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UNITED STATES ATOMIC ENERGY COMMISSION

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Annual Report to Congress

OF THE

ATOMIC ENERGY COMMISSION

FOR

1966

January 1967

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LETTER OF SUBMITTAL

WASHINGTON, D.C.,
January 31, 1967.

SIRS: We have the honor to submit herewith the Annual Report of the United States Atomic Energy Commission for 1966 as required by the Atomic Energy Act of 1954.

Respectfully,

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

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

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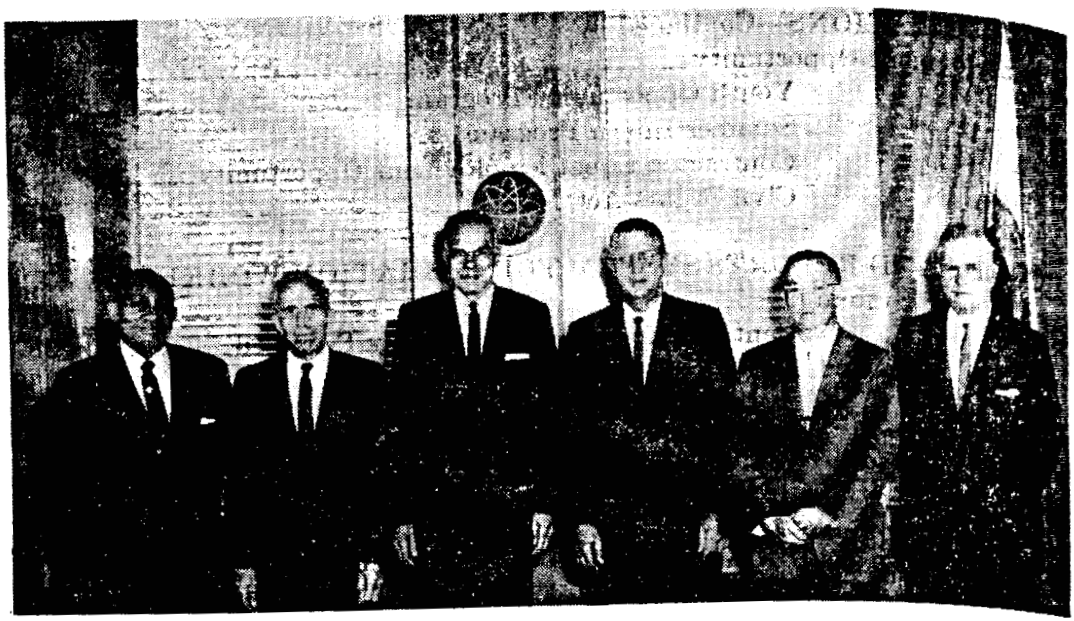

The Atomic Energy Commission. The five-man Atomic Energy Commission and the AEC's General Manager are, reading *left to right*: Commissioner Samuel M. Nabrit, Commissioner Wilfrid E. Johnson, Chairman Glenn T. Seaborg, General Manager Robert E. Hollingsworth, Commissioner James T. Ramey, and Commissioner Gerald F. Tape. Commissioners Nabrit and Johnson were sworn in at a White House ceremony on August 1, 1966, that also commemorated the 20th anniversary of the signing of the Atomic Energy Act of 1946 which established the AEC. Photo *below* shows (*left* to *right*): Carson M. Howell, member of the White House staff, swearing in Commissioners Johnson and Nabrit as President Lyndon B. Johnson and Vice President Hubert H. Humphrey look on.

An Introductio To:

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Because of the t will not be in ope 31, 14 nuclear po Mwe, were operal built, those under c

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An Introduction To:

THE ATOMIC ENERGY PROGRAM IN 1966

The year 1966 saw atomic energy become a major factor in the planning for meeting the Nation's future electric power needs as 55 percent of the new steam-electric generating capacity announced by U.S. utilities was for nuclear plants.

During the 12-month period, the utility industry announced plans for installing 26 individual reactors as the heat sources in central generating stations with an expected output of 21,224 net megawatts of electric power (Mwe). Applications for construction of 16 power reactors were filed during the year, 4 of which had been announced in 1965.

Because of the time necessary for construction, most of these plants will not be in operation before the 1970–72 period. As of December 31, 14 nuclear power stations, having a total capacity of 1,886[1] net Mwe, were operable. (Appendix 4 lists the nuclear plants already built, those under construction, and those planned.)

The orders for nuclear powerplants by utilities in 1966 were greater than had been estimated in the near-term portion of an AEC forecast, announced in early June, of the growth of nuclear power through 1980. However, future orders may follow a cyclical pattern like that characteristic of conventional plants. For the installed capacity of nuclear powerplants in the United States through 1980, the 1966 forecast gave a range of 80,000 to 110,000 Mwe compared with a 1964 AEC estimate of between 60,000 and 90,000 Mwe and an earlier AEC estimate in 1962 of 40,000 Mwe. The mid-point of the 1966 forecast (95,000 Mwe) corresponds to about 25 percent of the Nation's total projected output of electric energy in 1980 (see chart, page 3).

The upsurge in nuclear power station planning had a widespread effect on the nuclear industry as well as on the AEC's operations and

[1] Figure includes AEC-owned Hanford "N" reactor and Shippingport, Pa., reactor which did not require licensing.

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programs. It came at a time when steps were being taken within the AEC to improve and quicken the licensing procedures; it showed the need for new uranium exploration to meet the future fuel needs; it brought about changes in AEC projections of the demand on diffusion plants to enrich uranium to meet civilian power needs; it strengthened the United States' stature in the world's nuclear market; and it testified to the close cooperative effort that has grown over the years between the AEC and industry.

Commissioners

On March 1, 1966, Dr. Glenn T. Seaborg began his sixth year as Chairman of the Atomic Energy Commission. He has held the Chairmanship longer than any of his four predecessors during the 20-year history of the AEC. (Admiral Lewis L. Strauss formerly held the longevity record as AEC Chairman, from June 2, 1953, to June 30, 1958. In addition, Admiral Strauss had also served as a member of the Commission from November 12, 1946, to April 15, 1950, for a combined service record of almost 8½ years.)

Dr. Gerald F. Tape, who was first sworn-in as a Commissioner on July 15, 1963, was reappointed for a 5-year term which expires June 30, 1971. Commissioner James T. Ramey, who was sworn-in on July 1, 1964, is currently serving a 5-year term of office.

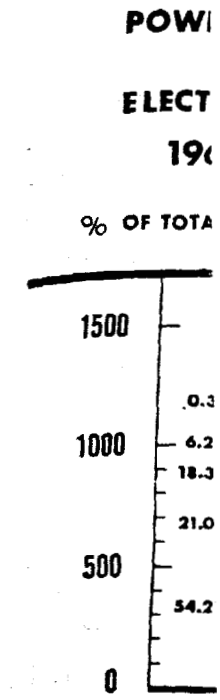
On August 1, 1966, Commissioners Samuel M. Nabrit and Wilfrid E. Johnson were sworn-in. Commissioner Nabrit, who was President of Texas Southern University, Houston, was sworn-in to fill a vacant 5-year term. Commissioner Johnson, who had managed the General Electric Co's operations at the AEC's Hanford, Wash., Plant filled the unexpired term of Commissioner John G. Palfrey who had resigned to take up research work at the John F. Kennedy Memorial Library in Boston. The White House ceremony also marked the 20th anniversary of the signing of the Atomic Energy Act of 1946 which established the AEC.

CONTENTS SUMMARY

On the next 28 pages of this "Annual Report to Congress for 1966"[2] the contents are very briefly summarized on a chapter-by-chapter basis. A supplemental report, "Fundamental Nuclear Energy Research—1966,"[3] describes many of the more noteworthy advances being made under AEC-sponsored basic research and development.

[2] This "Annual Report to Congress for 1966" is available to the public under an alternate title, "Major Activities in the Atomic Energy Programs—January-December 1966", available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for ——.

[3] "Fundamental Nuclear Energy Research—1966" is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $2.50.



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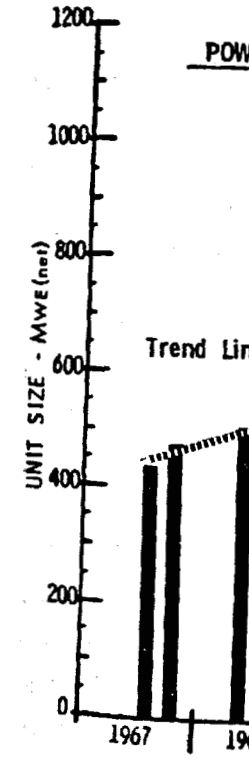
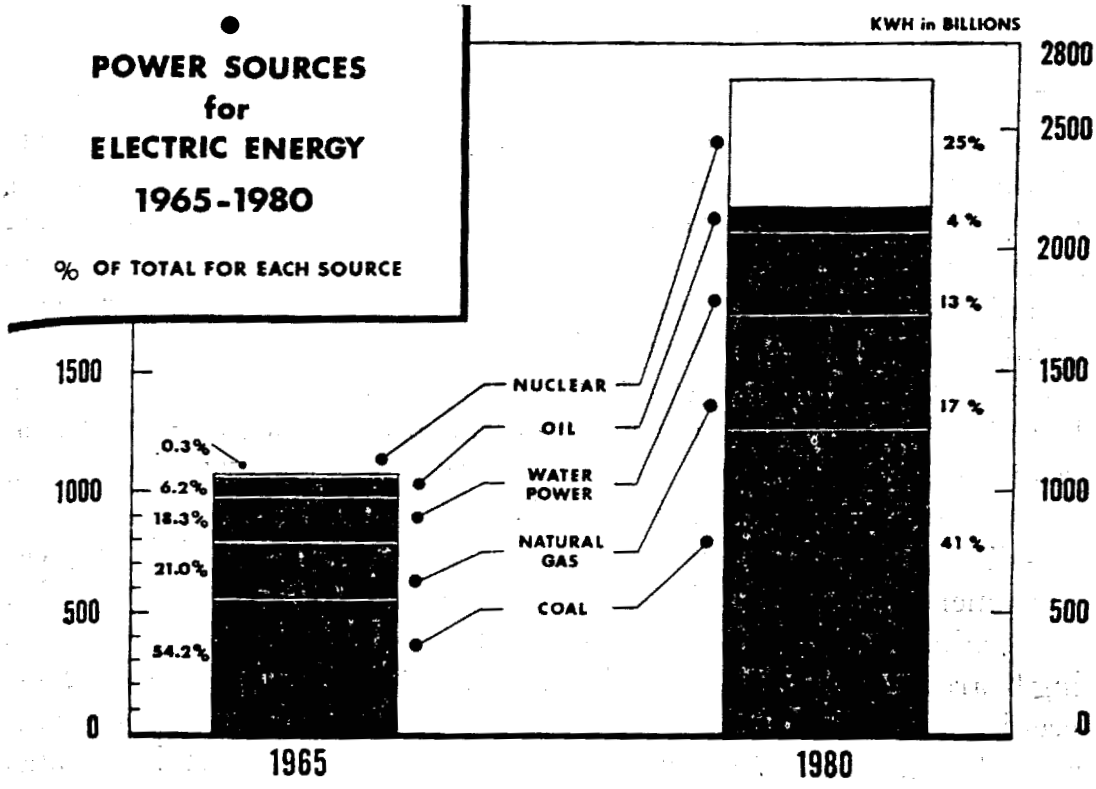
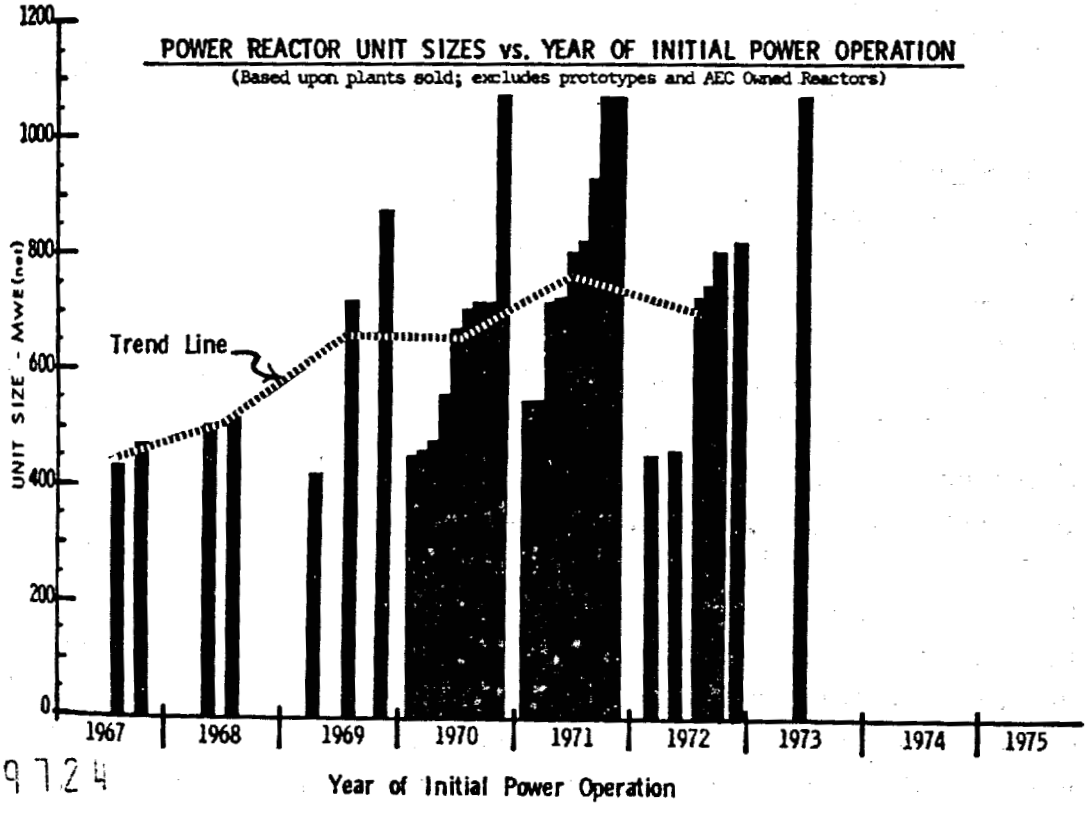




Nuclear Power Growth. As a result of 1966 activities by the utilities industry in planning for nuclear power stations, current forecasts are that by 1980 installed nuclear capacity will be between 80,000 and 110,000 megawatts of electricity (Mwe). As shown in the chart *above* this installed capacity will be capable of producing about 25 percent—as compared to the 0.3 percent in 1965—of the nearly 2,800 billion kilowatt hours of electricity expected to be generated by all means. The chart *below* shows the unit size trend in current reactor plant orders.



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Licensing and Regulating the Atom

● A notable development in the atomic energy field in 1966 was the marked increase in the number of applications to construct and operate civilian nuclear powerplants that were submitted to the AEC. In all, 11 utilities filed applications with the AEC during the year for authority to construct 16 large power reactors with an aggregate capacity of 11,524 electrical megawatts—more than 11 times the total capacity of all licensed nuclear power facilities which had been completed since the first civilian plant began operations a decade ago. The large number of additional utility disclosures of nuclear power plans during the year indicated that the increased rate of construction permit applications will continue into 1967.

● To expedite facility licensing proceedings, the AEC, in September, amended its regulations and issued a statement of general policy concerning the conduct of public hearings by atomic safety and licensing boards. Dealing essentially with uncontested initial licensing proceedings, these actions included clarification of the role of the boards, and liberalization of the "*ex parte*" rule which had restricted intra-agency communications in such cases. Also, during April, the Commission appointed a second review panel from outside the Government to conduct a study aimed at possible improvements in AEC procedures for handling contested nuclear facility licensing cases. This panel's recommendations are expected to be reported in early 1967.

● The AEC has also examined its radioisotope licensing process with the aim of simplifying procedures where possible, consistent with safety. On October 31, the Commission started action to appoint a panel from outside the Government to make an independent appraisal of the developing program, including changes contemplated by the AEC.

● Significant progress was made during the year in the development of safety criteria, standards, and codes for nuclear reactors. A revised technical specifications system for licensed nuclear facilities was issued in proposed form for comment and for interim guidance of applicants. Further guidance on the technical information required of applicants for construction permits and operating licenses was also included in the proposed amendments. Industry participation increased in the development of design and performance criteria for reactor systems, components, and structures.

● The Price-Anderson indemnity legislation was amended in 1966 to authorize the AEC to make emergency payments for the purpose of providing immediate assistance in the unlikely event of a nuclear incident, and to further authorize the waiver of certain defenses in the event of an "extraordinary nuclear occurrence" in order to facilitate recovery of claims for personal injuries or property damage.

