb. 18, 1959	Dec. 31, 1985
Euratom	Additional Agreement to Joint Nuclear Power Program.	July 25, 1960	Dec. 31, 1995
International Atomic Energy Agency (IAEA).	Supply of materials, etc	Aug. 7, 1959	Aug. 6, 1975

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Trilateral Safeguards Agreements

Participant	Scope	Effective date
U.S./IAEA/Argentina	Trilateral for application of IAEA safeguards to US-supplied materials.	Mar. 1, 1966
U.S./IAEA/Australia	----do----	Sept. 26, 1966
U.S./IAEA/Austria	----do----	Dec. 13, 1965
U.S./IAEA/Republic of China	----do----	Oct. 29, 1965
U.S./IAEA/Greece	----do----	Jan. 13, 1966
U.S./IAEA/Indonesia	----do----	Dec. 4, 1967
U.S./IAEA/Iran	----do----	Dec. 6, 1967
U.S./IAEA/Israel	----do----	June 15, 1966
U.S./IAEA/Japan	----do----	Nov. 1, 1963
U.S./IAEA/Philippines	----do----	Sept. 24, 1965
U.S./IAEA/Portugal	----do----	Dec. 15, 1965
U.S./IAEA/South Africa	----do----	Oct. 8, 1965
U.S./IAEA/Spain	----do----	Dec. 9, 1966
U.S./IAEA/Thailand	----do----	Sept. 10, 1965
U.S./IAEA/Vietnam	----do----	Oct. 25, 1965
U.S./IAEA/Brazil	----do----	(2)

Agreements for Cooperation for Mutual Defense Purposes [4]

Participant	Effective date
NATO	Mar. 12, 1965
Australia	Aug. 14, 1957
Belgium	Sept. 5, 1962
Canada	July 27, 1959
France (Land-based Prototype Fuel Supply Agreement)	July 20, 1959
France	Oct. 9, 1961
Germany, Federal Republic of	July 27, 1959
Greece	Aug. 11, 1959
Italy	May 24, 1961
Netherlands	July 27, 1959
Turkey	July 27, 1959
United Kingdom [5]	Aug. 4, 1958

[1] Extending agreement signed but not yet in force.
[2] Provisionally in force.
[3] Effective date to be established.
[4] Except for the Agreement with France of July 20, 1959, all these Agreements provide for exchange of classified information as provided for in Section 144b of the Atomic Energy Act.
[5] The United Kingdom agreement is the only one that also provides for the exchange of weapon design information or exchange of nuclear materials for use in a weapon development and fabrication program.

Table 1.—SPECI

Name of cent
Aerospace Nuclear Saf mation Center.
Accelerator Informatio
Applied Science Data
Argonne Code Center.
Atomic and Molecular Information Center.
Charged Particle Cross Information Center.
Computer Index Neut Center.
Criticality Data Cente
Fused Salts Informatio
Gamma-Ray Spectrum
Information Center for Exposure.
Information Integratio
Isotopes Information C
Laboratory Animal Inf Center.
Liquid Metals Inform Center.
National Neutron Cro Center. [3]
National Oceanograph Center.
Nuclear Data Project.
Nuclear Desalination I tion Center.
Nuclear Safety Inform Center.
Radiation Chemistry I Center.
Radiation Effects Info Center.
Radiation Shielding In
Rare-Earth Informatic
Reactor Physics Const Center.
Research Materials In Center.
Shock Wave Data Cer
Thermodynamic Prop Metals and Alloys.

[1] Further detail as t whom services are av Centers," available fre
[2] Name changed fro
[3] Name changed fro

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APPENDIX 8

TECHNICAL INFORMATION

Table 1.—SPECIALIZED INFORMATION AND DATA CENTERS SPONSORED BY AEC[1]

Name of center	Location	Address
Aerospace Nuclear Safety Information Center.	Sandia Laboratory	P.O. Box 5800, Albuquerque, N. Mex. 87115.
Accelerator Information Center	Oak Ridge National Laboratory	P.O. Box Y, Oak Ridge, Tenn. 37830.
Applied Science Data Group[2]	Lawrence Radiation Laboratory	P.O. Box 808, Livermore, Calif. 94550.
Argonne Code Center	Argonne National Laboratory	9700 South Cass Ave., Argonne, Ill. 60440.
Atomic and Molecular Processes Information Center.	Oak Ridge National Laboratory	P.O. Box X, Oak Ridge, Tenn. 37830.
Charged Particle Cross Section Information Center.	Oak Ridge National Laboratory	P.O. Box X, Oak Ridge, Tenn. 37830.
Computer Index Neutron Data Center.	AEC Division of Technical Information Extension.	P.O. Box 62, Oak Ridge, Tenn. 37830.
Criticality Data Center	Oak Ridge National Laboratory	P.O. Box Y, Oak Ridge, Tenn. 37830.
Fused Salts Information Center	Sandia Laboratory	P.O. Box 5800, Albuquerque, N. Mex. 87115.
Gamma-Ray Spectrum Catalog	National Reactor Testing Station	P.O. Box 1845, Idaho Falls, Idaho 83401.
Information Center for Internal Exposure.	Oak Ridge National Laboratory	P.O. Box X, Oak Ridge, Tenn. 37830.
Information Integration Group	Lawrence Radiation Laboratory	P.O. Box 808, Livermore, Calif. 94550.
Isotopes Information Center	Oak Ridge National Laboratory	P.O. Box X, Oak Ridge, Tenn. 37830.
Laboratory Animal Information Center.	Argonne National Laboratory	9700 South Cass Ave., Argonne, Ill. 60440.
Liquid Metals Information Center.	Atomics International	P.O. Box 309, Canoga Park, Calif. 91304.
National Neutron Cross Data Center.[3]	Brookhaven National Laboratory.	Upton, L.I., N.Y. 11973.
National Oceanographic Data Center.	U.S. Naval Oceanographic Office	Washington, D.C. 20390.
Nuclear Data Project	Oak Ridge National Laboratory	P.O. Box X, Oak Ridge, Tenn. 37830.
Nuclear Desalination Information Center.	Oak Ridge National Laboratory	P.O. Box Y, Oak Ridge, Tenn. 37830.
Nuclear Safety Information Center.	Oak Ridge National Laboratory	P.O. Box. Y, Oak Ridge, Tenn. 37830.
Radiation Chemistry Data Center.	Radiation Laboratory	University of Notre Dame, Notre Dame, Ind. 46556.
Radiation Effects Information Center.	Battelle Memorial Institute	505 King Ave., Columbus, Ohio 43201.
Radiation Shielding Information	Oak Ridge National Laboratory	P.O. Box. X, Oak Ridge, Tenn. 37830.
Rare-Earth Information Center	Ames Laboratory	Iowa State University, Ames, Iowa 50010.
Reactor Physics Constants Center.	Argonne National Laboratory	9700 South Cass Ave., Argonne, Ill. 60439.
Research Materials Information Center.	Oak Ridge National Laboratory	P.O. Box X, Oak Ridge, Tenn. 37830.
Shock Wave Data Center	Lawrence Radiation Laboratory	P.O. Box 808, Livermore, Calif. 94550.
Thermodynamic Properties of Metals and Alloys.	Lawrence Radiation Laboratory	University of California, Berkeley, Calif. 94720.