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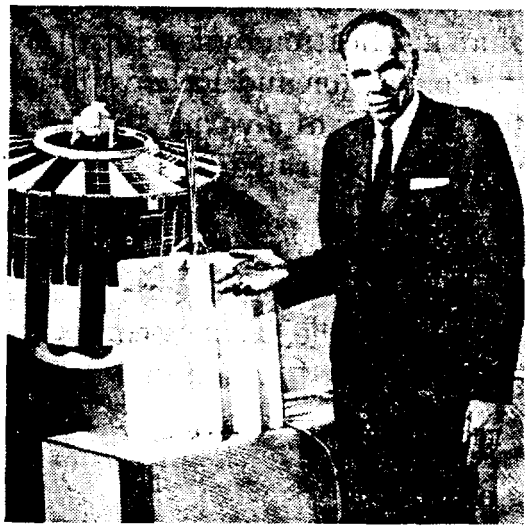
Reactors and Other Nuclear Facilities Licensing

- The AEC issued construction permits for five large nuclear powerplants representing a total capacity of 3,272 Mwe: Consolidated Edison Co.'s Indian Point Unit 2 and Rochester Gas & Electric Co.'s Robert Emmett Ginna Unit 1, in New York; Commonwealth Edison Co.'s Dresden Units 2 and 3 in Illinois; and the Millstone Nuclear Power Station in Connecticut, submitted by the Connecticut Light & Power, Hartford Electric Light, Western Massachusetts Electric and Millstone Point companies.
- A provisional operating license was issued for the Philadelphia Electric Co.'s Peach Bottom Atomic Power Station Unit 1, a 40 Mwe high temperature, gas-cooled reactor in southeastern Pennsylvania, the first of its type to be put into commercial operation in the United States.
- The AEC also issued five construction permits and five operating licenses for research reactors.
- In April, the AEC licensed for operation the first privately owned irradiated nuclear fuel processing plant—constructed in western New York by Nuclear Fuel Services, Inc.—and in November, received an application from the General Electric Co. for permission to construct the second such facility, to be located at Morris, Ill.
- Safety reviews were completed of an application by Isochem Inc., to build the proposed Fission Products Conversion and Encapsulation Plant (FPCE) at Hanford, Wash., for recovery of a variety of radioisotopes from the radioactive waste stream generated at the AEC's Hanford Plant.
- At year's end, the AEC had under review 12 applications for permission to construct 16 central station nuclear power reactors, including the largest yet submitted for licensing—the Tennessee Valley Authority's twin 1,065-Mwe reactors proposed for location in northern Alabama.

The Regulation of Radioactive Materials

- In the field of radioactive materials regulation, the number of licenses administered in both the Federal and State programs continued to increase. Four more States—Alabama, Nebraska, New Hampshire, and Washington—assumed certain of the AEC's regulatory authority over atomic energy materials, bringing to 15 the number of States signing agreements with the AEC under Section 274 of the Atomic Energy Act.
- A Memorandum of Understanding was completed between the AEC and the Interstate Commerce Commission, setting forth the manner in which each agency will exercise its authority with respect to safety in the transport of radioactive materials.

ATOMIC ENERGY LANDMARKS



Historic Landmark No. 1. During the year, the U.S. Department of Interior designated four atomic energy sites as national historic landmarks. The first plaque was unveiled on February 21 in a ceremony commemorating the 25th anniversary of the discovery of the heavy nuclear element, plutonium, and dedicating the discovery laboratory—Room 307 of Gilman Hall on the Berkeley Campus of the University of California—as a National Historic Landmark. The photo shows Under Secretary of Interior John Carver, *left*, with three of the co-discoverers of plutonium, AEC Chairman Glenn T. Seaborg, *second from left*, Dr. Arthur C. Wahl, now professor of chemistry at Washington University, St. Louis, and Dr. Edwin M. McMillan, director of the AEC's Lawrence Radiation Laboratory. Drs. Seaborg and McMillan shared the Nobel Prize for plutonium and related research. The National Historic Landmark plaque has been placed in the room, where the definitive experiment in the discovery of plutonium—its chemical separation—took place on the night of February 23–24, 1941. In photo at *left*, Dr. Seaborg, points to two modern devices that make use of the man-made element, plutonium. In the foreground is the SNAP–27 which will supply power for experiment packages to be left on the moon by astronauts. In the background, is the grapefruit-sized SNAP–3A, atop a Navy navigational satellite. Put into orbit in 1961, the device, powered by plutonium, is still sending signals back to earth. This was the first use of nuclear power in space.

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Historic Landmark No. 2. On August 26, President Lyndon B. Johnson became the first President to visit the AEC's National Reactor Testing Station in Idaho when he unveiled the plaque designating the Experimental Breeder Reactor No. 1 (EBR-I) as a National Historic Landmark. The EBR-I on December 20, 1951, was the first nuclear reactor to generate useful amounts of electricity. Photo *above* shows, *left to right:* Under Secretary of the Interior John A. Carver, AEC Chairman Glenn T. Seaborg, Commissioner Gerald F. Tape, Commissioner Samuel M. Nabrit, Commissioner James T. Ramey, and President Johnson with the National Park Service plaque. Photo *below* shows President Johnson holding the historic light bulb presented to him by Argonne National Laboratory during the ceremony. The bulb is one of the four original bulbs lighted by the world's first useful electricity from atomic heat—produced by EBR-I. *Left to right* are Commissioner James T. Ramey (partially hidden), Rep. Chet Holifield, Chairman of the Joint Committee on Atomic Energy, Chairman Seaborg, and the President.

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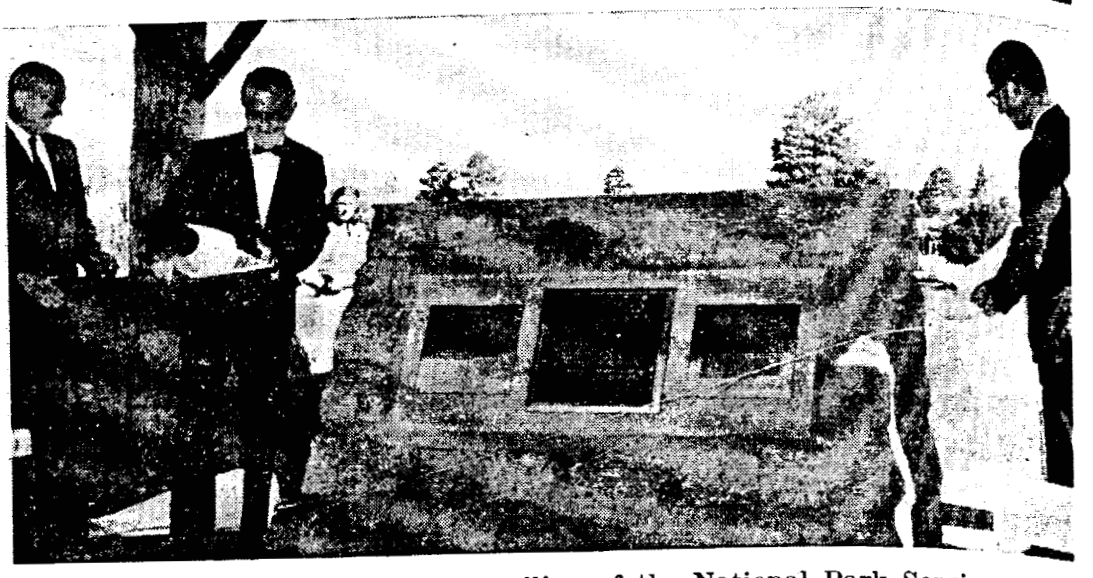
ATOMIC ENERGY LANDMARKS



Historic Landmark No. 3. The unveiling of the National Park Service plaque designating the AEC's Los Alamos Scientific Laboratory as a National Historic Landmark—a site possessing "exceptional value in commemorating or illustrating the history of the United States"—was held on October 8, 1966, at Los Alamos, N. Mex. Taking part in the ceremony were, *left to right*, Dr. Norris E. Bradbury, Director of the Los Alamos Scientific Laboratory; Charles C. Campbell, Area Manager, AEC, Los Alamos Area Office, and William E. Brown, Regional Historian, National Park Service, U.S. Department of the Interior. The two smaller plaques describe the laboratory's achievements in the development of nuclear weapons and contributions to fundamental scientific knowledge and to peaceful applications of atomic energy. The location of the landmark monument is near the spot where components of the first nuclear weapons were assembled in a stone ice house, previously used by the Los Alamos Ranch School to store ice cut from the adjacent pond.

At Idaho Dedication. The dedication of the EBR-1 reactor as a National Historic Landmark drew a wide representation of Federal officials, including (*left to right*) AEC Commissioner James T. Ramey; VAdm. Hyman G. Rickover, USN, Director of the AEC's Division of Naval Reactors, and Deputy Commander for Nuclear Propulsion, Naval Ship Systems Command, U.S. Navy; and John T. Conway, Executive Director of the Joint Committee on Atomic Energy.

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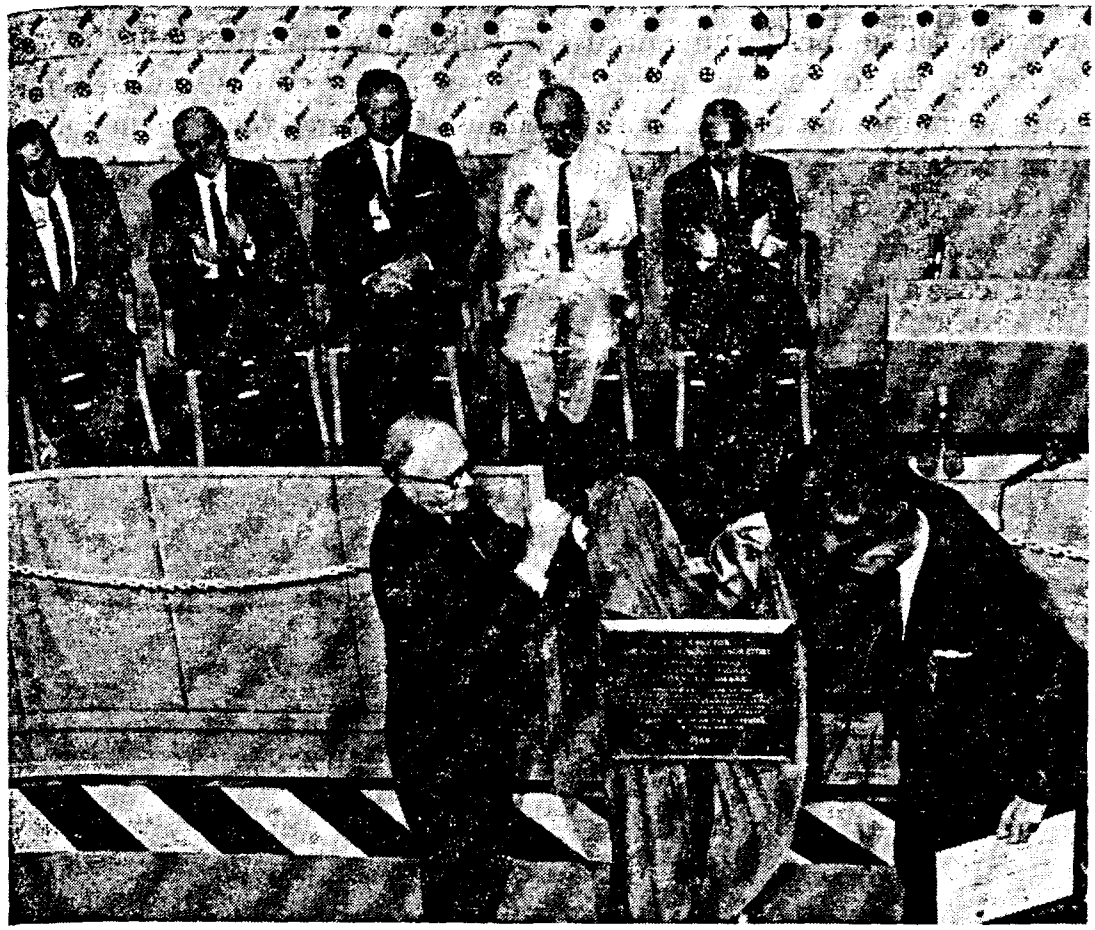
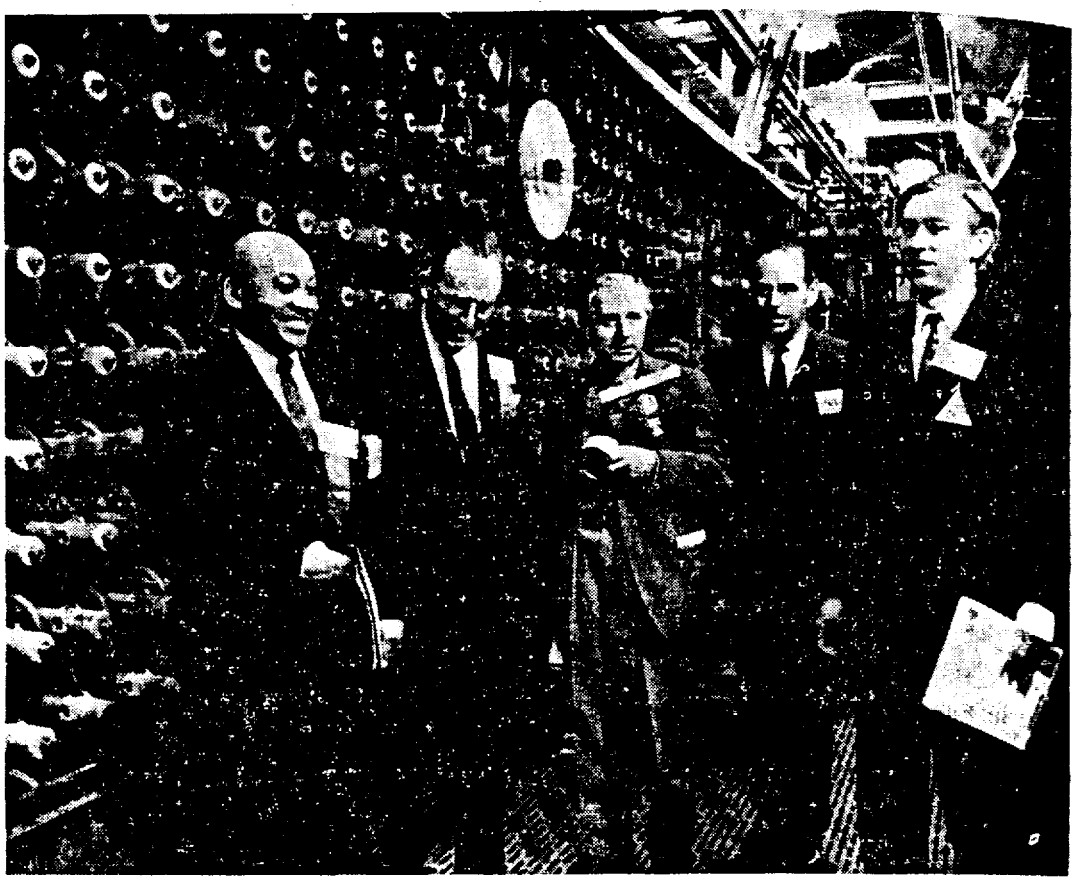


Historic Landmark No. 4. The world's first production reactor and the first to produce usable amounts of radioisotopes—the X-10 Reactor at the AEC's Oak Ridge National Laboratory (ORNL) in Tennessee—was dedicated as a National Historic Landmark on September 13. First operated on November 4, 1943—an event which marked another early step in the beginning of man's control of the tremendous power locked within the nucleus of the atom—the X-10 was shut down in 1963. Construction on the graphite reactor, which was first used to produce fissionable plutonium, had started in February 1943, just two months after the late Enrico Fermi operated the world's first reactor at the University of Chicago. At the time of its closing, the X-10 was the oldest operating reactor in existence. Photo shows Elbert Cox (*left*), regional director of the Southeastern region of the National Park Service, and AEC Chairman Glenn T. Seaborg (*right*) unveiling the commemorative plaque. In the background is the face of the old reactor and, *left to right:* Clark E. Center, a Vice-President of Union Carbide Nuclear Division, Union Carbide Corp., and Production manager at Oak Ridge; S. R. Sapirie, manager of the AEC's Oak Ridge Operations Office; Howard C. Brown, AEC's Assistant General Manager; Dr. Eugene P. Wigner, noted physicist and former Research Director of ORNL; and Dr. Alvin M. Weinberg, Director of ORNL and a Vice-President of Union Carbide Nuclear Division.

Source and Special Nuclear Materials

● Two important steps were taken in 1966 to further implement the Private Ownership of Special Nuclear Materials Act of 1964. One was the establishment on December 23 of criteria for furnishing uranium enrichment services, and the other was the July announcement

of several related policies with respect to sale and lease of enriched uranium. The AEC announced the following post-1968 policies on uranium: (*a*) to continue using the $8 per pound of U_3O_8 charge for the feed component of the AEC schedule of charges for enriched uranium for sale or lease; (*b*) to establish toll enrichment as the preferred method of providing enriched uranium; (*c*) to provide a plan equivalent to toll enrichment under which AEC-owned enriched uranium under lease after December 31, 1970, can be converted to private owner-



Reactor Shutdown Verification Systems. One of the disarmament proposals made by the United States at the 18-Nation Disarmament Conference in Geneva is for agreement to halt the production of fissionable materials for use in nuclear weapons. In connection with the verification requirements of that proposal, the AEC demonstrated a simple, reliable, and easily installed system that could be used to detect whether a production reactor shut down under such an agreement had been operated between visits of inspectors. During November, a large group of representatives of delegations to the United Nations saw the system demonstrated at a reactor which has been shut down since July 1965 at the AEC's Hanford Plant in the State of Washington. Photo shows the face of the reactor with one of the components of the verification system (top center) installed and *left* to *right:* Dr. Samuel M. Nabrit, member of the U.S. Atomic Energy Commission; Adrian S. Fisher, Deputy Director of the U.S. Arms Control and Disarmament Agency; Jacques Tine, French Minister and Deputy Permanent Representative to the United Nations; I. Virgin, member of Swedish Parliament; and Martin M. R. Morland, United Kingdom, Disarmament Delegation. The verification system was developed for the AEC by its contractors at Hanford.

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● The near-term future of the uranium industry brightened as the impact of the Private Ownership of Special Nuclear Materials Act of 1964 began to be evident. For instance, concurrent with the expansion of plans for nuclear powerplants, utilities and other companies which supply nuclear fuel began placing long-term orders for uranium concentrate. Uranium purchased by the AEC became wholly from domestic sources as foreign contracts expired.

● At Hanford, the world's largest operating nuclear power generating station became operational as the 786,000 net electrical kilowatt Washington Public Power Supply System powerplant began to use the steam produced in the AEC's adjacent "N" production reactor in its turbine-generators. However, at year's end, the power output was limited to half its design level because of failure of a high-voltage transformer in the BPA's transmission system.

● A 1-year high-flux demonstration run of a production reactor at the Savannah River Plant, S.C., ended successfully. The reactor had been operated at the highest thermal neutron flux (6.1×10^{15} n/cm^2-sec.) ever attained by any reactor in the world.

● During the year, a simple, reliable, and unobtrusive system for international verification that a nuclear reactor shut down under international agreement had not been operated between inspections, was demonstrated at a shutdown Hanford production reactor to representatives of delegations to the United Nations General Assembly. The system uses a special "fingerprint" seal and tape containing cobalt which would become radioactive if the reactor were operated.

● During the year, the AEC announced that the feed materials plant at Weldon Spring, Mo., would be closed down.

● There was a further total reduction of 715,000 electrical kilowatts in the usage of electricity at the Oak Ridge, Tenn., Portsmouth, Ohio, and Paducah, Ky., gaseous diffusion plants. At year's end, the AEC announced that studies would be made on the possibility of selling or leasing one or more of the gaseous diffusion plants to private industry.

● The AEC withdrew from the routine production and sale of 19 more radioisotopes. This brings the total to 36 radioisotopes which are no longer produced by the AEC since (May 1961) they are commercially available. During the year, the AEC turned over all cobalt 60 encapsulation services, for its own and other Government work, to private industry.

● On July 22, 1966, the Commission appointed an *ad hoc* Advisory Panel on Safeguarding Special Nuclear Material to review and ap-

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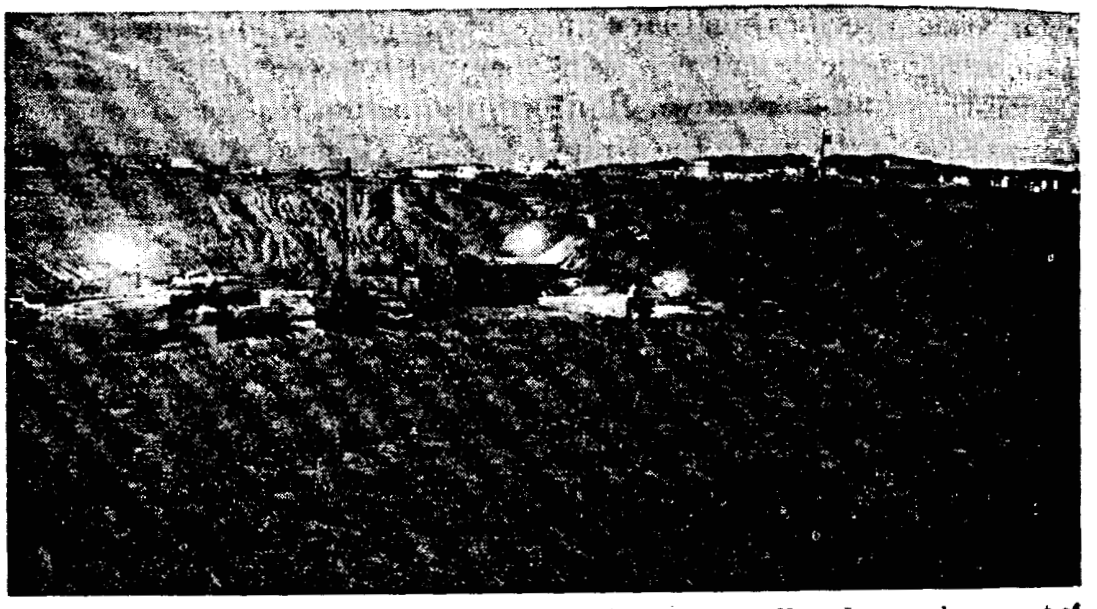
praise current and proposed AEC policies and procedures in connection with the Commission's evaluation of the effectiveness of controls in this field. The Commission has asked the panel to include in its review the U.S. program for safeguarding special nuclear material distributed abroad under the "Atoms for Peace" program. The panel is expected to complete its report early in 1967.

The Nuclear Defense Effort

- The AEC continued: (*a*) the maintenance of the limited nuclear test ban treaty safeguards; (*b*) the development of devices and improved techniques for use in underground testing; and (*c*) the development of devices designed to meet Department of Defense (DOD) requirements. Under Presidential authorization, the production of nuclear weapons continued to meet the DOD military requirements.
- A total of 40 underground nuclear tests were announced during 1966, including 7 DOD effects or detection events and 4 Plowshare events.
- The AEC continued to participate in the joint AEC–DOD Vela program (detection of nuclear explosions underground, in the atmosphere, and in space). The six AEC-instrumented satellites—launched in pairs in 1963, 1964, and 1965—continued their detection function and



Cyclamen Experiment. Re-drilling operations were well underway by sunset of May 5, 1966, the day of the Cyclamen heavy element experiment at the Nevada Test Site. This experiment was an adjunct to a weapons development test. The nuclear detonation occurred 1,000 feet underground and the subsequent collapse of the detonation-produced cavity caused a subsidence on the surface (note the ground cracks in foreground). Three drilling rigs were used to recover samples from just beneath the shot point. Samples must be recovered as rapidly as possible because of the short half-lives of the heavy elements formed during the detonation. The first samples of Cyclamen debris, which contained measurable amounts of fermium 257 (element 100), were recovered and returned to Los Alamos Scientific Laboratory for analysis 26 hours after the detonation.

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preparations were underway for a fourth launch in early 1967. In the Vela Uniform (detection of underground nuclear explosions) program, three prototype unmanned seismic observatories were being evaluated under different climatic environments, and a second nuclear detonation experiment was conducted in the Tatum Salt Dome, near Hattiesburg, Miss.

Naval Propulsion Reactors

● At the end of 1966, the Nation's operational nuclear fleet was composed of 66 submarines, including 40 of the Polaris missile-launching type, and 3 surface ships—an aircraft carrier, a guided-missile frigate, and a guided-missile cruiser. The 41st and last of the Polaris submarines planned—the *Will Rogers*—was launched at mid-year. Congress has authorized the construction of a second nuclear-powered aircraft carrier, a guided-missile frigate, and procurement of long-lead-time material for an additional guided-missile frigate. Development continues on improved naval nuclear propulsion plants and reactor cores for installation in ships ranging in size from aircraft carriers to a small, deep submergence research and oceanographic vehicle.

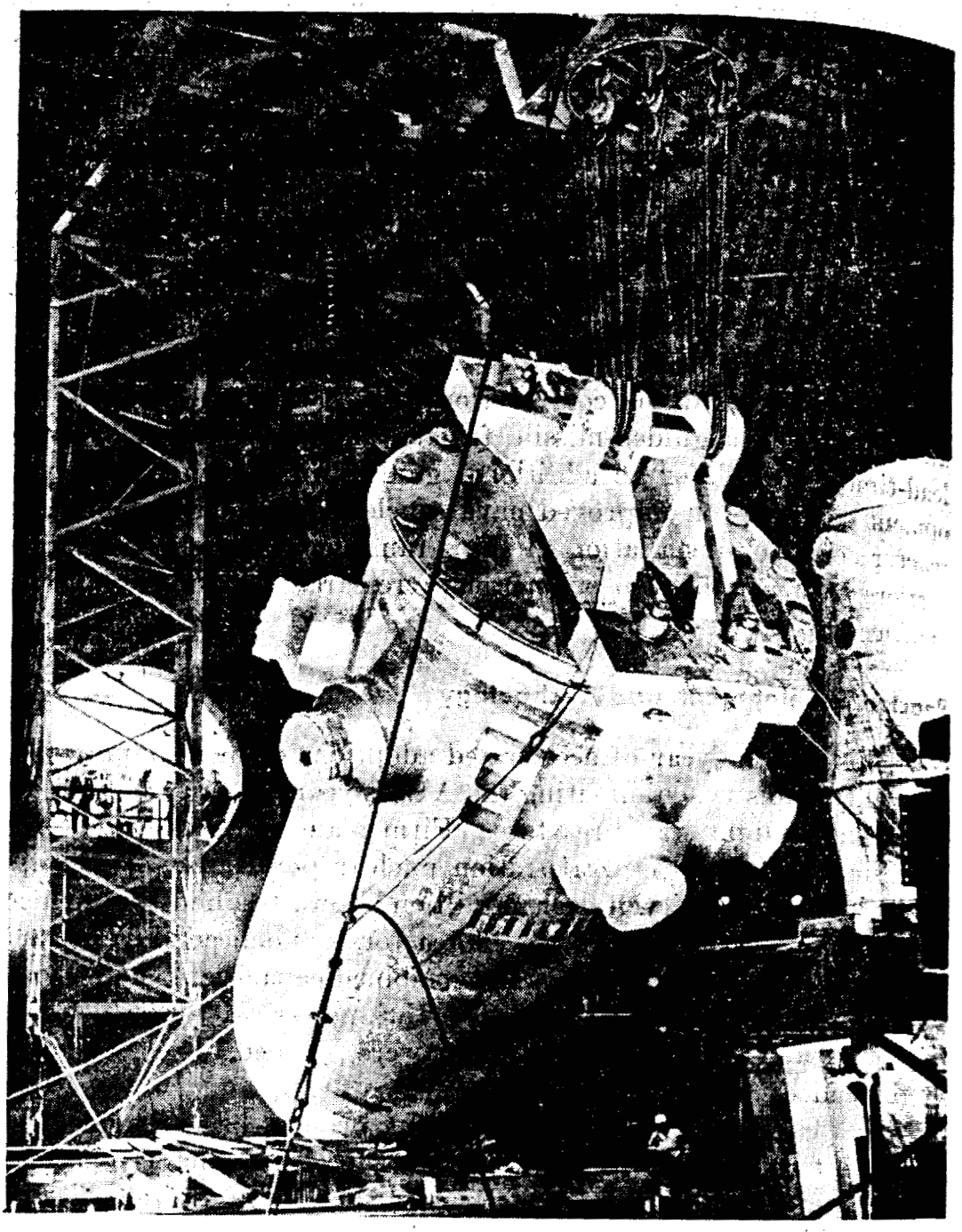
Reactor Development and Technology

● This was the year of accelerated adoptions of nuclear power by the utility industry, culminating the AEC's years of research and development on light water reactors. Firm plans were announced for the installation of 26 central station nuclear power reactors with a total initial net capacity of over 21 million kilowatts, almost four times as much as the capacity of the 10 reactors announced during 1965 and almost six times as much as the combined capacity of the 20 commercial, prototype, and demonstration U.S. power reactors which had been built, were under construction, or were planned for construction by the end of 1964.

● The year also saw the AEC put on a priority basis the development effort on the liquid metal-cooled fast breeder reactor concept—an advanced reactor concept which, when successfully developed and introduced into commercial use, will make use of nearly all the energy contained in the Nation's nuclear fuel resources and thus extend the availability of a low-cost source of energy far into the future.

● Substantial progress was made in the application of nuclear energy to the large-scale desalting of sea and/or brackish water. The AEC received Congressional authorization to participate in a cooperative project with the Metropolitan Water District of Southern California and the Department of the Interior for the construction of a two-unit nuclear power-desalting plant with a combined net electrical

generating capacity of approximately 1,600 Mwe and, initially, a desalting unit capable of reclaiming 50 million gallons per day of fresh water from the sea.



First Plant of Its Size. The San Onofre Nuclear Generating Station in southern California is expected to be in commercial operation in early 1967. This Bechtel Corp. photo shows the 265-ton, 30-foot long pressurized water reactor vessel being moved into position. The turbine generator unit has a 450 Mwe potential rating, although the station will operate at a 375 Mwe level on the initial core loading—72 tons of uranium dioxide that is expected to last about 3½ years. Bechtel is engineer-constructor, and Westinghouse is providing the reactor plant equipment and steam and electrical apparatus for the Southern California Edison and San Diego Gas & Electric companies project. It will be the largest commercial nuclear powerplant to be operated in the United States.

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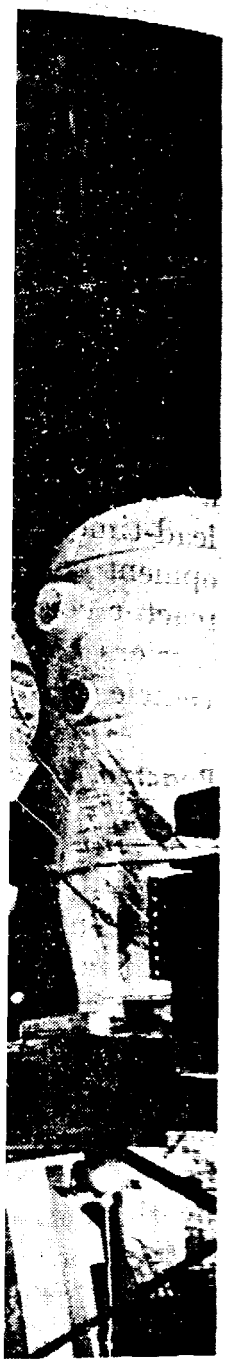

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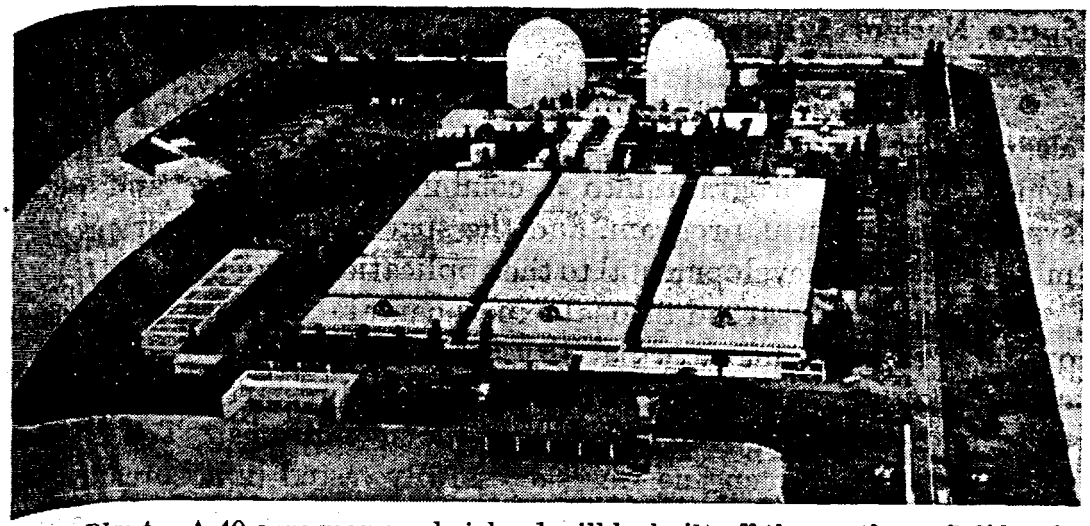

Island Plant. A 40-acre man-made island will be built off the southern California coast for a dual-purpose nuclear power and desalting project being undertaken by the Metropolitan Water District of Southern California (MWD), the AEC, and the Department of Interior. The island, to be built more than a half-mile off shore between Huntington Beach and Seal Beach, will provide room for two 800 Mwe light water reactors which will produce heat for a power station and a desalting facility initially capable of producing 50 million gallons a day (mgd) of potable water from the ocean. This will be the first large-scale demonstration of nuclear energy for these dual purposes. A Bechtel Corp. study showed that the island location would be approximately $30 million cheaper than an alternate land site. The model *above* shows one of the various site plans under study. Photo *below* shows the signing of the agreement that led to the 1966 negotiations for the project. *Left* to *right* are: (*seated*) AEC Commissioner James T. Ramey; Secretary of the Interior Stewart L. Udall; Representative Chet Holifield of California and Chairman of the Joint Committee on Atomic Energy; (*standing*) R. A. Skinner, General Manager of the MWD; Stephen D. Bechtel, Sr., Chairman of the Board of the Bechtel Corp.; and Joseph Jensen, Chairman of the Board, MWD.

Space Nuclear Systems

● In the space nuclear power program, the joint AEC–NASA nuclear-rocket program progressed from a graphite reactor engine system technology program into a combined technology and engine system development program, and the space electric power program moved from the developmental to the applications stage.

● During the year, additional experimental data were accumulated on the high performance capabilities of nuclear-rocket systems. Nuclear rocket reactors were started, stopped, and restarted without difficulty and operated over a wide range of conditions. The Nation's first nuclear-rocket engine was successfully tested in a "breadboard" configuration. Work also proceeded on the next phase of the engine system technology program—to build and test ground experimental engines.

● The year also saw continuing progress in the development of nuclear energy systems to provide the source of electrical energy in space applications. A reactor-powered electric generating system completed one full year of continuous ground-test operation.