[1] Further detail as to the subject scope covered and services provided by each center and the users for whom services are available is provided in a "Directory of USAEC Specialized Information and Data Centers," available free from the USAEC, P.O. Box 62, Oak Ridge, Tenn. 37830.

[2] Name changed from Scientific Information Systems Group.

[3] Name changed from Sigma Center.

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Table 2.—AEC-SPONSORED BOOKS, MONOGRAPHS, AND PROCEEDINGS PUBLISHED IN 1967

Books

The Radiobiology of Cultured Mammalian Cells—M. M. Elkind, G. G. Whitmore, Gordon and Breach Science Publishers, New York City, $31.50 L/R edition, $14.25 P/S edition.[1]

Mathematical Theory of Radiation Dosimetry—J. J. Fitzgerald, G. L. Brownell, F. J. Mahoney, Gordon and Breach Science Publishers, New York City, $30.00 L/R edition, $11.25 P/S edition.[1]

Radioisotope Measurement Applications in Engineering—R. P. Gardner, R. L. Ely, Jr., Reinhold Publishing Corp., New York City, $16.00.

Radiation Monitoring, A Programmed Instruction Book—J. E. Wade and G. E. Cunningham, $3.00.[2]

Sourcebook on Atomic Energy—3rd Edition, Samuel Glasstone, D. Van Nostrand Co., Inc., Princeton, N. J., $9.25.

Plutonium Handbook: A Guide to the Technology, Volume 1—O. J. Wick, Editor, Gordon and Breach Science Publishers, New York City, $22.25 L/R edition, $13.25 P/S edition.[1]

Plutonium Handbook, A Guide to the Technology, Volume 2—O. J. Wick, Editor, Gordon and Breach Science Publishers, New York City, $56.00 L/R edition, $28.00 P/S edition.[1]

Engineering for Nuclear Fuel Reprocessing—J. T. Long, Gordon and Breach Science Publishers, New York City, $56.00 L/R edition, $28.00 P/S edition.[1]

Secrets of the Nucleus—J. S. Levinger, Scholastic Book Services, New York City, $0.50.

Monographs (Cooperating Society)

Soil-Plant System in Relation to Inorganic Nutrition—(American Institute of Biological Sciences) M. Fried, H. Broeshart, Academic Press, New York City, $15.00.

Tritium-Labeled Molecules in Biology and Medicine—(American Institute of Biological Sciences), L. E. Feinendegen, Academic Press, New York City, $17.00.

Ceramic Fuel Elements—(American Society for Metals), R. B. Holden, Gordon and Breach Science Publishers, New York City, $12.50 L/R edition, $4.25 P/S edition.[1]

The Foundations of Neutron Transport Theory—(American Nuclear Society), R. K. Osborn and S. Yip, Gordon and Breach Science Publishers, New York City, $5.50 L/R edition, $2.50 P/S edition.[1]

Dispersion Fuel Elements—(American Society for Metals), A. N. Holden, Gordon and Breach Science Publishers, New York City, $11.00 L/R edition, $5.25 P/S edition.[1]

Alkali Metal Handling and Systems Operating Techniques—(American Nuclear Society), J. W. Mausteller, Gordon and Breach Science Publishers, New York City, $10.50 L/R edition, $5.00 P/S edition.[1]

Symposium Proceedings (Published by the AEC)

Luminescence Dosimetry—F. H. Attix, Editor, $3.00.[2]

Neutron Noise, Waves, and Pulse Propagation—R. E. Uhrig, Editor, $3.00.[2]

Use of Computers in Analysis of Experimental Data and the Control of Nuclear Facilities—B. I. Spinrad, Editor, $3.00.[2]

Thorium Fuel Cycle—R. G. Wymer, Editor, $3.00.[2]

[1] L/R—library and reference edition; P/S—professional and student edition.

[2] Available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151.

Table 3.—TITLE

Accelerators (F,S)
Animals in Atomic
Atomic Fuel (F,S)
Atomic Power Saf
Atoms at the Scien
Atoms in Agricult
Atoms, Nature, an
Careers in Atomic
Computers
Controlled Nuclea
Cryogenics, The U
Direct Conversion
Fallout from Nucl
Food Preservation
Genetic Effects of
Index to the Under Series [2]
Microstructure of
Neutron Activatio
Nondestructive Te
Nuclear Clocks
Nuclear Energy fo
Nuclear Power an

[1] Single copies (Information, P.O.
[2] Published in 1
[3] Revised in 19(
(F) French trans
(S) Spanish tran
(I) Italian trans

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Table 3.—TITLES OF BOOKLETS IN THE AEC'S "UNDERSTANDING THE ATOM" SERIES [1]

Accelerators (F,S)
Animals in Atomic Research [2]
Atomic Fuel (F,S)
Atomic Power Safety
Atoms at the Science Fair (S)
Atoms in Agriculture (F,S)
Atoms, Nature, and Man
Careers in Atomic Energy
Computers
Controlled Nuclear Fusion
Cryogenics, The Uncommon Cold [2]
Direct Conversion of Energy (F,S)
Fallout from Nuclear Tests
Food Preservation by Irradiation (S)
Genetic Effects of Radiation
Index to the Understanding the Atom Series [2]
Microstructure of Matter [3]
Neutron Activation Analysis (F,S)
Nondestructive Testing
Nuclear Clocks
Nuclear Energy for Desalting [3] (F,S,I)
Nuclear Power and Merchant Shipping
Nuclear Power Plants
Nuclear Propulsion for Space [2]
Nuclear Reactors (F,S)
Nuclear Terms, A Brief Glossary
Our Atomic World (F,S)
Plowshare (S)
Plutonium
Power from Radioisotopes
Power Reactors in Small Packages
Radioactive Wastes
Radioisotopes and Life Processes
Radioisotopes in Industry
Radioisotopes in Medicine
Rare Earths
Reading Resources in Atomic Energy [2]
Research Reactors
SNAP, Nuclear Space Reactors (F)
Synthetic Transuranium Elements
The Chemistry of the Noble Gases [2]
The First Reactor [2]
Whole Body Counters [3]
Your Body and Radiation

[1] Single copies (limit: three titles per request) available free from the USAEC-Technical Information, P.O. Box 62, Oak Ridge, Tenn. 37830.
[2] Published in 1967.
[3] Revised in 1967.
(F) French translation available.
(S) Spanish translation available.
(I) Italian translation available.

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APPENDIX 9

FILM LIBRARIES

As part of its information and education program, the AEC maintains motion picture libraries and deposits films with nonprofit sublibraries from which qualified borrowers throughout the United States and Canada may obtain 16mm 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 on public service telecasts. The AEC's domestic film libraries located at the following AEC offices serve requests from the indicated 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.