Isotopic Heat and Power Applications

● Interest in, and requirements for, radioisotope electric generating systems in the space programs continued to grow. The Department of Defense transmitted definite requirements for radioisotope thermoelectric generators for the provision of power for an advanced navigational satellite. In addition, the DOD stated a definite interest in two other radioisotope generator systems, one for 500-watt short-lived missions and the other for 250-watt long-lived missions.

● First-generation isotope power systems, using strontium 90 as fuel, have been in operation for several years and have clearly demonstrated the feasibility of developing long-lived energy sources capable of unattended operation in remote areas of the world and further progress continued on the development of future systems.

● Studies have indicated the potential usefulness of radioisotopes as an energy source for a cardiac "pacemaker" which would be used to stimulate the pulsing action of a malfunctioning heart. Under the joint sponsorship of the AEC, the National Institutes of Health, and the Newark Beth Israel Hospital, a completely self-contained plutonium 238-powered heart pacer is being developed. It will have a power level of about 30 to 100 microwatts and a functional life of 10 years. Although the medical profession already implants battery-powered "pacemakers" in certain heart patients, these devices require frequent replacement because the batteries are short-lived; the nuclear "pacemaker" would reduce the need for this periodic surgery.

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• Power sources have been fabricated using the metal or compounds of plutonium 238, polonium 210, curium 242, promethium 147, and strontium 90; development of encapsulated fuel forms of curium 244 and cobalt 60 is underway; and cerium 144, cesium 137, thulium 170 and 171, and krypton 85 are under consideration as candidate heat sources. Plutonium 238, already in use as a heat-power source in space satellites, shows a potential usefuness for land and sea thermoelectric units. However, since the overall demand for this radioisotope apparently will exceed the supply in the near future, efforts are underway to use lower-grade plutonium 238, to increase its rate of recovery from scrap generated in fuel source manufacturing, and to explore alternative isotopic fuels, such as curium 244, which have comparable characteristics.

Isotopic Radiation Applications

• The AEC has petitioned the Food and Drug Administration for clearance of radiation processed strawberries for unlimited human consumption. In addition to a four- to seven-day extension that can double the shelf-life of strawberries, significant reductions in spoilage are attainable with radiation. Savings in reduced spoilage will more than off-set irradiation costs. Clearances on one or more of the six species of fish—cod, flounder, haddock, ocean perch, pollack, and sole—previously petitioned are not expected until late 1967, due to FDA's request for additional microbiological and efficacy data. Numerous commercial-like test shipments showed that commercially-packed irradiated haddock fillets had a 17-day storage life while the non-irradiated controls were acceptable up to 11 days. Ten large food store chains with over 8,000 retail outlets are cooperating with the AEC by participating in evaluation studies of the handling of irradiated foods under regular commercial-type shipping and storage. Other recent work has shown that effective control of rots and molds in fruits, such as peaches, can be obtained without textural damage by using a combination hot-water dip plus a radiation dose one-half of that previously required.

• Industry and the AEC have under evaluation several specific radiation processing systems for possible future commercial applications. Examples are paint and electronic components manufacture, and inhibition of bacterial growth in liquid systems, such as in jet fuel and petroleum. Two private firms started producing radiation processed wood-plastic materials in developmental commercial quantities and several others announced they would enter the market in the future.

• An automated quality control pilot plant was put into operation at Austin, Tex., to help the coal, aluminum, and steel industries evaluate neutron activation analysis. The sensitive chemical analyti-

cal method has been successfully applied to measure ash and caloric content in coal and the content of silicon and aluminum in aluminum ore—both on rapidly moving belts. Use of activation analysis in crime detection, now accepted as legal evidence, is increasing. The AEC and the Office of Law Enforcement Assistance of the Department of Justice are developing data to increase the statistical certainty of detection of a wide variety of materials. The Internal Revenue Service has more than 500 cases in which activation analysis is part of the evidence.

The Plowshare Program

● The year was marked by increasing industrial interest and participation in developing underground nuclear explosive engineering techniques to enhance the recovery, or provide for the storage, of natural resources. Initial site preparation was started in New Mexico for Project Gasbuggy—a cooperative AEC-El Paso Natural Gas Co. experiment to increase natural gas productivity. In addition, two gas recovery proposals for the Colorado area were made by industry; an AEC-industry study showed the feasibility of using a nuclear cavity for the storage of natural gas; and 24 firms joined in a study which may lead to a proposal to use nuclear detonations for recovery of oil from oil shale. A major copper company studied the feasibility of a project in which a nuclear explosive would be used to break up an underground copper ore body so that the copper could be leached from the broken ore.

International Cooperation

● Among the important developments in the AEC's international cooperation program was the negotiation of new Agreements for Cooperation under which the United States undertook to sell to other nations special nuclear material to cover long-range nuclear fuel requirements for power reactors. Active cooperative programs were continued with various international atomic energy groups. The International Atomic Energy Agency (IAEA), which has received strong U.S. support, held its 10th annual meeting in September. In October, the third and last power reactor built under the Joint U.S.-Euratom Power Reactor Program achieved criticality.

● The United States continued to emphasize the importance it attaches to achieving wide agreement on international safeguards to assure that nuclear materials and equipment will not be diverted from peaceful to military purposes. The United States, with the cooperation of the privately owned company, made available for international

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inspection by the IAEA the Nuclear Fuel Services, Inc. chemical processing plant. The transfer of bilateral U.S. safeguards responsibilities to administration by the IAEA continued. IAEA inspection of the Yankee Atomic Electric Co.'s reactor at Rowe, Mass., has shown that such inspection does not interfere with plant operations.

- International interest in the development of dual purpose nuclear power-desalting plants continued to grow in 1966. Pursuant to an agreement with Greece, a U.S. team visited Athens during September to work with Greek representatives on the feasibility of a dual purpose nuclear facility for the production of electricity and freshwater in the Athens area. A jointly-financed engineering feasibility study for a nuclear power-desalting plant was concluded by Israel and the United States. The U.S.-Mexican-IAEA nuclear desalting study group met once in 1966.
- The Presidential announcement of an increase to 250,000 kilograms of uranium 235 in enriched uranium allocated for foreign distribution again indicated the importance the United States attaches to providing long-term fuel supplies to foreign countries. By mid-1966, the total value of special nuclear and other materials distributed under the "Atoms for Peace" program was approximately $214.4 million.

Research Facilities and Projects

- A major milestone in high energy physics in the United States was the successful operation of the world's highest energy electron accelerator—the two-mile-long, 20-Bev microwave linear accelerator at the Stanford Linear Accelerator Center (SLAC) near Palo Alto, Calif.
- On November 8, the National Transplutonium Program facilities at Oak Ridge National Laboratory were dedicated. The first two of these facilities, the High Flux Isotope Reactor (HFIR) and the Transuranium Processing Facility (TRU) are already in use for producing transplutonium elements. The facilities provided by the Transuranium Research Laboratory (TRL) make this research complex a focal point for both chemical and physical research with the transplutonium elements.
- On December 16, 1966, the Commission announced its selection of the Weston, Ill., site as the location for the proposal 200-Bev National Accelerator Laboratory. The search for a site for the proposed accelerator facility had been narrowed to six potential locations when a National Academy of Sciences (NAS) committee made its recommendations to the AEC in March. During 1965, the AEC had received

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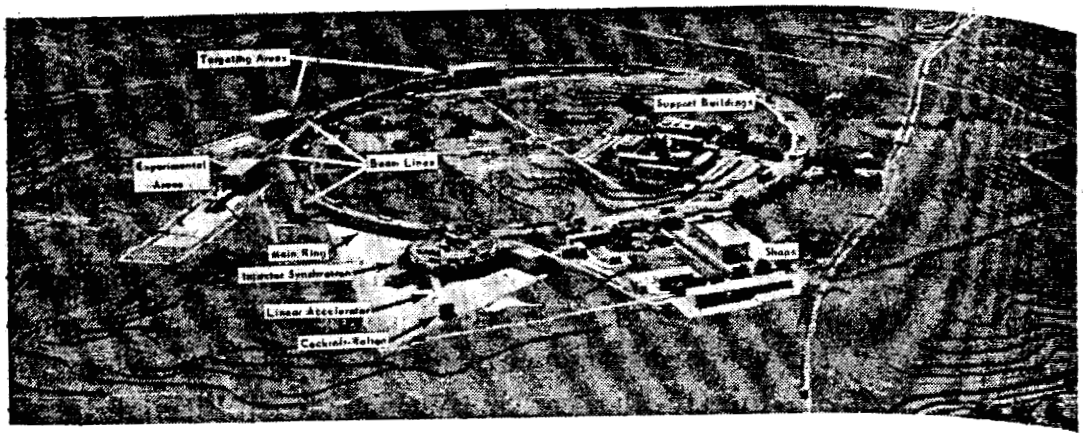
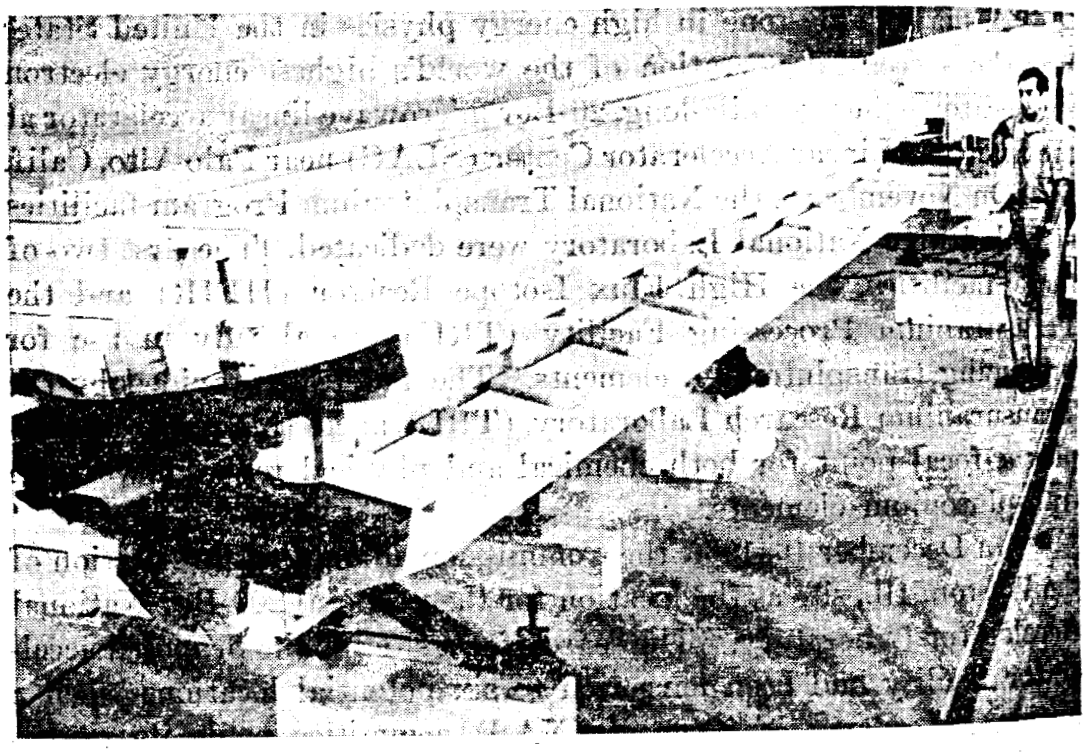


200 Bev Accelerator. Photo, *above,* shows a model of the proposed 200 Bev accelerator and National Accelerator Laboratory which would be built at Weston, Ill. The model was prepared at the AEC's Lawrence Radiation Laboratory, Berkeley, where a group has been conducting design studies of the proposed accelerator since 1963. The model explains the main components of the giant accelerator and the sequence of acceleration of particles: (*a*) the Cockcroft-Walton starts protons off; (*b*) linear accelerator boosts particles to 200 million electron volts; (*c*) injector synchrotron raises energy of protons to 8 billion electron volts (Bev); and (*d*) the main ring, nearly a mile in diameter, in which protons would be accelerated to their ultimate energy of 200 Bev. Two beam lines and experimental areas are also shown. The support buildings of the model include a library, offices, laboratories, computer facilities, cafeteria, etc. Photo, *below,* shows wooden mock-ups of magnets of the type designed at Berkeley for use in the 200 Bev accelerator. The proton beam would pass through the small oblong-shaped pipe (*lower left*).



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126 proposals from 46 States recommending more than 200 sites for the proposed facility. The AEC's evaluation showed 85 proposals as meeting the basic criteria for the location, and it was from these that the NAS committee selected the six best locations: Ann Arbor, Mich; Brookhaven National Laboratory, Upton, N.Y.; Denver, Colo.; Madison, Wis.; Sacramento, Calif.; and Weston, Ill.

- Operation HENRE (High Energy Neutron Reactions Experiment) was started in Nevada for the purpose of improving the understanding of the propagation of neutrons and gamma rays in the atmosphere near the earth's surface. The 1,527-foot BREN tower is being used to hoist an accelerator neutron source for operation at various distances from the surface. The civil defense research project at Oak Ridge National Laboratory, Tenn., was expanded to include studies on biological and chemical weapons defenses so that systems for protection against nuclear effects will not be vulnerable to nonnuclear weapons.
- Construction or remodeling of three laboratories was completed during the year to provide additional space for research on radiation effects in biological systems and atmospheric dispersion of radioactivity. A new low background counting facility will become operational in early 1967 at Brookhaven National Laboratory; a new cocarcinogenesis research laboratory at Oak Ridge is now housed in a building previously used in the uranium production complex; and a new facility has been completed at Pacific Northwest Laboratory for atmospheric science studies.

Nuclear Education and Training

- An estimated 2,300 students and 1,700 faculty from 750 institutions of higher education and 525 high schools participated in the AEC's principal educational assistance programs. In addition, visiting lecturers, consultations, conferences, and seminars were attended by some 6,000 faculty and 24,000 students. These individuals represented all 50 States, the District of Columbia, and Puerto Rico.
- The AEC continued its program for strengthening nuclear science and engineering education in colleges and universities with emphasis upon graduate level courses. A total of 276 predoctoral students were supported on campuses through predoctoral fellowships in nuclear science and engineering, and health physics. The nuclear traineeship program, designed to help increase the numbers of centers of excellence in nuclear engineering, supported 102 graduate students. Faculty institutes, co-sponsored with the National Science Foundation, provided advanced education for 400 college faculty and 550 high school teachers. Teaching equipment grants for nuclear laboratories assisted 114 colleges and universities.

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● Concurrent with the campus-oriented activities, a strong program was maintained for a variety of cooperative endeavors centered at AEC multi-program laboratories through which faculty and students had many opportunities for research participation and study. Laboratory fellowships permitted 116 graduate students to use AEC facilities for thesis research. Through a wide variety of other programs, including seminars, conferences, workshops, courses and general university use of laboratory equipment, a total of 1,100 students and 400 faculty from 550 colleges and universities participated in university-laboratory cooperative programs.

● In September, 10 technicians from 5 multi-program laboratories reported to 8 colleges and universities for undergraduate study. This program permits these students to complete work for baccalaureate degrees which they had been pursuing on a part-time basis for a number of years.

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Informational Activities

● Notable progress was made in planning for the development of an international nuclear information system. Under this system, participating nations would abstract and index their significant literature on peaceful uses of nuclear energy, in return for which they would share in the services and products of a common computer-processed store of information.

● The AEC and NASA began the joint preparation and distribution to industry of summaries of non-nuclear technical innovations resulting from research and development work at Argonne National Laboratory.

● Active and well attended "Atoms in Action" Science Centers were conducted in The Netherlands, Ireland, Costa Rica, and Nicaragua at the invitation of those countries and with the collaboration of their scientists.

● The AEC and its contractors have responded enthusiastically to President Johnson's request to Government agencies for improvement in their service and communications to the public. The AEC's efforts have included posters and letter writing courses to point up the need for clear language in dealing with questions from the public. The AEC's public information staff also has increased its efforts to assist the growing number of utilities interested in nuclear power by providing materials to these companies for their use in public understanding programs. Another indication of interest in atomic energy is found in the increased use of AEC's motion picture film service; 15 new films were added to the film libraries during the year.

● Basic principles in classification and declassification are being revised; coordination was achieved with other Federal agencies on

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Edison Commemoration. For the tenth consecutive year, the AEC and its contractors helped commemorate the February 11 (1857) birthday of Thomas Alva Edison by providing tours of its facilities to high school science students and teachers. Thousands of students and teachers toured various AEC installations during the 1966 commemoration. In photo *above*, the functions of the Sodium Reactor Experiment (SRE) are explained to some of the 500 Los Angeles students who toured the Atomics International-operated facility near Santa Susana, Calif. During December, the decision to deactivate the SRE, which first began operation in 1957 was announced. In photo *below*, a Monsanto Research Corp. scientist explains some of the work being done on heat-producing radioisotopes at the AEC's Mound Laboratory, Miamisburg, Ohio.

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release of space power information; and about 14,000 additional documents were declassified and made available to science and industry.

● The AEC's access permit program continued to provide, on a controlled dissemination basis, classified information in nine areas required by industry but which cannot be declassified. Continuing declassification of research and development work and the related reports has caused the number of access permits to decline from a maximum of 1,432 in 1958 to 427 at the end of November.

● The AEC was granted 251 U.S. and 382 foreign patents during the year and, pursuant to its policy of dissemination of technical information and data to the public, has issued 10 press releases listing new U.S. and foreign patents. A total of 1,158 non-exclusive licenses has been granted on U.S. patents available for licensing. The Commissioner of Patents referred to the AEC for review 699 privately owned patent applications in the atomic energy field under Section 152 of the Atomic Energy Act of 1954, as amended. The AEC has acquired rights in 98 patent applications after completion of investigations.

Operational Safety

● During the year, operations at existing AEC facilities were reviewed for air and water pollution control measures; in general, the operation of AEC facilities meets the requirements of the Executive Orders on abatement of pollution. However, some facilities will require modifications for improved sewage treatment, better confinement of possible leakage from oil and chemical storage tanks, and in one instance, improved treatment of chemical wastes.

● Five AEC contractors and one AEC field office—Dow Chemical Co., Phillips Petroleum Co., South Carolina office of the U.S. Forest Service, E. I. du Pont de Nemours & Co., Las Vegas-Tonapah-Reno Stage Line and the Idaho Operations Office—earned the Commission's Award of Honor for outstanding safety performance. For the sixth time in 11 years, the AEC received the National Safety Council's highest award for an outstanding industrial safety record.

Industrial Participation Aspects

● In working toward a position of industrial maturity—which has been evidenced by the upsurge of power reactor announcements—close cooperation and good communication between the AEC and the nuclear industry have been essential. The Commissioners continued to meet with nuclear industry leaders for a free exchange of ideas and discussion of common problems. Cooperative activities with industry included revisions to the AEC's regulatory procedures, steps directed toward the commercial utilization of plutonium as a reactor fuel, the

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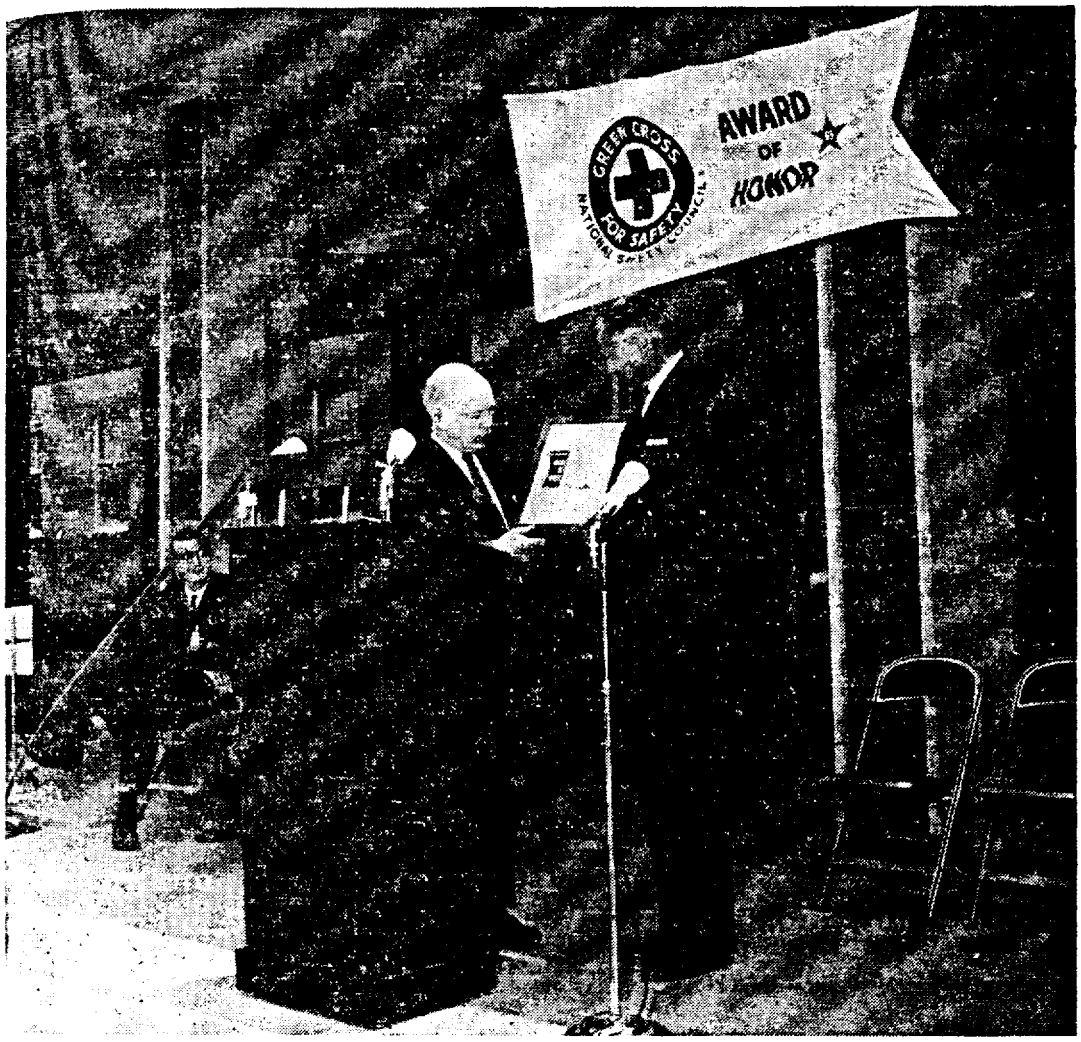
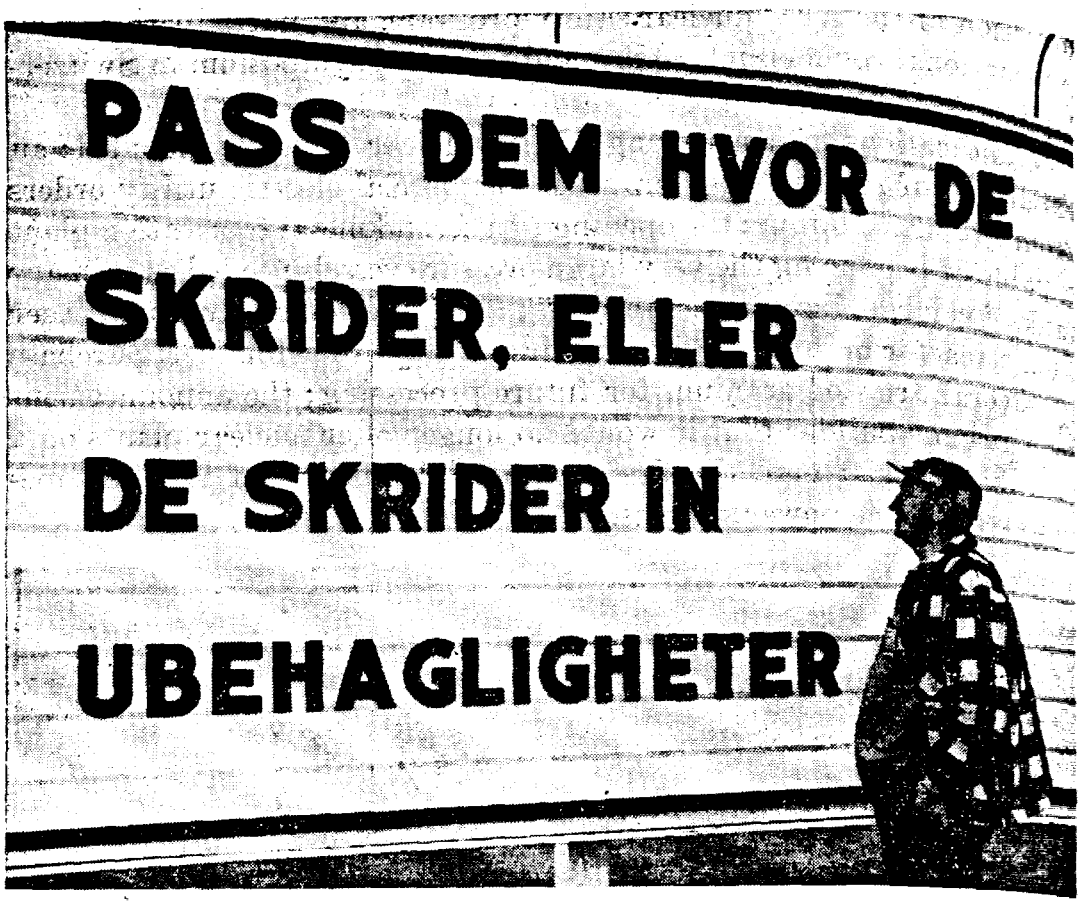
direction of the AEC nuclear safety program, and participation in an international commercial exhibit and technical symposium in Switzerland.

● Indications of a maturing of the nuclear industry included: an expansion of reactor suppliers with commercial electric utility orders from two firms to four; the opening of a second metal fabrication plant capable of producing the very large pressure vessels needed as primary tanks for large, light water reactors; a supplier of reactor fuel, other than a reactor builder, received its first utility order for fuel; purchase by several firms of uranium for future processing; the announcement by a reactor builder that it would no longer offer nuclear plants on a "turnkey" basis; and, the first commercial offering of radioisotope-powered electric power systems.



Sixth National Safety Award. On July 12, AEC Chairman Glenn T. Seaborg (*right*) accepted, on behalf of the AEC and its contractors, the National Safety Council's (NSC) Award of Honor for 1965 from Howard Pyle (center), President of the NSC. The ceremony, marking the sixth time (1955, 1960, 1962, 1963, 1964, and 1965) the coveted honor has been awarded to the AEC, was held at the AEC's Germantown, Md., headquarters. The AEC, through its employees and contractor personnel, has made a notable achievement in industrial safety; for 1965, its safety record ratio was 1.73 as compared with the overall industry average of 6.53.



Safety Slogan. Few employees knew at first glance what this safety sign said at the entrance to Isochem Inc., plant operations at Hanford, Wash. However, those with a knowledge of Swedish understood the safety message: "Watch Where You Step or You'll Step Into Trouble." This unique safety communication accomplished its purpose. Phones rang busily in the safety office as curious callers asked for translations. Those who didn't call read the English version a few days later. The AEC's chemical processing facilities, operated by Isochem since the first of 1966, have turned in excellent safety performance over the years. In the past ten years, four National Safety Council Awards of Honor have been won, each representing three million-man-hours worked without a disabling injury.

● The value of interstate compacts for regional development in the atomic energy field has been well demonstrated by activities of the 5-year-old Southern Interstate Nuclear Board. Steps were also taken by two State Governors' Conferences to form a 13-State Midwest Nuclear Compact, and a 15-State and Territory Western Interstate Agreement.

Administrative and Management Matters

● The last two of seven new contractors previously selected to operate segments of the Hanford production plant and related facilities near Richland, Wash., took over their portions of the work from General Electric Co. Eleven contracting firms now are engaged in a

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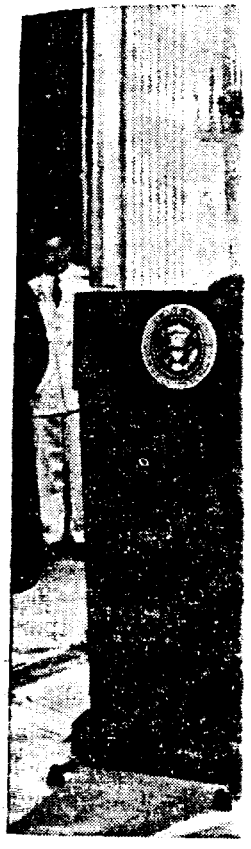

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wide variety of "diversification" projects, which will broaden the economic base of the area. At the National Reactor Testing Station, Idaho, two major firms engaged in nuclear work formed a subsidiary company—Idaho Nuclear Corp.—to take over part of the work previously performed by Phillips Petroleum Co. Phillips will continue to conduct the AEC's extensive safety program at the Idaho station. Under a new contractual arrangement, the development of policies for Argonne National Laboratory (ANL) will be done collaboratively by the Argonne Universities Association and the University of Chicago; the University of Chicago will continue to be responsible for management and operation of ANL, in accordance with these policies.

● Plant facilities of the Connecticut Advanced Nuclear Engineering Laboratory, at Middletown, which had been closed in 1965, were purchased by United Aircraft Corp. for approximately $16 million

Distinguished Service Award. The AEC's General Manager Robert E. Hollingsworth was one of five Government career employees to receive the 1966 President's Award for Distinguished Federal Civilian Service. During the White House ceremony, President Johnson said, "We know from our own history how very important is the fair administration of laws by men who place the country's welfare above their own. This is one definition of a truly good and great public servant." The President characterized Mr. Hollingsworth as a man "who has used imaginative methods within the Atomic Energy Commission, to liberate and encourage the fullest expression of creative energies of his staff." Photo shows (*left to right*) Civil Service Commission Chairman John W. Macy, Jr., Mrs. Hollingsworth, AEC Chairman Glenn T. Seaborg, Mr. Hollingsworth, and the President.

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in a competitive-bid sale conducted by the General Services Administration. The new owner was providing employment for 1,500 workers in the plant at the end of the year.

● Other AEC installations and Federal agencies took advantage of the unique plant facilities and technology available at AEC's Oak Ridge, Tenn., and Paducah, Ky., plants, thus increasing the effective use of these facilities. An extensive vocational-technical training program, under interagency sponsorship, was launched at Oak Ridge.

Lawrence Award. The five scientists chosen to receive the AEC's 1966 Ernest O. Lawrence Award were: Dr. Harold M. Agnew, Los Alamos Scientific Laboratory, Los Alamos, N. Mex., for his highly significant contributions to the development of nuclear weapons and for his outstanding success in working with the Armed Services to assure the maximum safety and effectiveness of atomic weapons systems; Dr. Ernest C. Anderson, Los Alamos Scientific Laboratory, for outstanding contributions to nuclear medicine, to biological research, to archeological dating, and for the development of liquid scintillation counting which made possible early neutrino experiments and the liquid scintillator whole body counter; Dr. Murray Gell-Mann, California Institute of Technology, Pasadena, Calif., 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. John R. Huizenga, Argonne National Laboratory, Argonne, Ill., for outstanding accomplishments in elucidating nuclear fission processes, especially in the study of spontaneous fission; and Mr. Paul R. Vanstrum, Union Carbide Corp., Oak Ridge, Tenn., for his outstanding technical administration and leadership in the development of isotopic separation processes for uranium and for his technical contributions in developing the zonal-gradient liquid centrifuge for biological uses. Each recipient received a citation, a medal, and $5,000. Photo, taken after the April 27 award ceremony, shows (*left to right*) Mr. Vanstrum, Dr. Huizenga, Dr. Anderson, and Dr. Agnew. Dr. Gell-Mann was unable to attend the ceremony.

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- Termination of AEC ownership and management of the utilities and municipal installations at the community of Los Alamos, N. Mex., was moving toward culmination. Los Alamos County has contracted with the AEC to operate in the community area, the gas and electric distribution systems and most all of the municipal functions. The community telephone system was under negotiation for sale, the school facilities were transferred to the County Board of Education Trustees, and real estate sales were progressing.
- Facilities owned by the Government and operated by 40 AEC cost-type contractors employed about 104,000 persons, an increase of 2.7 percent over the previous year.
- During the first 10 months of 1966, 1,448,637 man-hours were lost by strikes representing approximately 0.7 percent of the total working time scheduled compared to 420,885 man-hours or 0.2 percent of scheduled time lost in the same period of 1965. Strikes at the Nevada Test Site, the National Reactor Testing Station, and at the Hanford complex accounted for over 80 percent of the lost time.
- Cost-type contractors at AEC facilities responded to The President's Youth Opportunity Campaign by hiring 1,000 young people during the summer. About one-quarter were members of minority groups. The AEC also instituted a "summer intern program" for students who had completed three years of college; 64 youths took advantage of the program.
- During the year, the percentage of Negroes employed directly by AEC increased from 4.3 to 6.4. In its contractor compliance program, AEC conducted on-site reviews of 582 privately owned establishments. Minority employment by AEC cost-type contractors increased during the year from 5.9 percent to 7.3 percent of total employment.
- The AEC has proposed that the Atomic Energy Act be amended to authorize the AEC to provide financial assistance to States participating in a uniform record-keeping system for radiation workers.
- The Council of State Governments has adopted proposed uniform workmen's compensation legislation for radiation injury, incorporating standards proposed by the AEC.
- Small business, for the fifth consecutive year, continued to receive more than 45 percent of the subcontracts let by AEC prime contractors.
- The Board of Contract Appeals continued throughout 1966 as an effective means of resolving contract disputes. The Board was able to expeditiously resolve contracts disputes, using to the fullest extent the informal procedures established by the board and the mandatory conference which the Commission provided in the board's rules. The membership of the board was expanded to 20 members.

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Fermi Award. The AEC's Enrico Fermi Award for 1966 went to Professor Otto Hahn, 87, who lives in Goettingen, West Germany; Professor Lise Meitner, 87, who was born in Vienna and worked for many years in Germany, who now lives in England; and Professor Fritz Strassmann, 64, Director, Institute of Inorganic and Nuclear Chemistry, Mainz University, Mainz, West Germany. The three scientists were selected as joint recipients because of their combined and individual efforts in discovering nuclear fissioning. Photo *above* shows Drs. Hahn (*left*) and Strassmann (*right*) with AEC Chairman Glenn T. Seaborg after the award ceremony on September 23 during the International Atomic Energy Agency conference in Vienna, Austria. Dr. Meitner was unable to attend the ceremony in Vienna, the city of her birth. Photo *below* shows the award presentation made to Dr. Meitner at her Cambridge, England, home on October 23. On the *left* is Dr. Meitner's nephew, Professor O. R. Frisch, a physicist who collaborated with her in predicting that when an atom of uranium is split—as discovered by Drs. Hahn and Strassmann in 1938—each fragment could ". . . give rise to a chain of disintegrations . . . ." The fissioning discovery and theory led the late Dr. Fermi, leader of a group of scientists at the University of Chicago, to achieve the first self-sustained nuclear chain reaction on December 2, 1942. The 1966 Fermi Award was the first time: (*a*) the $50,000 prize was shared; (*b*) it was presented to foreign scientists; and (*c*) a woman was the recipient.