Foreign Loans. Many of the films are available for loan from: the AEC's liaison offices at the American Embassies in Tokyo, Brussels, London, and Buenos Aires, the U.S. Information Service post at the American Embassy in Stockholm, the Film Library of the International Atomic Energy Agency in Vienna, the American Film Library in The Hague, and the National Science Film Library in Ottawa, Canada. Residents of other nations may seek assistance directly from the nearest U.S. Information Service post at an American Embassy, which can arrange to borrow prints from the AEC in Washington via the U.S. Information Agency, Washington.

NEW AEC FILMS MADE AVAILABLE TO THE PUBLIC DURING 1967*

Professional Level

DEVELOPMENT AND FABRICATION OF HFIR TARGET ELEMENTS: 14½ minutes, color, produced by AEC's Oak Ridge National Laboratory. Design and development of the High Flux Isotope Reactor, and development of manufacturing processes for the transuranium program.

INSIDE THE YANKEE CORE: 32 minutes, color, produced by Westinghouse Electric Corporation for the AEC. Describes extensive and complete post-irradiation study on an expended commercial power-reactor core.

LINK: 8 minutes, color, produced by the AEC's Argonne National Laboratory. Current experiments in high energy physics which involve analysis of immense quantities of data.

PARACHUTE DEVELOPMENT AT SANDIA: 11 minutes, color, produced by Sandia Corp. for the AEC. Innovations developed to solve problems when parachutes are used to recover test vehicles traveling at supersonic speeds.

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* More complete descriptions of new films available for public showings are included in the "Popular Level" and "Professional Level" film catalog and catalog inserts available without charge, from Director, Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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PERSIMMON—A NUCLEAR PHYSICS EXPERIMENT: 16 minutes, color, produced by AEC's Los Alamos Scientific Laboratory. Various nuclear experiments requiring a very high neutron flux using the underground detonation of a nuclear explosive.

PLANT GROWTH IN COMPENSATED FIELDS: 7 minutes, color, produced by AEC's Argonne National Laboratory. Mechanical servo-system to neutralize the gravitational effects in all directions by servo-motors controlled by a computer program.

Professional and Popular Level

SANDIA SPIN-OFF: 15 minutes, color, produced by AEC's Sandia Laboratory. Nuclear weapons program "spin-off" applications: laminar air flow, ion plating, automating circuit card etching layouts.

SOLAR ECLIPSE EXPEDITION 1966: 32 minutes, color, produced by the AEC's Los Alamos Scientific Laboratory. Three major experiments designed and built for the 1966 eclipse expedition to study the sun's corona.

SUPERCONDUCTING MAGNETS: 12½ minutes, color, produced by AEC's Argonne National Laboratory. Basic design problems in producing completely stable superconducting magnets of very large size.

Popular Level

ATOMIC POWER TODAY: SERVICE WITH SAFETY (abridged version). 15 minutes, color, produced by Seneca Productions, Inc. Central Station Atomic Power Plants and how they serve the Nation now and will continue to do so in the future.

ATOM SMASHERS: 18 minutes, color, produced by Handel Film Corp. Principles, purposes, and methods of particle accelerators used by physicists to study the sub-atomic particles of matter.

BONUS FOR PUERTO RICO: 20 minutes, color, produced by AEC's Oak Ridge Operations Office. Construction and initial operation of the small Boiling Nuclear Superheat Reactor, first nuclear powerplant in the tropics.

BROOKHAVEN SPECTRUM: 25 minutes, color, produced by AEC's Brookhaven National Laboratory. Varied aspects of nuclear research and engineering at Brookhaven—experiments in biology, chemistry, medicine, physics, and reactor technology.

DESALTING THE SEAS: 17 minutes, color, produced by AEC's Oak Ridge National Laboratory. Various methods for purifying saline waters through the use of nuclear energy, with particular emphasis on large-scale dual purpose nuclear-electric desalting plants.

THE FIFTH FUEL: 22 minutes, color, produced by AEC's Oak Ridge Operations Office. Steps involved in preparing enriched uranimum (U^{235}) from the mining operation, through the chemical and metallurgical process to obtain a pure material and eventually structured as fuel elements.

GUARDIAN OF THE ATOM: 28½ minutes, color, produced by AEC Headquarters. The broad "peaceful uses" picture of research activities in atomic energy development, and role and responsibilities of the AEC.

OAK RIDGE NATIONAL LABORATORY AND ITS SCIENTIFIC ACTIVITIES: 17 minutes, color, produced by AEC's Oak Ridge National Laboratory. Varied activities and facilities at the laboratory, involving nuclear research, fundamental and applied research in all fields of science.

THE DAY TOMORROW BEGAN: 30 minutes, color, produced by AEC's Argonne National Laboratory. Historical footage and interviews re-enact the planning, design, and operation of "Chicago Pile 1." Produced to commemorate the 25th anniversary of the first self-sustained nuclear chain reaction.

UNDERGROUND NUCLEAR WEAPONS TESTING: 27 minutes, color, produced by AEC's Nevada Operations Office. AEC's role in underground testing of nuclear weapons at the Nevada Test Site, safely and within the framework of the limited nuclear test ban treaty.

EMPLOYME

Total Employees----
Total Engineers-----
Mechanical Engine
Electrical & Electro
Chemical Engineers
Nuclear & Reactor
Metallurgical Engin
Civil Engineers----
Other Engineers---
Total Mathematicians
Total Physical Scient
Chemists----------
Physicists---------
Metallurgists------
Geologists & Geoph
Other Physical Scie
Total Life Scientists-
Health Physicists--
Medical Scientists..
Biological Scientists
Other Life Scientist
Total Technicians---
Draftsmen---------
Electrical & Electro
Other Engineering T
Health Physics Tec
Life Science Technic
Physical Science Te
Other Technicians.
Nuclear Reactor Ope
All Other Employees

[1] Includes nonprofit

[2] R&D—research a

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APPENDIX 10

EMPLOYMENT IN ATOMIC ENERGY FIELD BY OCCUPATIONAL CATEGORY [1]

Occupations	Government establishments		Private establishments	
	Total	Number in R&D [2]	Total	Number in R&D [2]
Total Employees	102,293	17,961	35,457	5,902
Total Engineers	13,125	9,065	8,586	4,043
Mechanical Engineers	3,958	2,883	3,088	1,588
Electrical & Electronics Engineers	3,326	2,505	1,869	1,013
Chemical Engineers	1,681	1,089	465	236
Nuclear & Reactor Engineers	1,040	890	913	561
Metallurgical Engineers	454	393	360	220
Civil Engineers	343	141	449	78
Other Engineers	2,323	1,164	1,442	347
Total Mathematicians	1,408	1,125	234	190
Total Physical Scientists	7,680	6,577	2,083	1,508
Chemists	3,062	2,381	799	448
Physicists	3,591	3,320	934	837
Metallurgists	522	487	219	154
Geologists & Geophysicists	40	24	67	36
Other Physical Scientists	465	365	64	33
Total Life Scientists	1,459	1,194	273	161
Health Physicists	415	202	154	68
Medical Scientists	106	82	7	4
Biological Scientists	923	899	94	81
Other Life Scientists	15	11	18	8
Total Technicians	15,979	NA	7,817	NA
Draftsmen	2,028	NA	2,162	NA
Electrical & Electronics Technicians	3,875	NA	1,290	NA
Other Engineering Technicians	3,633	NA	1,259	NA
Health Physics Technicians & Radiation Monitors	1,012	NA	404	NA
Life Science Technicians	456	NA	152	NA
Physical Science Technicians	1,972	NA	697	NA
Other Technicians	3,003	NA	1,853	NA
Nuclear Reactor Operators	646	NA	365	NA
All Other Employees	61,996	NA	16,099	NA

[1] Includes nonprofit establishments.

[2] R&D—research and development; includes only scientific and engineering personnel.

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APPENDIX 11

AEC FINANCIAL SUMMARY FOR FISCAL YEAR 1967 *

The Atomic Energy Commission, an independent agency responsible to the President and Congress, assumed accountability for some $2.2 billion appropriation expenditures made by its predecessors, primarily the Manhattan Engineer District, on January 1, 1947. Since that time, the AEC itself has received $40.8 billion in appropriations from Congress. Of this total ($2.2 billion plus $40.8 billion), the AEC has invested $8.1 billion in its net assets (not including the value of certain inventories excluded for security reasons); has used $34.5 billion in operations; and has returned to the Treasury or transferred to other U.S. agencies a total of $0.4 billion.

Fiscal year 1967 marks the completion of the first full 20 years of the AEC's responsibility for the development, use, and control of atomic energy and the production of nuclear weapons. A chart showing the costs incurred for selected years during the period for each of the major programs is included here.

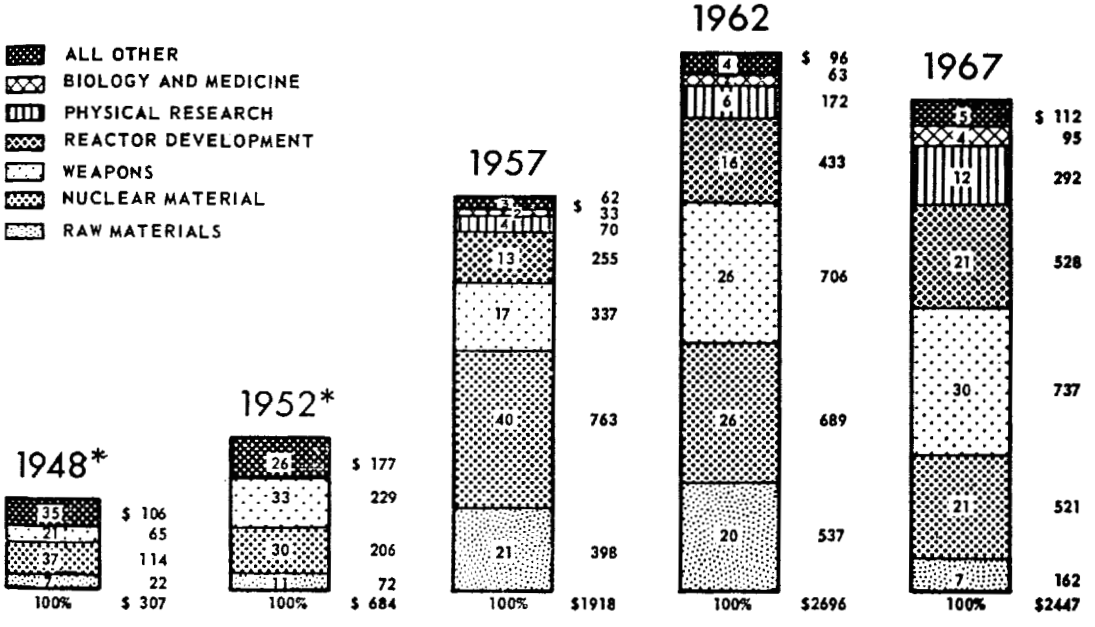
The trends of costs for the various programs and for the agency as a whole, show the effect of events that have had an impact on the use and control of atomic energy. Of particular importance was the revision of the Atomic Energy Act in 1954 to provide for greater emphasis on developing and promoting peaceful uses of atomic energy, the costs of the peaceful efforts have since taken a larger proportion of AEC funds.

The 1964 change in the law to permit private ownership of special nuclear materials is contributing to the current interest in nuclear reactors as a source of power for civilian uses. More than half of the new steam-electric generating capacity announced by U.S. companies during fiscal year 1967 was nuclear.

*Material in this appendix is extracted from the "U.S. Atomic Energy Commission—1967 Financial Report," available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, price 50 cents.

SUMMARY OF NET OPERATING COSTS

DOLLARS IN MILLIONS



* DATA FOR THE REACTOR DEVELOPMENT, PHYSICAL RESEARCH, BIOLOGY AND MEDICINE AND ALL OTHER PROGRAMS FOR 1948 AND 1952 HAVE BEEN COMBINED.

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This 20 years of experience has confirmed the wisdom of the AEC policy of contracting with commercial firms or educational and other nonprofit organizations to do most of the work involved in actually achieving the AEC goals.

The many people responsible for the operation and management of the large-scale industrial and research activities of the Atomic Energy Commission require knowledge of the cost of each step in its operations. The AEC accounting system must not only supply such knowledge but must comply with the requirements of Federal Government fund accounting. The system developed to meet both these requirements has the approval of the General Accounting Office. Like industrial accounting systems it follows accrual and cost accounting principles, including the recording of depreciation. The accounting records maintained by major contractors for their AEC activities are an integral part of the Commission's system of financial management. This summary is a consolidation of information obtained from financial reports made to the AEC by its contractors and information obtained from AEC records.

STATEMENT OF OPERATIONS

	Fiscal Year	
	1967	*1966*
	(In thousands)	
Production		
Procurement of raw materials	$162,000	$206,310
Production of nuclear materials	521,316	543,931
Weapons development and fabrication	736,593	729,570
	1,419,909	1,479,811
Research and development		
Development of nuclear reactors	528,028	488,769
Physical research	291,911	265,002
Biology and medicine research	95,208	90,757
Plowshare	14,730	15,766
Isotope development	7,667	7,750
	937,544	868,044
Community operations		
Expenses	5,038	7,838
Revenues	(3,288)	(5,006)
	1,750	2,832
Sales of materials and services		
Cost	65,124	52,917
Revenue	(77,270)	(61,097)
	(12,146)	(8,180)
Education and training	10,008	10,014
AEC administrative expenses	89,492	83,872
Security investigations	6,250	6,340
Other expenses	13,019	9,639
Other income	(19,302)	(12,642)
Net cost of operations*	2,446,524	2,439,730
Special items		
Adjustments to costs of prior years—net	32,026	52,847
Transfers to inventories—net	(112,629)	(145,203)
Net cost of operations—after special items*	$2,365,921	$2,347,374

* Includes depreciation of $350 million in 1967 and $329 million in 1966

COSTS INCURRED BY RESEARCH LABORATORIES

A major portion of AEC research and development is conducted in Government-owned laboratories operated by educational institutions and industrial concerns under AEC contracts. On June 30, 1967, the AEC's investment in research facilities totaled $2.8 billion. Of this amount, $1.9 billion was invested in the major Government-owned laboratories. These facilities included research reactors, particle accelerators, general laboratory buildings, equipment, and research devices. Research and development work conducted in AEC laboratories include central station nuclear power design and development, research in the physical and life sciences, nuclear weapons development, research on peaceful applications for nuclear explosives and research to improve nuclear materials processes and techniques.