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Chapter 1

LICENSING AND REGULATING THE ATOM

A marked increase in applications to construct and operate civilian nuclear powerplants in 1966 highlighted the Atomic Energy Commission's task of protecting the public health and safety in the peaceful use of the atom. This, coupled with a growing number of announcements of plans for other nuclear reactors, heralded a period of intense licensing and regulatory activity in connection with the electric power industry's stepped-up schedules for atomic power in the 1970's. During the year, major actions continued to improve the licensing process and further assure the carrying out of the AEC's regulatory responsibilities with respect to both nuclear facilities and the use, transport, and disposal of radioactive materials.

The growth of the industry and the advent of private ownership of special nuclear material also prompted the AEC to begin development of regulatory requirements designed to further assure the safeguarding of special nuclear material from the standpoint of the common defense and security (see Chapter 4—Source and Special Nuclear Materials).

THE INCREASE IN NUCLEAR POWERPLANT APPLICATIONS

The electric power industry's early scheduling of commercial nuclear power on a large scale in 1966 exceeded the most optimistic forecasts. During the year, 11 utilities submitted construction permit applications for 16 power reactors designed to produce an aggregate of 11,524 megawatts of electric power (Mwe). Four of the 16 reactors had been announced as planned during 1965. Nearly all of these proposed reactors are scheduled for commercial operation in 1970 and 1971.

At year's end, applications were in prospect for 16 more large power reactors, plans for which had been publicly announced in 1965 and 1966 by 12 utilities and utility groups. These planned reactors, which would add another 13,072 net Mwe to central station nuclear power-

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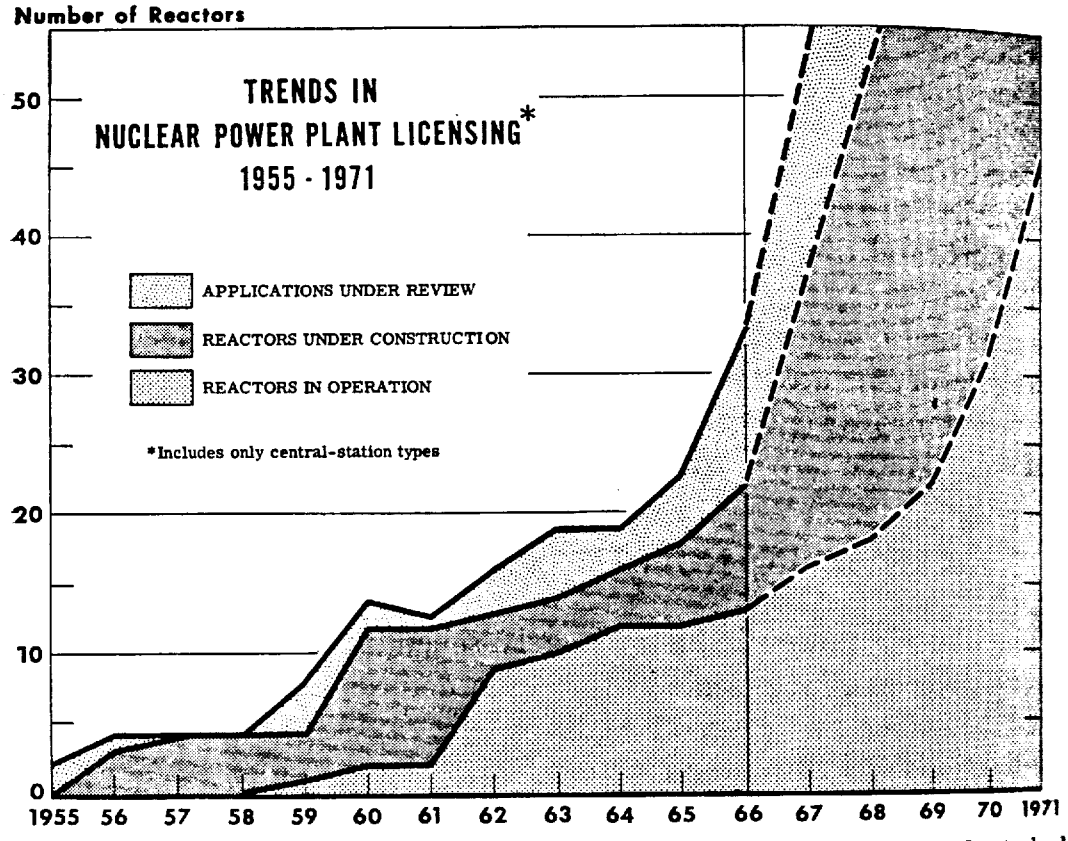
plant capacity, also are projected for commercial operation in the early 1970's.

More Announcements Foreseen

In addition to prelicensing meetings with companies which submitted applications or announced their plans in 1966 to build reactors, the AEC's regulatory staff held discussions with representatives of several other utilities which have either firm or tentative nuclear power plans for the future that had not been publicly announced by year's end. In these meetings, prospective applicants were given informal staff views on siting questions and matters associated with safety features of projected reactors, and information on the procedural aspects of the AEC licensing process. Also, meetings were held with manufacturers to discuss conceptual designs for nuclear reactors, or to conduct prelicensing reviews of reactor systems and components.



Licensing Trend. By the end of 1966, 12 central station nuclear powerplants had been licensed or authorized for operation; 10 others were in various stages of construction; and applications were under review for the construction of 16 more large nuclear power reactors. At year's end, there were indications that the current high rate of applications for construction permits would continue during 1966. In the chart, projections beyond 1966 indicate potential new applications for power reactor construction permits in 1967 and estimated total number of operating power reactors by 1971 if all applications currently under review and those for which plans have been indicated are approved. Licensed reactors continue under AEC surveillance throughout their lifetimes.

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End-of-Year Status

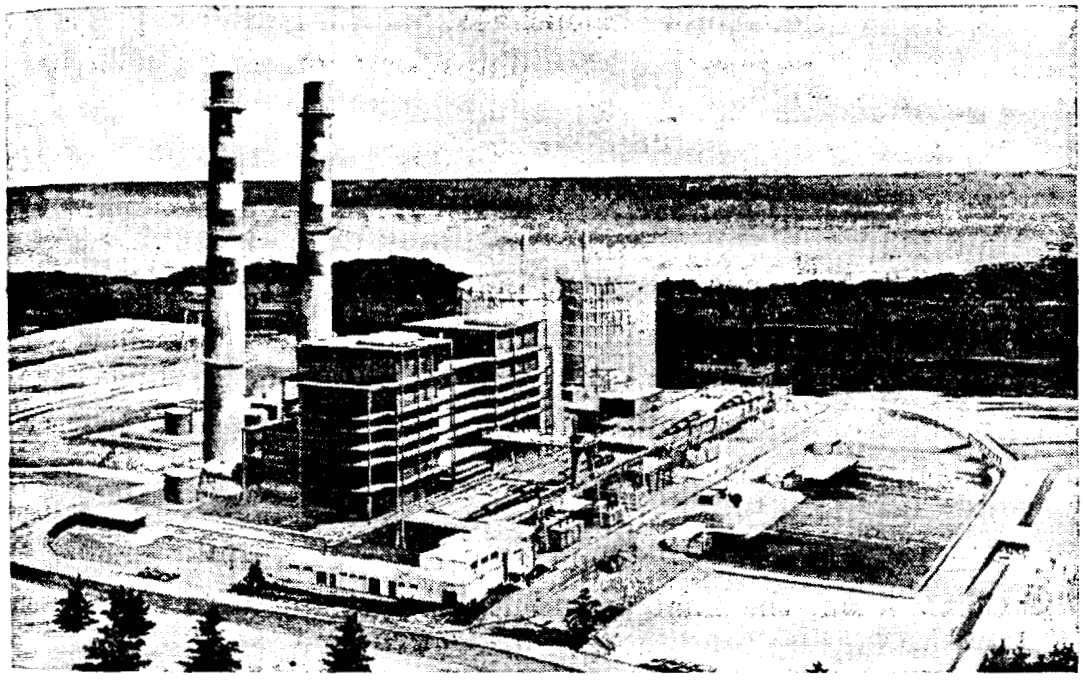
The status of regulated central station nuclear powerplants and applications in process at the end of 1966 was as follows:

- Ten under construction, with capacity of more than 5,000 net Mwe.
- Twelve either in operation or which have achieved criticality, with installed capacity of slightly over 1,000 net Mwe.
- Sixteen under review or awaiting decisions of atomic safety and licensing boards, with a combined capacity of more than 11,000 net Mwe.

(See Appendix 4 for listing of central station nuclear powerplants in operation, under construction, under review, or planned.)

"Double-Header" Applications

Of particular interest among the 1966 applications were reactors larger than any previously proposed for licensing, and four applications for the simultaneous licensing of two reactors. The "double-header" applicants included: the Tennessee Valley Authority (TVA),



Turkey Point. The above is an artist's rendering of the Florida Power & Light Co.'s Turkey Point power generating complex on the southern shore of Biscayne Bay, 30 miles south of Miami. The Bechtel Corp. is performing engineering-construction responsibilities for both the two conventional 425-Mwe units (square buildings in *foreground*) and the two Westinghouse pressurized water nuclear units of 722 Mwe each (circular buildings in *background*). Construction of the initial nuclear unit is slated to begin early in 1967 with operation scheduled for 1970; the second unit will be in operation a year later.

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two 1,065-Mwe reactors at its projected Browns Ferry Nuclear Power Plant near Decatur, Ala.; Florida Power & Light Co., twin 722-Mwe reactors at Turkey Point, Fla.; Commonwealth Edison Co., twin 715-Mwe units near Cordova, Ill.; and Duke Power Co., two 839-Mwe units in western South Carolina. (Individual applications and licensing actions are discussed in Chapter 2—Reactors and Other Nuclear Facilities Licensing.)

IMPROVING THE REGULATORY PROCESS

Keeping pace with the increasing nuclear power activity, the AEC has continued to improve its licensing procedures. Significant progress was made in the further development of reactor safety standards and in providing definitive guidance to utilities and other applicants in the preparation of applications for facility construction permits. During the year, a review panel appointed by the Commission conducted a study designed to seek improvements in the AEC's procedures for handling contested facility licensing cases. In the materials licensing field, another independent panel began a comprehensive review of AEC policies and procedures for regulating and licensing the uses of radioisotopes.

RULE CHANGES AND POLICY

On January 21, 1966, the AEC published in the *Federal Register* for comment and interim guidance: (*a*) proposed changes in its regulations designed to shorten AEC reactor licensing proceedings and to clarify some existing regulations, and (*b*) a Statement of General Policy concerning the conduct of public hearings by atomic safety and licensing boards. Largely reflecting several recommendations made in 1965 by a special Regulatory Review Panel[1] appointed by the Commission, the final amendments and policy statement were

[1] The Regulatory Review Panel (also known as the "Mitchell Panel") appointed by the Commission in 1965 focused its attention primarily on policies and procedures regarding uncontested cases (see pp. 18, 297–299, 305–307, "Annual Report to Congress for 1965"). Members were: William Mitchell, Washington, D.C., attorney and former General Counsel of AEC, *Chairman;* Dr. Manson Benedict, head of the Department of Nuclear Engineering, Massachusetts Institute of Technology, Cambridge; Roger J. Coe, Vice President, Yankee Atomic Electric Co., Boston, Mass.; Dr. Emerson Jones, President, Technical Management, Inc., Lincoln, Nebr.; Dr. C. Rogers McCullough, Senior Vice President, Nuclear Utility Services, Washington, D.C.; James F. Young, Vice President for Engineering Services, General Electric Co., N.Y.C.; and Dr. Walter H. Zinn, Vice President, Combustion Engineering, Windsor, Conn.

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published in the *Federal Register* on September 30, 1966, and became effective October 30, 1966. (Proposed and effective changes in AEC rules and regulations are summarized in Appendix 5.)

CFR Changes

Principal changes to Parts 2, 50, 55, and 115 of Title 10, Code of Federal Regulations (CFR) are:

(*1*) In uncontested facility construction permit application cases, the atomic safety and licensing board will determine: (*a*) whether the application and record of the proceeding contain sufficient information, and (*b*) whether the AEC regulatory staff review has been adequate to support the findings and the issuance of a provisional construction permit as proposed by the Director of Regulation.

(*2*) The Commission's "*ex parte*" rules limiting communications between Commissioners and boards on the one hand, and the AEC staff on the other hand, were relaxed to facilitate Commission review, and to permit greater access by the Commission and its presiding officers (hearing examiners or boards who conduct public hearings) to the expertise of the regulatory staff in dealing with the safety considerations involved in uncontested initial licensing proceedings.

(*3*) Technically qualified alternates may be appointed to atomic safety and licensing boards to serve in the event that a board member should become unavailable before the start of a hearing.

(*4*) The initial decision of a board or a hearing examiner directing issuance or amendment of a construction permit or authorization will become effective immediately, without the necessity of the applicant filing a motion, unless good cause has been shown by a party to the proceeding why the decision should not become immediately effective. The initial decision will continue to be subject to review by the Commission and to any order the Commission may make within 45 days after issuance.

(*5*) Jurisdiction of a board or hearing examiner will terminate at the time the initial decision becomes the final decision of the Commission, or when the Commission takes final action.

(*6*) Clarification was made of the point that certain design and technical information need not be submitted until the operating stage.

The Statement of General Policy explains procedures to be followed by the boards in the conduct of public hearings on construction permit applications.

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Review Panel on Contested Cases

On April 4, a second review panel [2] was appointed by the Commission to study AEC procedures in contested nuclear facility licensing cases and to recommend possible improvements. The new panel study is a sequel to the work of the 1965 Regulatory Review Panel which dealt primarily with uncontested facility cases. The results of the review are expected to be presented to the Commission early in 1967.

DEVELOPMENT OF SAFETY STANDARDS FOR REACTORS

Significant progress in developing reactor safety standards was made, particularly in the areas of: (*a*) general design criteria for nuclear powerplant construction permits, including supplementary design criteria for major components and systems of reactors; and (*b*) improved technical specifications for licensed nuclear facilities and further guidance for applicants on the content and preparation of safety analysis reports.

Design Criteria for Nuclear Reactors

Development continued on the "General Design Criteria for Nuclear Power Plant Construction Permits," which had been issued in proposed form with a public announcement on November 22, 1965,[3] for comment and interim guidance. Representing an effort to set forth design and performance criteria for reactor systems, components, and structures which have evolved in AEC licensing experience, these proposed criteria have already served to guide a number of prospective applicants and reactor equipment manufacturers. Recognizing that additional criteria are needed in the evaluation of reactor design details, the AEC initiated, with industry cooperation, two programs to develop detailed supplementary criteria for water reactors.

A cooperative study has been undertaken under the auspices of the United States of America Standards Institute (USASI) to develop specific design performance criteria for components and systems of pressurized water reactors. Under an experimental arrangement with USASI's Nuclear Standards Board, seven task groups, with regulatory staff assistance, worked on supplementary criteria in assigned areas throughout 1966. The principal manufacturers of pres-

[2] Members are William Mitchell, Washington, D.C., attorney and former General Counsel for the AEC, *Chairman;* Gerald Charnoff, Washington, D.C., attorney and formerly legal projects manager of the Atomic Industrial Forum; and Roger Coe, Vice President, Yankee Atomic Electric Co., Boston, Mass.