The 10 laboratories listed 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 throughout this report.

[In thousands]

Laboratories	Cost of completed plant June 30, 1967	Operating costs fiscal year	
		1967	1966
Ames Research Laboratory	$20,700	$9,036	$8,326
Argonne National Laboratory [1]	325,300	87,360	82,872
Bettis Atomic Power Laboratory [1]	131,143	63,045	57,627
Brookhaven National Laboratory	224,433	60,894	58,616
Knolls Atomic Power Laboratory [1]	142,275	52,722	41,717
Lawrence Radiation Laboratory [2]	293,401	167,090	161,370
Los Alamos Scientific Laboratory [2]	242,507	106,216	104,373
Oak Ridge National Laboratory	329,032	92,263	84,877
Pacific Northwest Laboratory	98,252	42,803	34,186
Savannah River Laboratory	70,167	13,144	12,835

[1] Includes facilities at National Reactor Testing Station, Idaho.
[2] Includes facilities at Nevada Test Site.

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BALANCE SHEETS

[In thousands]

Assets	June 30, 1967	June 30, 1966	Liabilities and AEC Equity*	June 30, 1967	June 30, 1966
Cash			Liabilities		
Funds in U.S. Treasury	$1,457,187	$1,522,072	Accounts payable and accrued expenses	$334,939	$313,900
Cash on hand and with contractors	2,592	11,678	Advances from other agencies	11,288	14,209
Transfers from other agencies	5,166	5,765	Funds held for others	14,977	15,037
			Accrued annual leave of AEC employees	10,016	9,582
	1,464,945	1,539,515	Deferred credits	10,961	16,799
Accounts Receivable			Total Liabilities	382,181	369,518
Federal agencies	42,515	53,707			
Other	56,140	54,261	AEC Equity, July 1	8,286,916	8,334,578
	98,655	107,968	Additions		
			Funds appropriated—net	2,198,864	2,365,893
Inventories			Non-reimbursable transfers from other agencies	6,558	7,326
Source and nuclear materials leased and at research installations	869,723	842,780		2,205,422	2,373,219
Special reactor materials	91,283	103,864			
Stores	89,796	88,891			
Isotopes	42,744	39,988	Deductions		
Other special materials	14,575	14,667	Net cost of operations—after special items	2,365,921	2,347,374
			Non-reimbursable transfers to other agencies	60,708	73,498
	1,108,121	1,090,190	Funds returned to U.S. Treasury		9
				2,426,632	2,420,881
Plant					
Completed plant and equipment	8,819,749	8,747,500			
Less—Accumulated depreciation	3,353,727	3,194,952	AEC Equity, June 30	8,065,706	8,286,916
	5,466,022	5,552,548	Total Liabilities and AEC Equity	$8,447,887	$8,656,434
Construction work in progress	242,583	300,044			

Plant		
Completed plant and equipment	8,819,749	8,747,500
Less—Accumulated depreciation	3,353,727	3,194,952
	5,466,022	5,552,548
Construction work in progress	242,583	300,044
	5,708,605	5,852,592
Other	67,561	66,169
Total Assets	$8,447,887	$8,656,434

	2,426,632	2,420,881
AEC Equity, June 30	8,065,706	8,286,916
Total Liabilities and AEC Equity	$8,447,887	$8,656,434

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 the 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 Treasury selling price at June 30, 1967, the value of the silver on loan was $83,529,198. The value of silver lost and the cost of recovering and processing that on hand and returning it to the Treasury is estimated at $787,000.
   c. Plant and equipment on loan from other Federal agencies at June 30, 1967 amounting to $37,695,000.
   d. Contested claims against others of $3,249,000.
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, 1967, the estimated liabilities would have amounted to $162,800,000.
   b. Contingent liabilities for claims against the AEC of $16,356,000.
   c. Commitments for an estimated 28,636 tons of U_3O_8 at an estimated cost of $387,760,000.
   d. Commitments under section 56 of the Atomic Energy Act of 1954, as amended, for acquisition of plutonium and uranium enriched in the isotope 233. Estimated commitments of $800,000 for fiscal year 1968 are based upon projected quantities of uranium enriched in the isotope 233 to be produced by domestic licensees and delivered to the 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.
   e. Outstanding contracts, purchase orders and other commitments of $1,145,000,000.

COSTS INCURRED BY GEOGRAPHICAL LOCATIONS

The table on this page shows the costs incurred by the AEC in fiscal year 1967. 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*	Plant and capital equipment	Total
Alabama	$71	$5	$76
Alaska	15,941	----------	15,941
Arizona	2,063	----------	2,063
Arkansas	289	----------	289
California	262,950	46,672	309,622
Colorado	52,104	9,355	61,459
Connecticut	10,739	1,399	12,138
Delaware	94	----------	94
District of Columbia	13,755	77	13,832
Florida	15,027	2,274	17,301
Georgia	1,227	19	1,246
Hawaii (including Pacific Test Area)	2,550	26	2,576
Idaho	56,161	15,662	71,823
Illinois	81,633	25,662	107,295
Indiana	2,998	166	3,164
Iowa	14,059	3,072	17,131
Kansas	504	----------	504
Kentucky	53,138	772	53,910
Louisiana	332	----------	332
Maine	297	----------	297
Maryland	50,961	1,079	52,040
Massachusetts	24,254	3,995	28,249
Michigan	6,231	706	6,937
Minnesota	4,864	372	5,236
Mississippi	83	----------	83
Missouri	78,182	5,356	83,538
Montana	51	----------	51
Nebraska	959	145	1,104
Nevada	143,223	15,137	158,360
New Hampshire	87	----------	87
New Jersey	17,019	2,651	19,670
New Mexico	359,421	38,299	397,720
New York	120,196	30,047	150,243
North Carolina	1,525	874	2,399
North Dakota	47	----------	47
Ohio	106,811	11,488	118,299
Oklahoma	443	----------	443
Oregon	1,487	15	1,502
Pennsylvania	105,491	7,767	113,258
Puerto Rico	3,006	407	3,413
Rhode Island	916	----------	916
South Carolina	95,500	13,437	108,937
South Dakota	2,530	----------	2,530
Tennessee	194,617	25,902	220,519
Texas	16,244	3,256	19,500
Utah	16,363	49	16,412
Vermont	44	----------	44
Virginia	2,738	130	2,868
Washington	128,636	16,740	145,376
West Virginia	264	----------	264
Wisconsin	3,582	123	3,705
Wyoming	29,801	----------	29,801
Foreign countries	26,290	273	26,563
Total	$2,127,798	$283,409	$2,411,207

*Excludes depreciation.