[3] AEC press announcement H-252, Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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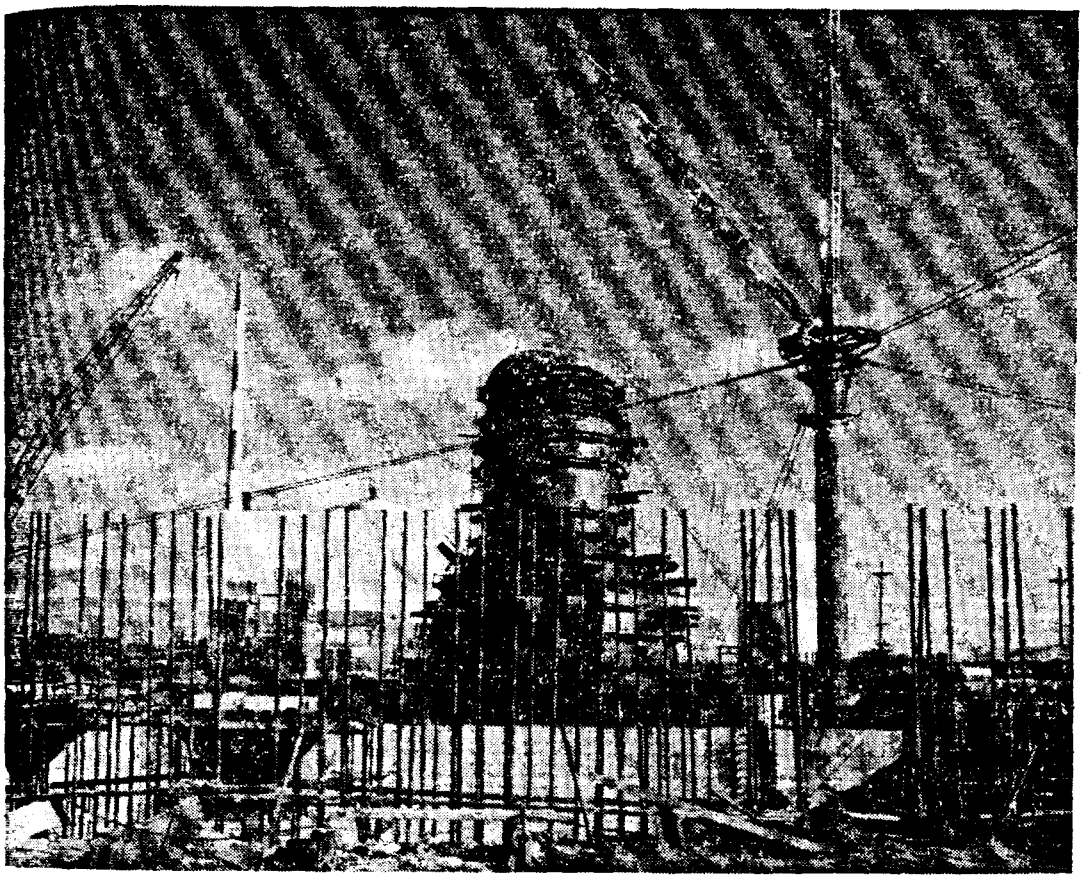
surized water reactors participated in the effort, which is expected to produce draft criteria early in 1967.

In parallel with the pressurized water reactor program, the AEC has undertaken development of similar criteria for boiling water reactors in cooperation with the principal designer of this type.

Code Development for Pressure Vessels

The AEC has cooperated closely with the American Society of Mechanical Engineers' (ASME) Code Committee on Boiler and Pressure Vessels in its effort to extend effectiveness of the code in nuclear applications. This program was aimed at: (*a*) exploring ways in which the code for reactor pressure vessels might be improved, and (*b*) developing procedures to extend equivalent code coverage to



Dresden Units. Workmen at Commonwealth Edison Co.'s Dresden Nuclear Power station near Morris, Ill., in mid-November, 1966, topped out the steel drywell that will enclose the Dresden 2 reactor. Shaped like an inverted light bulb, the 110-foot-high structure contains over 700 tons of steel. Dresden 2, a 715-net-megawatt unit, is scheduled for service early in 1969. A similar unit, Dresden 3, also is under construction at the site (steel rods in *foreground*) and is scheduled for service in 1970. Both additions are being built by General Electric Co., with Sargent & Lundy as the architect-engineer. The tall stack in the *background* is the original Dresden 200 Mwe plant that has been producing commercial electricity since 1960.

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all pressure-retaining components of reactor primary systems such as piping, valves, and pumps.

New Technical Specifications System

A revised system of technical specifications (license conditions) for nuclear reactors was published in the *Federal Register* on August 16 for a 120–day comment period and also to provide interim guidance to applicants for construction permits and operating licenses. Developed over a two-year period with the assistance of a task force that included key AEC regulatory personnel, members of the AEC's Advisory Committee on Reactor Safeguards (ACRS), members of the Atomic Safety and Licensing Board Panel, and scientists from AEC contractor organizations, the proposed changes in 10 CFR Part 50 of AEC regulations are designed to focus attention of both licensee management and the AEC on those reactor features which are vital to safety. Experience has shown that all the previous detail characterizing technical specifications is not essential to safety. Since technical specifications are a part of the operating license of each reactor, and define important safety features which cannot be changed without AEC approval, they are a central feature of the continuing relationship between the AEC and the licensee during the operating lifetime of the reactor.

The proposed new technical specifications system would require applicants, in technical information submitted in support of applications for construction permits, to emphasize the principal safety features of the facility and their relationship to the site. They would also be required to emphasize analysis and evaluation in the final safety analysis report submitted at the operating license stage in order to show that safety functions will be accomplished. The applicant's proposed technical specifications would be required with the application for an operating license.

Under the proposed regulation changes, the applicants also are given definitive guidance, for the first time, on the types of information needed by the AEC at the construction permit stage and at the operating license stage.

To further assist applicants, a "Guide for the Organization and Contents of Safety Analysis Reports" has been prepared. It is designed to expedite review of licensing cases by specifying more clearly the information needed by the AEC in its evaluation.[4]

[4] The guide may be obtained from the Commission's Public Document Room, 1717 H Street, N.W., Washington, D.C., or by writing to the Director, Division of Reactor Licensing, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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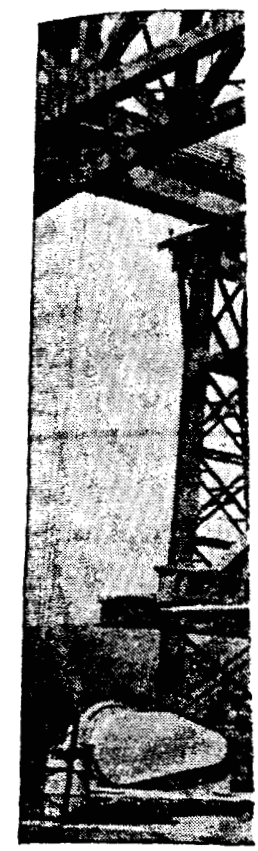

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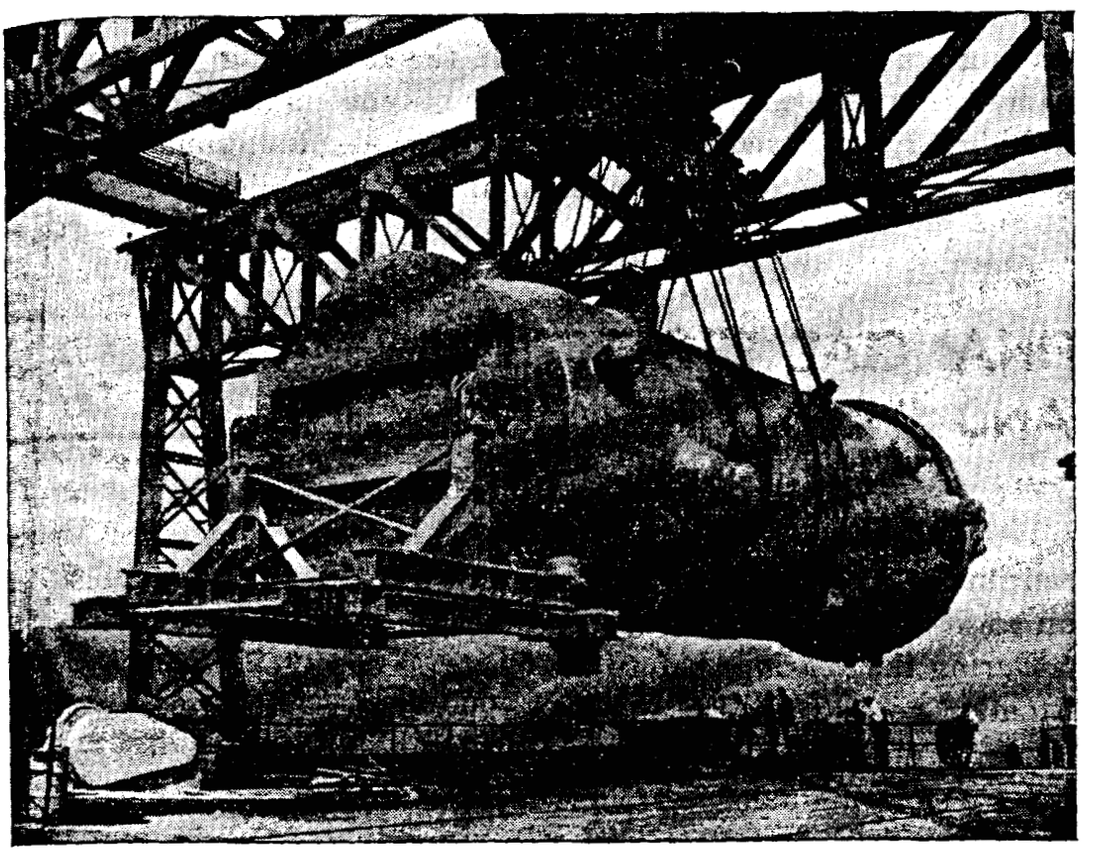
Study Launched on Reactor Fuel Cooling Systems

On October 21, the Commission established a task force [5] from the nuclear industry and the AEC's national laboratories to review emergency core cooling systems for power reactors, and the phenomena associated with core meltdown. AEC staff representatives are participating in the study. The AEC's Advisory Committee on Reactor Safeguards participated in discussions with the Commission leading to establishment of the task force.



Start of Epic Voyage. The 657-ton, 5-story high reactor vessel for the Niagara Mohawk Power Corp.'s nuclear power station on Lake Ontario—largest piece of nuclear power equipment ever made—is shown lifted by a river dock crane for loading onto a special barge on the Tennessee River at Chattanooga, Tenn. Built by Combustion Engineering, Inc., the massive vessel was too large to travel by rail or highway. Thus, it began an epic 2,100-mile voyage on Sept. 30, 1966, which took it over six rivers, two canals, and four of the Great Lakes, terminating in mid-November at the site of the Nine Mile Point Nuclear Station north of Oswego, N.Y., on the shore of Lake Ontario. Starting out on the Tennessee River, the barge also traveled over the Ohio, Mississippi, Illinois, St. Clair and Detroit Rivers, the Chicago Canal, Lakes Michigan, Huron, Ontario, and Erie, and the Welland Canal. Although the Army Corps of Engineers was prepared to lower the level of the Chicago Canal, water ballast was used to permit safe passage, with six inches to spare, under the bridges of downtown Chicago and out onto Lake Michigan. A large crane awaited arrival of the vessel at the site where General Electric Co. is constructing Niagara Mohawk's 500-Mwe boiling water reactor.

[5] Members of the task force are: Dr. William Krasny Ergen, Oak Ridge National Laboratory, Oak Ridge, Tenn., *Chairman;* Dr. Louis Baker, Jr., Argonne National Laboratory,

IMPROVING RADIOISOTOPE LICENSING

On October 31, the Commission appointed an 11-member panel[6] of persons from outside the Government to review and appraise the AEC's policies and procedures for regulating and licensing the uses of by-product materials (radioisotopes).

The AEC has been examining its regulatory program with the aim of simplifying the radioisotope licensing process where possible while maintaining the excellent safety record that has been achieved. In making an independent appraisal of the developing program, the panel will give special attention to changes contemplated by the AEC and identify improvements that might be made. Its recommendations will be reported to the Commission and made public in mid-1967.

FINANCIAL PROTECTION AND INDEMNIFICATION

During 1966, further improvements were made in the Price-Anderson indemnity legislation[7] which Congress had extended in 1965 for an additional 10 years, from August 1, 1967 to August 1, 1977.

During the hearings before the Congressional Joint Committee on Atomic Energy (JCAE) which preceded enactment of the 1965 legislation, a number of problem areas were identified relating to how persons suffering damage from a nuclear incident might obtain rapid and adequate financial compensation.

Argonne, Ill.; Eric Stephen Beckjord, Westinghouse Electric Corp., Pittsburgh, Pa.; A. Philip Bray, General Electric Co., San Jose, Calif.; Dr. Salomon Levy, General Electric Co., San Jose, Calif.; I. Harry Mandil, MPR Associates, Washington, D.C.; David L. Morrison, Battelle Memorial Institute, Columbus, Ohio; Warren E. Nyer, Phillips Petroleum Co., Idaho Falls, Idaho; Michael F. Valerino, Combustion Engineering, Inc., Windsor, Conn.; Robert E. Wascher, Babcock and Wilcox Co., Lynchburg, Va.; and T. R. Wilson, Phillips Petroleum Co., Idaho Falls, Idaho.

[6] Panel members are: George F. Trowbridge, a partner in the Washington, D.C., law firm of Shaw, Pittman, Potts, Trowbridge & Madden, *Chairman;* Dr. Lauchlin M. Currie, Mamaroneck, N. Y.; Dr. John M. Heslep, Department of Public Health, State of California, Berkeley, Calif.; Dr. Wilfred R. Konneker, Mallinckrodt Chemical Works, St. Louis, Mo.; Dr. Seymour Rothchild, New England Nuclear Corp., Boston, Mass.; Dr. Merrill A. Bender, Roswell Park Memorial Institute, Buffalo, N.Y.; Donald T. Green, Picker X-Ray Corp., Cleveland, Ohio; Herbert Parker, Consultant, Pacific Northwest Laboratory, Hanford, Wash.; Dr. John P. Ryan, Minnesota Mining and 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.

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

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Concern was expressed, for example, that there was no assurance that all State courts would impose a rule of strict liability in the event of a nuclear incident. A victim's inability to prove negligence in such a case might preclude compensation for his injury or damage. Further concern involved varying State laws respecting the time within which a tort action may be brought. The limitation period in many States is considered inadequate in cases of delayed manifestation of radiation injuries. Thus, there was concern that victims in different jurisdictions might be subjected to unequal and possibly unfair treatment.

Several related problems were identified including: (*a*) the difficulty that could be expected if a large number of suits arising out of a serious nuclear incident were filed in different jurisdictions, (*b*) the problem of apportioning insurance and indemnity funds, and (*c*) the lack of coordinated procedures for the processing of claims for emergency relief.

1966 AMENDMENTS

Subsequent to the identification of these problems, remedial legislation was drafted through cooperative efforts of the staffs of the AEC, the JCAE, and representatives of utilities, reactor manufacturers, insurers, and suppliers. The bills were introduced by Congressman Price and Senator Anderson. Following hearings before the JCAE on June 19–21, the amending legislation was passed by the Congress and on October 13, was signed by the President. (Public Law 89–645.)

Emergency Assistance Provided

The amendments, among other things, authorize the Commission and insurers to make emergency assistance payments available to claimants immediately following a nuclear incident without requiring claimants to sign a release. In the event of an "extraordinary nuclear occurrence," as defined in the amendments, parties to indemnity agreements or financial protection policies may be required by the Commission to waive certain defenses, including negligence, contributory negligence, governmental immunity, and statutes of limitations shorter than three years from the time the claimant learns of his injury and its cause, up to a maximum of 10 years.

In addition, all actions resulting from an extraordinary nuclear occurrence may be consolidated in the U.S. District Court for the district in which the occurrence takes place, and plans of distribution may be approved by the court if it appears that liability for a single extraordinary nuclear incident may exceed the limitation of liability.

The Commission is now preparing for publication and public comment criteria setting forth the bases it will use in determining whether

an "extraordinary nuclear occurrence" has taken place, as well as appropriate amendments to its regulations.

Agreements in Effect

At the end of the year, 85 indemnity agreements were in effect with AEC licensees. Coverage included the operation of 12 power reactors, 4 test reactors, 71 research reactors, 17 critical facilities, a chemical reprocessing facility, and the N.S. *Savannah;* the storage only of nuclear fuel at 7 reactor sites; and 2 construction permits. During the 12 months ended November 30, the AEC billed a total of $123,573.82 in indemnity fees.

To date, the excellent radiation safety record has been such that there have been no claims under licensee indemnity agreements.

RADIATION SAFETY RECORD OF LICENSEES

The approximately 7,000 AEC materials and facility licensees, as a whole, continued to compile a good radiation safety record during 1966.

Licensees are required by Section 20.403 of the AEC regulation 10 CFR Part 20 to report certain defined incidents occurring in licensed operations which involve human exposures to radiation, the release of radioactive material, the shutdown of facilities, or property damage.[8] In all, 24 incidents of sufficient significance to justify investigation were reported and investigated in the 12-month period ending November 30, and only seven of these resulted in radiation exposures exceeding AEC-specified limits. Nine persons were involved in these exposures, and there were no fatalities due to radiation exposure. (The four facility incidents reported in 1966 are described in Chapter 2 under "Inspections of Facilities," and the 20 incidents involving radioactive materials licensees are discussed in Chapter 3 under "Radiation Incidents.")

In general, the record of AEC licensees in complying with requirements of their licenses and AEC regulations has been very good.

[8] Types of incidents required to be reported pursuant to 10 CFR Part 20 are described on page 302, "Annual Report to Congress for 1965." Licensee reports on all such incidents are filed for public inspection in the AEC Public Document Room, 1717 H Street NW., Washington, D.C. 20545.

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Chapter 2

REACTOR AND OTHER NUCLEAR FACILITY LICENSING

The AEC's regulatory program for nuclear facilities is aimed toward assuring that the construction and operation of reactors and other nuclear facilities is conducted in a manner consistent with public health and safety and the common defense and security. The program encompasses both proposed new facilities and surveillance of operations of existing facilities.

THE REGULATORY PROCESS

In addition to its licensing activities, the AEC's regulatory staff has responsibility for the conduct of safety reviews of reactor facilities owned and operated by the AEC and by the Department of Defense, providing advice on siting, design and operation of reactors, and porting operations for nuclear vessels.