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Cornell Universi
Duke University
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Florida, Univers
Georgia Institute
Georgia, Univers
Harvard Univers
Hawaii, Univers
Illinois, Universi
Iowa, State Univ
Johns Hopkins U
Kansas, Univers
Louisiana State
Maryland, Univ
Massachusetts In
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Minnesota, Univ
New York Univ
North Carolina S
North Carolina,
Northwestern U
Notre Dame, U
Ohio State Univ
Oregon State U
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Princeton Unive
Puerto Rico, U
Purdue Universi
Rensselaer Poly
Rice University
Rochester, Univ
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Stanford Univer
Syracuse Unive
Tennessee, Univ
Texas, Universi
Tufts Universit

See footnote

COSTS INCURRED BY COLLEGES AND UNIVERSITIES

In addition to the activities of the AEC laboratories, some of which are operated for the AEC by universities or associations of universities, the AEC had other contracts with 237 colleges or universities for atomic energy work. The following table shows that the cost of this work totaled about $128 million in fiscal year 1967 and identifies each university where costs in excess of $250,000 were incurred.

Colleges and Universities	Fiscal year 1967	
	Rank by dollar volume of costs incurred	Total costs* (in thousands)
Arizona, University of	53	$360
Arkansas, University of	59	289
Brandeis University	56	324
Brown University	39	648
California Institute of Technology	12	2,722
California, University of	2	8,144
California, University of, at Los Angeles	14	2,560
Carnegie Institute of Technology	20	1,903
Case Institute of Technology	29	1,092
Chicago, University of	21	1,859
Colorado, University of	33	918
Columbia University	7	4,796
Cornell University	23	1,636
Duke University	24	1,618
Florida State University	28	1,121
Florida, University of	44	518
Georgia Institute of Technology	50	396
Georgia, University of	52	374
Harvard University	4	7,638
Hawaii, University of	40	607
Illinois, University of	8	4,442
Iowa, State University of	43	535
Johns Hopkins University	32	979
Kansas, University of	48	427
Louisiana State University	60	282
Maryland, University of	18	2,196
Massachusetts Institute of Technology	3	7,819
Michigan State University	15	2,351
Michigan, University of	13	2,645
Minnesota, University of	16	2,320
New York University	5	5,359
North Carolina State University	55	328
North Carolina, University of	61	282
Northwestern University	54	349
Notre Dame, University of	25	1,423
Ohio State University	36	680
Oregon State University	37	678
Oregon, University of	45	517
Pennsylvania State University	42	557
Pennsylvania, University of	19	2,074
Pittsburgh, University of	41	582
Princeton University	1	16,012
Puerto Rico, University of	17	2,297
Purdue University	26	1,303
Rensselaer Polytechnic Institute	27	1,157
Rice University	30	1,052
Rochester, University of	6	5,201
Southern California, University of	49	406
Stanford University	38	678
Syracuse University	57	307
Tennessee, University of	22	1,644
Texas, University of	34	783
Tufts University	46	513

See footnotes at end of table.

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COSTS INCURRED BY COLLEGES AND UNIVERSITIES—Continued

Colleges and Universities	Fiscal year 1967	
	Rank by dollar volume of costs incurred	Total costs* (in thousands)
Utah, University of	31	$1,033
Virginia, University of	35	716
Washington State University	58	293
Washington, University of	11	2,792
Washington University	51	381
Western Reserve University	47	507
Wisconsin, University of	10	3,057
Yale University	9	4,253
Other (176 colleges or universities)		7,675
Total		$128,408

*These costs exclude depreciation and include construction and capital equipment.

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ACF Industries, Inc.
Aerojet-General Corp.
Anaconda Co.
Atlas Corp.
Atomics International
Bendix Corp.
Catalytic Constructlo
Combustion Engineeri
Douglas United Nucl
Dow Chemical Co.
Edgerton, Germeshau
E. I. du Pont de Nem
Federal-Radorock-Ga
General Atomic Divis
General Electric Co.
Goodyear Atomic Co
Holmes & Narver, In
Homestake-Sapin Par
Idaho Nuclear Corp.
Isochem, Inc.
Kerr-McGee Corp.
Martin Marietta Corp
Mason & Hanger-Silas
Monsanto Research C
National Lead Co.
Pan American World
Phillips Petroleum C
Reynolds Electrical a
Sandia Corp.-Western
Union Carbide Corp.
United Nuclear Corp
Utah Construction &
Western Nuclear, Inc.
Westinghouse Electri
Other

Total

*These costs exclu

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 1967, the AEC's principal prime industrial contractors accomplished work amounting to some $1,594 million. The table on this page lists the industrial, supply, production, and research and development contractors who incurred costs exceeding $5 million. Except for depreciation, costs for the operation of laboratories are included in the costs of related contractors.

Industrial organizations	Fiscal year 1967	
	Rank by dollar volume of costs incurred	Total costs* (in thousands)
ACF Industries, Inc.	20	$18,696
Aerojet-General Corp.	9	39,959
Anaconda Co.	28	12,019
Atlas Corp.	25	15,035
Atomics International Division, North American Aviation, Inc.	12	29,182
Bendix Corp.	6	79,145
Catalytic Construction Co.	33	5,454
Combustion Engineering Inc.	32	8,173
Douglas United Nuclear, Inc.	10	39,433
Dow Chemical Co.	11	35,938
Edgerton, Germeshausen & Grier, Inc.	15	27,883
E. I. du Pont de Nemours & Co.	4	105,750
Federal-Radorock-Gas Hills Partners	34	5,368
General Atomic Division, General Dynamics Corp.	26	13,716
General Electric Co.	3	111,384
Goodyear Atomic Corp.	8	43,333
Holmes & Narver, Inc.	17	25,327
Homestake-Sapin Partners	22	17,335
Idaho Nuclear Corp.	14	27,911
Isochem, Inc.	13	28,603
Kerr-McGee Corp.	18	24,483
Martin Marietta Corp.	27	12,143
Mason & Hanger-Silas Mason Co.	23	17,333
Monsanto Research Corp.-Monsanto Co.	16	27,774
National Lead Co.	19	23,190
Pan American World Airways, Inc.	24	15,296
Phillips Petroleum Co.	29	10,567
Reynolds Electrical and Engineering Co., Inc.	5	80,090
Sandia Corp.-Western Electric Co., Inc.	2	202,824
Union Carbide Corp.	1	265,781
United Nuclear Corp.	21	17,503
Utah Construction & Mining Co.	31	8,994
Western Nuclear, Inc.	30	9,208
Westinghouse Electric Corp.	7	65,611
Other	----------	123,356
Total	----------	$1,593,797

*These costs exclude depreciation and include construction and capital equipment.

5010541

AEC PLANT AND EQUIPMENT BY LOCATION

[At costs as of June 30, 1967]

Location and contractor	Authorized plant and equipment (in millions)			
	Completed	Construction work in progress	Estimated cost to complete construction projects [1] [2]	Total
CALIFORNIA				
Aerojet-General Corp., Sacramento				
Reactor Facilities	$0.7	----	----	$0.7
Atomics International, Division of North American Rockwell Corp., Canoga Park and Santa Susana				
Reactor and Research Facilities	52.6	$0.7	$9.0	62.3
California Institute of Technology, Pasadena Research Facilities	1.7	.1	1.9	3.7
University of California, Lawrence Radiation Laboratory:				
Berkeley	108.3	3.4	9.6	121.3
Livermore	176.5	10.8	41.4	228.7
Total	284.8	14.2	51.0	350.0
University of California, Davis				
Bio-Med Research Facilities	4.5	.4	.3	5.2
University of California, Los Angeles				
Medical Research Facilities	1.9	----	.3	2.2
Edgerton, Germeshausen & Grier, Inc., Santa Barbara				
Test Facilities	2.4	.1	.6	3.1
Sandia Corp., Livermore				
Research Facilities	25.9	.3	2.1	28.3
Stanford University, Palo Alto:				
Linear Accelerator	109.0	3.1	3.4	115.5
Other Research Facilities	13.1	4.9	7.5	25.5
Total	122.1	8.0	10.9	141.0
Total California	496.6	23.8	76.1	596.5
COLORADO				
University of Colorado, Boulder	1.5	----	----	1.5
Dow Chemical Co., Boulder				
Rocky Flats Plant	118.5	7.7	52.4	178.6
Lucius Pitkin, Inc., Grand Junction				
Uranium Handling, Sampling and General Facilities	4.2	----	.2	4.4
Total Colorado	124.2	7.7	52.6	184.5
CONNECTICUT				
Combustion Engineering, Inc., Windsor				
Submarine Reactor Facilities	16.3	----	.1	16.4
Yale University, New Haven				
Linear Accelerator	9.7	----	.6	10.3
Total Connecticut	26.0	----	.7	26.7

See footnotes at end of table.

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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				
General Electric Co., Clearwater				
Pinellas Plant	$19.3	$2.1	$5.0	$26.4
IDAHO				
National Reactor Testing Station, Idaho Falls				
Argonne National Laboratory				
Reactor Facilities	42.4	2.9	4.8	50.1
General Electric Co.				
Knolls Atomic Power Laboratory	19.8	----------	.3	20.1
Idaho Nuclear Corp.				
Advanced Test Reactor	48.7	3.1	6.9	58.7
Army Reactor Area	4.5	----------	.2	4.7
Chemical Processing Plant	62.6	.6	2.5	65.7
Engineering Test Reactor	14.8	----------	.1	14.9
Experimental Beryllium Oxide Reactor	10.9	----------	----------	10.9
Experimental Organic Cooled Reactor	9.5	----------	----------	9.5
General Facilities	55.3	.8	3.1	59.2
Materials Test Reactor	15.0	.2	.3	15.5
Test Reactor Area	22.4	.3	1.3	24.0
Total	243.7	5.0	14.4	263.1
Phillips Petroleum Co.				
General Facilities	----------	----------	5.8	5.8
Nuclear Safety Test Engineering	11.7	8.3	13.5	33.5
Power Burst Facility	.1	3.6	7.5	11.2
Special Power Excursion Reactor Test	9.4	----------	.6	10.0
Total	21.2	11.9	27.4	60.5
Westinghouse Electric Corp.				
Large Ship Reactor	35.9	----------	----------	35.9
Submarine Thermal Reactor	16.6	1.2	----------	17.8
Other Research Facilities	18.5	.9	2.3	21.7
Total	71.0	2.1	2.3	75.4
Total Idaho	398.1	21.9	49.2	469.2
ILLINOIS				
University of Chicago, Argonne				
Argonne National Laboratory	282.9	21.8	82.2	386.9
University of Chicago, Chicago				
Argonne Cancer Research Hospital	5.5	.8	1.0	7.3
Research Equipment	1.4	.2	.3	1.9
University of Illinois, Urbana				
Research Facilities	1.7	----------	.7	2.4
Total Illinois	291.5	22.8	84.2	398.5

See footnotes at end of table.

5010543

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
INDIANA				
University of Notre Dame, Notre Dame				
Radiation Laboratory	$2.6	$0.1	$0.6	$3.3
IOWA				
Ames Research Laboratory, Ames				
Research Facilities	16.4	1.0	2.6	20.0
Research Reactor	4.3	.5	.1	4.9
Mason and Hanger, Burlington				
AEC Plant	39.3	.8	6.3	46.4
Total Iowa	60.0	2.3	9.0	71.3
KENTUCKY				
Union Carbide Corp., Paducah				
Feed Materials Plant	31.3	----------	----------	31.3
Gaseous Diffusion Plant	755.1	.5	1.3	756.9
Total Kentucky	786.4	.5	1.3	788.2
MARYLAND				
AEC Headquarters, Germantown	20.3	----------	2.6	22.9
University of Maryland, College Park				
Accelerator	----------	1.1	1.9	3.0
Total Maryland	20.3	1.1	4.5	25.9
MASSACHUSETTS				
Edgerton, Germeshausen & Grier, Inc., Boston				
Research Facilities	5.7	.2	2.5	8.4
Harvard University, Cambridge				
Cambridge Accelerator	20.2	1.4	3.6	25.2
Massachusetts Institute of Technology, Cambridge				
Research Facilities	5.8	.1	6.8	12.7
Total Massachusetts	31.7	1.7	12.9	46.3
MICHIGAN				
University of Michigan, Ann Arbor				
Research Facilities	2.0	----------	.1	2.1
MINNESOTA				
University of Minnesota, Minneapolis				
Linear Accelerator	5.8	.1	.1	6.0
Rural Cooperative Power Assn., Elk River				
Elk River Reactor	8.9	.3	1.4	10.6
Total Minnesota	14.7	.4	1.5	16.6

See footnotes at end of table.

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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
MISSOURI				
The Bendix Corp., Kansas City				
Kansas City Plant	$70.6	$4.5	$8.2	$83.3
National Lead Co., Weldon Spring				
Feed Materials Plant (deactivated)	58.9	----	----	58.9
Total Missouri	129.5	4.5	8.2	142.2
NEBRASKA				
Consumers Public Power District, Hallam				
Hallam Nuclear Power Facility (deactivated)	41.5	----	.1	41.6
NEVADA				
Jackass Flats:				
Nuclear Rocket Development Station Project Rover:				
Los Alamos Scientific Laboratory	15.1	----	----	15.1
Pan American World Airways, Inc	60.9	.8	5.7	67.4
Westinghouse Electric Corp	1.2	.3	----	1.5
Other Research Facilities	1.8	----	----	1.8
Total	79.0	1.1	5.7	85.8
Mercury:				
Edgerton, Germeshausen & Grier, Inc.				
Test Facilities	14.8	.1	3.9	18.8
Lawrence Radiation Laboratory				
Laboratory Facilities	8.6	----	.6	9.2
Reynolds Electrical & Engineering Co.				
Nevada Test Site	129.2	6.1	15.5	150.8
Total	152.6	6.2	20.0	178.8
Sandia Corp., Tonopah				
Research Facilities	11.2	.2	.3	11.7
U.S. Highway 95 Improvement, Las Vegas	4.3	----	.2	4.5
Total Nevada	247.1	7.5	26.2	280.8
NEW JERSEY				
Atomic Energy Commission, New Brunswick				
New Brunswick Laboratory	3.2	----	1.0	4.2
Princeton University, Princeton				
Model C Stellarator Facilities	24.9	----	.4	25.3
Princeton-Pennsylvania Accelerator	30.2	5.0	4.7	39.9
Total New Jersey	58.3	5.0	6.1	69.4

See footnotes at end of table.

5010545

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 MEXICO				
Albuquerque:				
ACF Industries, Inc.				
South Albuquerque Works	$34.8	----------	$0.2	$35.0
Edgerton, Germeshausen & Grier, Inc.				
Test Facilities	2.1	----------	.5	2.6
Lovelace Foundation Laboratory	4.2	$0.1	.7	5.0
Sandia Corp.				
Sandia Laboratory	169.4	9.1	32.0	210.5
Total	210.5	9.2	33.4	253.1
Los Alamos:				
University of California				
Los Alamos Scientific Laboratory	227.4	13.3	41.5	282.2
The Zia Co.				
Community and General Maintenance Facilities	106.0	.3	2.0	108.3
Total	333.4	13.6	43.5	390.5
Total New Mexico	543.9	22.8	76.9	643.6
NEW YORK				
New York City:				
Atomic Energy Commission				
Health and Safety Laboratory	2.5	----------	.2	2.7
Columbia University				
Accelerator and Research Facilities	4.1	.2	.4	4.7
New York University				
Computing and Other Research Facilities	4.1	--------	.1	4.2
Total	10.7	.2	.7	11.6
Associated Universities, Inc., Upton				
Brookhaven National Laboratory	224.4	20.8	71.2	316.4
General Electric Co., Schenectady and West Milton				
Knolls Atomic Power Laboratory	122.5	.5	22.3	145.3
Nuclear Materials and Equipment Corp., Niagara Falls				
Boron Plant	7.7	----------	.6	8.3
Rensselaer Polytechnic Institute, Troy				
Accelerator Facility	2.8	----------	.2	3.0
University of Rochester, Rochester				
Medical Laboratory and 130" Cyclotron	6.6	----------	.6	7.2
Total New York	374.7	21.5	95.6	491.8

See footnotes at end of table.

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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
NORTH CAROLINA				
Duke University, Durham				
Accelerator and Research Facilities	----------	$1.1	$1.4	$2.5
OHIO				
Battelle Memorial Institute, Columbus				
Research Facilities	$1.0	----------	----------	1.0
General Electric Co., Cincinnati				
Research Facilities	10.3	.4	1.1	11.8
Goodyear Atomic Corp., Portsmouth				
Gaseous Diffusion Plant	765.4	.7	1.6	767.7
Monsanto Research Co., Miamisburg				
Mound Laboratory	53.7	10.0	12.4	76.1
National Lead Co., Fernald				
Feed Materials Plant	115.9	.6	3.2	119.7
City of Piqua, Piqua				
Piqua Nuclear Power Facility	9.2	.3	.9	10.4
Reactive Metals, Inc., Ashtabula				
Feed Materials Facility	1.8	----------	.2	2.0
Total Ohio	957.3	12.0	19.4	988.7
PENNSYLVANIA				
Carnegie Institute of Technology, Pittsburgh				
Accelerator and Research Facilities	1.5	----------	----------	1.5
Duquesne Light Co., Shippingport				
Shippingport Atomic Power Station	62.7	.2	.6	63.5
Westinghouse Electric Corp., Large				
Astro Nuclear Laboratory	7.8	.2	.4	8.4
Westinghouse Electric Corp., Pittsburgh				
Bettis Atomic Power Laboratory	60.1	2.3	14.3	76.7
Total Pennsylvania	132.1	2.7	15.3	150.1
SOUTH CAROLINA				
E. I. du Pont de Nemours & Co., Inc., Aiken				
Savannah River Plant				
Feed Materials Production Facility	30.1	2.0	.4	32.5
General Facilities	166.1	.8	5.6	172.5
Heavy Water Production Facilities	163.6	.1	----------	163.7
Laboratory	70.2	2.2	3.1	75.5
Production Reactor and Separation Facilities	904.8	9.3	23.2	937.3
Total South Carolina	1,334.8	14.4	32.3	1,381.5

See footnotes at end of table.

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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;				
Oak Ridge Associated Universities				
Research Laboratory	$5.6	----------	$0.6	$6.2
Rust Engineering Co.				
Service Facilities	10.2	----------	----------	10.2
University of Tennessee				
Agriculture Research Laboratory and Farm	3.3	$0.3	.3	3.9
Union Carbide Corp.				
Gaseous Diffusion Plant	825.9	3.1	5.5	834.5
Oak Ridge National Laboratory	329.0	21.5	26.5	377.0
Y-12 Plant	386.0	2.9	66.5	455.4
Total Tennessee	1,560.0	27.8	99.4	1,687.2
TEXAS				
Mason and Hanger, Amarillo				
Pantex Plant	52.8	.5	8.0	61.3
Rice University, Houston				
Research Facility	1.6	.3	----------	1.9
Texas A and M University, College Station				
Research Facilities	----------	2.6	.4	3.0
Total Texas	54.4	3.4	8.4	66.2
UTAH				
University of Utah, Salt Lake City	1.2	----------	.1	1.3
WASHINGTON				
Richland:				
Battelle Memorial Institute				
Pacific Northwest Laboratory	98.3	4.9	11.0	114.2
Computer Sciences Corp.				
General Facilities	3.8	----------	.7	4.5
Douglas United Nuclear, Inc.				
Feed Materials Production Facilities	24.3	.2	.1	24.6
General Facilities	18.7	----------	.3	19.0
Production Reactor Facilities	574.1	3.6	3.5	581.2
Total	617.1	3.8	3.9	624.8
Isochem, Inc.				
General Facilities	2.9	----------	.4	3.3
Separation Facilities	247.5	11.5	12.2	271.2
Total	250.4	11.5	12.6	274.5
ITT/Federal Support Services, Inc.				
General Facilities	71.5	.7	2.5	74.7
J. A. Jones Construction Co.				
General Facilities	2.4	----------	----------	2.4
Total Washington	1,043.5	20.9	30.7	1,095.1

See footnotes at end of table.

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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
WEST VIRGINIA				
International Nickel Co., Huntington Pilot Plant	$4.7	----------	----------	$4.7
WISCONSIN				
Dairyland Power Cooperative, Genoa LaCrosse Boiling Water Reactor	.1	$10.1	$0.5	10.7
University of Wisconsin, Madison Research Facilities	1.2	----------	.2	1.4
Total Wisconsin	1.3	10.1	.7	12.1
PUERTO RICO				
University of Puerto Rico, Mayaguez and Rio Piedras Puerto Rico Nuclear Center	6.4	.1	2.5	9.0
Puerto Rico Water Resources Authority, Punta Higuera Boiling Nuclear Superheat Power Reactor	13.3	.1	1.0	14.4
Total Puerto Rico	19.7	.2	3.5	23.4
JAPAN				
National Academy of Sciences, Hiroshima Research Facilities	2.9	----------	.3	3.2
ALL OTHER	39.4	4.3	37.2	80.9
TOTAL	8,819.7	242.6	759.5	9,821.8

[1] Includes capital equipment.
[2] Includes plant and capital equipment authorized in Public Law 90-56, approved July 26, 1967.

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