The licensing of a power or test reactor involves a comprehensive safety analysis of the application for a construction permit by the AEC regulatory staff and an independent review by the Advisory Committee on Reactor Safeguards as required by the Atomic Energy Act of 1954, as amended. A mandatory public hearing is then conducted by an atomic safety and licensing board appointed by the Commission from the Atomic Safety and Licensing Board Panel. After the hearing, the board renders an initial decision which is then subject to review by the Commission. Essentially the same type of review process occurs with respect to an application for an operating license, except that a public hearing is not mandatory.[1] Licensed reactors continue under AEC surveillance throughout their lifetimes.

[1] The licensing process is described in detail in the booklet, "Licensing of Power Reactors," which may be obtained, without charge, by writing to the Division of Reactor Licensing, or the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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Role of the ACRS

The Advisory Committee on Reactor Safeguards (ACRS) is a statutory group established to advise the Commission with respect to the safety aspects of proposed and existing nuclear facilities. The committee (see Appendix 2 for listing of members) conducts an independent review of safety studies referred to it and presents its conclusions and recommendations to the Commission in written reports which are made part of the public record, except for classified material. The ACRS not only evaluates the safety aspects of proposed new facilities, but also reviews significant changes to existing facilities or their method of operation, and participates in the preparation and review of proposed safety standards. The ACRS is composed of representatives of the nuclear and other phases of American industry and of several national laboratories and academic institutions, who are experts in their fields with substantial experience in physics, engineering, chemistry, metallurgy, and environmental sciences.

During 1966, the full committee met on 14 occasions, and 69 meetings of ACRS subcommittees were held. The committee provided reports to the Commission on 13 privately or municipally owned facilities, 7 on Commission facilities, and 2 on facilities owned by other government agencies. In addition, the ACRS submitted six reports on general subjects such as periodic, comprehensive (10 year) reviews of operating power reactors and reactor safeguard research, and participated in the development of nuclear facility safety criteria and guides.

ASLB Hearings

Statutory Atomic Safety and Licensing Boards (ASLB) were established in 1962 to permit greater flexibility and informality in the conduct of power reactor licensing proceedings. Prior to the establishment of the boards, the public hearings were conducted by AEC hearing examiners. These boards are selected from a panel (see Appendix 2 for list of members) made up of technically qualified persons from the academic community, private industry, including AEC contractor personnel, and the AEC's hearing examiners. A three-man board—composed of two technical experts and one member qualified in the conduct of administrative proceedings—is drawn from the panel for each licensing matter referred to the ASLB by the Commission. In addition, a technically-qualified alternate is appointed to each board.

During 1966, six new boards were designated.

On November 30, the Commission established the positions of permanent Chairman and Vice Chairman of the ASLB Panel to coordinate the activities of the boards and help expedite the conduct of licensing hearings.

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MAJOR LICENSING ACTIONS

Nuclear facilities licensed or authorized for operation at the end of 1966 totaled 106 as compared to 99 at the end of 1965. These included 16 power reactors, mostly operated by privately owned public utilities; 3 test reactors, 2 owned by industrial firms and 1 by a Federal agency; 16 critical experiment facilities, primarily industrial; 70 research reactors, mostly owned and operated by universities and other educational groups; and 1 chemical separation facility. Also, four licenses for possession only were in effect. In addition, at the end of 1966, 20 construction permits and authorizations were in effect for the construction of 11 power reactors, 1 test reactor and 12 research reactors. (One permit covered five research reactors.)

In addition to undertaking review of the unprecedented number of nuclear powerplant applications received in 1966, the AEC completed several significant licensing actions during the year. These included issuance of:

- Construction permits for five large nuclear powerplants with a total capacity of 3,223 Mwe;
- Provisional operating license for one nuclear powerplant, and a full-term operating license for a second plant;
- Five construction permits and five operating licenses for research reactors; and
- Operating license for the first privately owned irradiated nuclear fuel processing plant.
- The staff also completed its safety review of an application by Isochem Inc., to construct the proposed Fission Products Conversion and Encapsulation Plant at Hanford, Wash., and the Commonwealth Edison Co.'s application to construct two reactors near Cordova, Ill.

At year's end, the AEC had under review 12 construction permit applications for 16 large power reactors—the majority of which were received in the last half of 1966—and for a second irradiated nuclear fuel processing plant.

POWER REACTORS

Significant licensing actions, new applications received, and the status of power reactors under construction are summarized below:

Construction Permit Applications

Malibu Nuclear Plant Unit 1

As a result of exceptions filed to an ASLB's initial decision of July 14, issuance of a construction permit for the Malibu, Calif., nu-

clear plant awaits a formal Commission review (see "Commission Adjudication" summary near end of this chapter).

Turkey Point Station Units 3 and 4

Application for a construction permit and a 40-year operating license was received on March 28 from the Florida Power and Light Co. for two pressurized water reactors at its Dade County, Fla., site. (Two fossil-fueled plants known as Units 1 and 2 are under construction at the same location.) Each reactor will have a 722 net electrical megawatt (Mwe) capacity derived from about 2,300 thermal megawatts (Mwt). They are scheduled for completion in 1970 and 1971, respectively. Westinghouse Electric Corp. will furnish the nuclear steam supply system, turbine generator, and initial fuel. Bechtel Corp. will procure all other materials and equipment for the project, perform engineering and construction services, and administer the Westinghouse contract.

Quad-Cities Station Units 1 and 2

On May 31, an application was received from the Commonwealth Edison Co. seeking a permit to build a large nuclear powerplant near Cordova, Ill., on the Mississippi River, about 20 miles northeast of the "Quad Cities" (Davenport, Iowa; Rock Island, Moline, and East Moline, Ill.). The Iowa-Illinois Gas and Electric Co. would participate in the project—a single-cycle, forced-circulation, boiling water reactor similar to Commonwealth Edison's Dresden 2 unit now under construction. The reactor would produce 715 net Mwe initially at a power level of 2,300 Mwt. It is scheduled for completion in mid-1970, and would be designed and constructed by the General Electric Co.

On August 18, Commonwealth Edison filed an amendment to its application to include Quad-Cities Station Unit 2, a "substantially similar" reactor proposed for construction at the same site, with completion scheduled in mid-1971. A hearing is scheduled to be held before an ASLB at Rock Island, Ill., on January 24, 1967, preceded by a prehearing conference on January 10 at the same location.

Palisades Nuclear Power Station

Application for a construction permit and operating license for a pressurized water reactor to be located on Lake Michigan's eastern shore in Covert Township, Van Buren County, Mich., was received

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June 3 from Consumers Power Co. of Michigan. Initial operation would be at power levels up to 2,200 Mwt with a 700 Mwe net output. Consumers expects an ultimate plant capacity of 821 Mwe derived from 2,640 Mwt. Combustion Engineering, Inc., will supply the nuclear steam supply system and the first core fuel under a fixed price contract, and the Bechtel Corp. will design and furnish the rest of the plant. Completion is expected in September 1970. Consumers already operates the 70-Mwe Big Rock Point Nuclear Plant (in operation since 1962) in northwestern Michigan.

Browns Ferry Nuclear Power Plant Units 1 and 2

The Tennessee Valley Authority (TVA) submitted an application, received on July 13, for a two-unit nuclear powerplant to be located in Limestone County, Ala., about 10 miles from Decatur on the north shore of Wheeler Reservoir. Each of the single-cycle, forced-circulation, boiling water units is designed for initial operation at 3,293 Mwt, producing 1,065 net Mwe—the largest power reactors yet proposed for licensing. General Electric Co. will furnish the major equipment package and be responsible to TVA for safety and adequacy of the plant with the plant itself to be designed and built by TVA. The construction schedule calls for commercial operation of Unit 1 by about October 1970, and Unit 2 a year later.

H. B. Robinson S.E. Plant Unit 2

Carolina Power and Light Co.'s application to build a closed-cycle, pressurized water reactor on the southwestern shore of Lake Robinson near Hartsville, S.C. was received July 25. To be initially operated at 2,094 Mwt with a net electrical output of 663 megawatts, the unit would have a common control room with Unit 1, an existing coal-fired steam electric plant, but with independently functioning equipment. Westinghouse Electric Corp. is handling the project on a turnkey basis with completion scheduled for late 1970. Ebasco Services, Inc., is architect-engineer-constructor.

Monticello Nuclear Generating Plant

Authorization to build a single-cycle, forced-circulation, boiling water reactor near Monticello, Minn., was requested by Northern States Power Co. of Minneapolis, in its application received on August 8. The plant is being designed for an initial power level of 1,469 Mwt and net electrical output of about 472 Mwe. General

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Electric Co. will design, engineer, and construct the reactor and turbogenerator portions of the plant and provide the initial fuel. A novel feature of this project calls for assembly of the reactor pressure vessel at the site, a job assigned to the Chicago Bridge & Iron Co. The construction schedule calls for an early 1967 start and completion late in 1970.

Point Beach Nuclear Plant Unit 1

The Town of Two Creeks, Manitowoc County, Wis., on the western shore of Lake Michigan, is the site of the Wisconsin Michigan Power Co.'s proposed closed-cycle, pressurized water nuclear powerplant. The Milwaukee firm's application, received August 31, is for a reactor designed to operate initially at 455 net Mwe, but the utility anticipates a full capability of 497 net Mwe in its safety analysis report. Certain plant components would be shared with a future Unit 2. Westinghouse was selected as prime contractor, with Bechtel Corp. the project engineer-constructor. Mid-1970 is the latest estimate for construction completion.

Fort St. Vrain Nuclear Generating Station

Application for a construction permit for a high-temperature, gas-cooled reactor—the first for a commercial power reactor in the Rocky Mountain area—was received October 20 from Public Service Co. of Colorado, located in Denver. The plant, to be a part of the AEC's Power Reactor Demonstration Program, will use reactor design principles similar to those of the Peach Bottom, Pa., reactor in producing a net electrical output of 330 Mw derived from 837 Mwt. The 2,163-acre site in Weld County, Colo., is 3½ miles northwest from Platteville and 35 miles north of Denver near the joining of the South Platte and St. Vrain Rivers. General Atomic Division of General Dynamics Corp. will design and construct the reactor, and fabricate and supply the fuel.

Oconee Nuclear Station Units 1 and 2

Duke Power Co., on Dec. 1, became the fourth 1966 applicant to file a "double-header" application for construction permits. The proposed twin pressurized water reactors would be located in eastern Oconee County, S.C., about 8 miles from Seneca and 21 from Anderson. The Babcock & Wilcox Co. will design, furnish, and provide technical supervision for erection, testing, and start-up of both nuclear steam supply systems, and furnish initial fuel. Bechtel Corp., serving as general consultant, will provide engineering assistance and advice during plant design and construction. It also will lay out and design the

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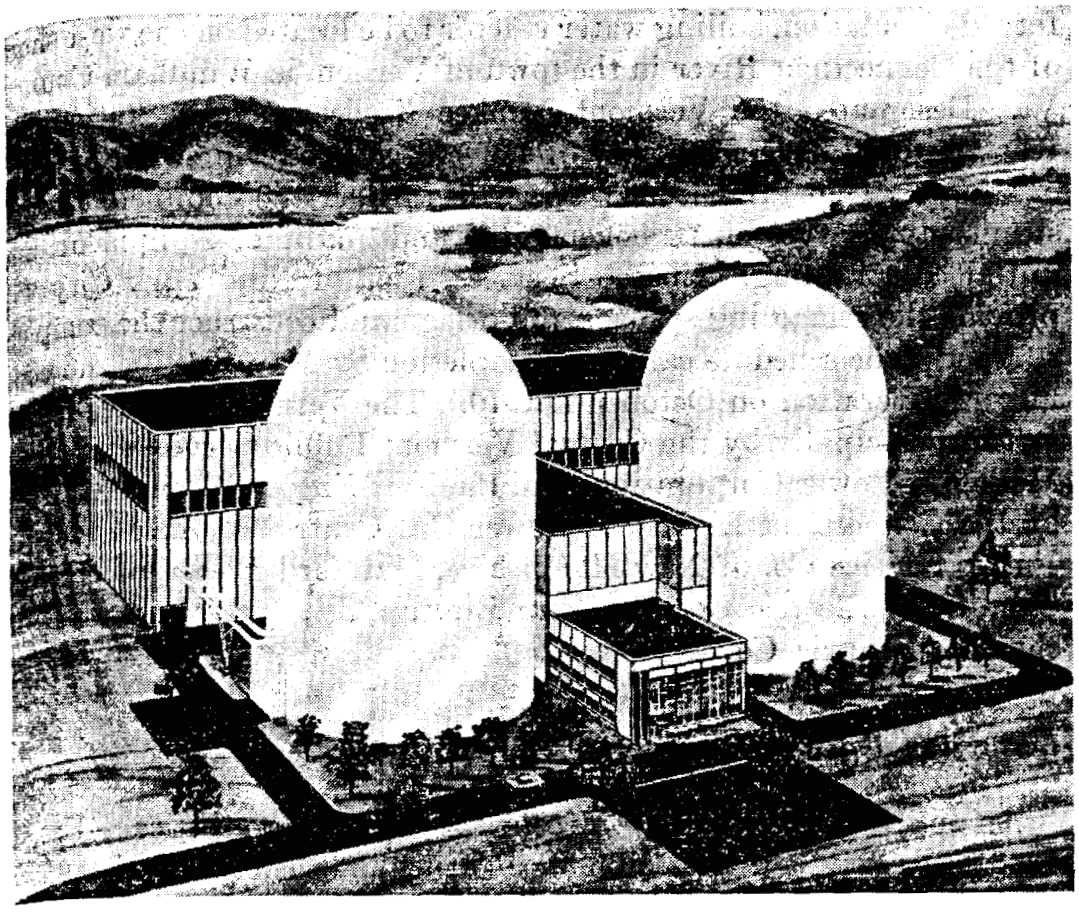

Oconee Nuclear Station. During the year, the Duke Power Co. ordered from the Babcock & Wilcox Co. two 839-Mwe pressurized water power reactors that will be the initial increment of a large-scale power generating complex in the northwestern corner of South Carolina. The project involves the damming of six small rivers to create two lakes as well as the construction of hydroelectric (conventional and pump-storage) plants and the nuclear units for a combined thermal and hydro capacity of more than 7,000 Mwe. The Bechtel Corp. artist's drawing shows the twin nuclear units; the first one is expected to be in operation in mid-1971, the second one, a year later. The two reactor vessels—42 feet high, 16 feet in diameter (outside), and each weighing 400 tons—will be fabricated at the new B&W facility near Mt. Vernon, Ind.

prestressed concrete, post-tensioned reactor building. Each reactor unit is planned to operate initially at power levels up to 2,452 Mwt, or 839 net Mwe, with an estimated ultimate output of 874 Mwe derived from 2,584 Mwt. Construction schedule calls for a September 1, 1967 start on Unit 1 and completion is December 1970, with Unit 2 to follow a year later.

An additional nuclear generating unit is being contemplated at the same site.

Vermont Yankee Nuclear Power Station

On Dec. 2, an application was received from the Vermont Yankee Nuclear Power Corp. for a construction permit for a single-cycle,

forced-circulation, boiling water reactor to be located on the west shore of the Connecticut River in the town of Vernon, in Windham County, Vt. Designated the Vermont Yankee Nuclear Power Station, the reactor would have a capacity of 1,593 Mwt, producing a net of about 514 Mwe. General Electric Co. will furnish the complete nuclear steam supply system, turbogenerator and auxiliary equipment, and initial core loading. Ebasco Services, Inc., of New York City will provide the remaining systems and design and construct the complete station. The schedule calls for completion by May 1, 1970, and commercial operation on October 1, 1970. The Vermont Yankee firm is owned principally by the Central Vermont Public Service and Green Mountain Power Corporations and the New England Power Co.; and by the Connecticut Light and Power Co., Central Maine Power Co., Public Service Co. of New Hampshire, Hartford Electric Light Co., Cambridge Electric Co., Montaup Electric Co., and Western Massachusetts Electric Co.

Burlington Nuclear Generating Station Unit 1

An application was received from a group of four utilities on Dec. 13, 1966, requesting authorization to construct a large Westinghouse Electric closed-cycle, pressurized water reactor on the Delaware River in New Jersey. The design calls for initial power of 3,083 Mwt, producing 993 net Mwe, and eventual output of 3,217 Mwt (1,033 net Mwe). Public Service Electric & Gas Co. filed the application for itself and three other owners—Atlantic City Electric, Delmarva Power & Light, and Philadelphia Electric Companies. Designated Burlington Nuclear Generating Station Unit 1, the plant will be on a 140-acre site adjacent to an existing fossil-fueled powerplant, about 11 miles southwest of Trenton and 17 miles northeast of Philadelphia. Public Service will be responsible for design, construction, operation and maintenance. The utility will act as architect-engineer and has engaged United Engineers & Constructors, Philadelphia, for plant construction. Although the application is for one unit, plant layout allows for "orderly expansion."

Reactors Under Construction

Indian Point Station Unit 2

An application was received December 6, 1965, from Consolidated Edison Co. of New York for construction of a second nuclear powerplant at its Westchester County site on the Hudson River's east bank. The pressurized water reactor, for which Westinghouse Elec-

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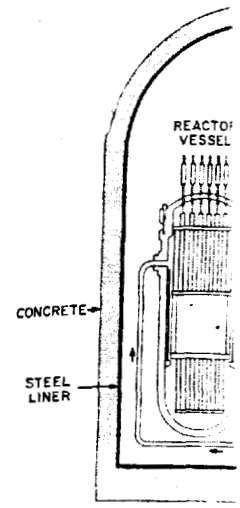

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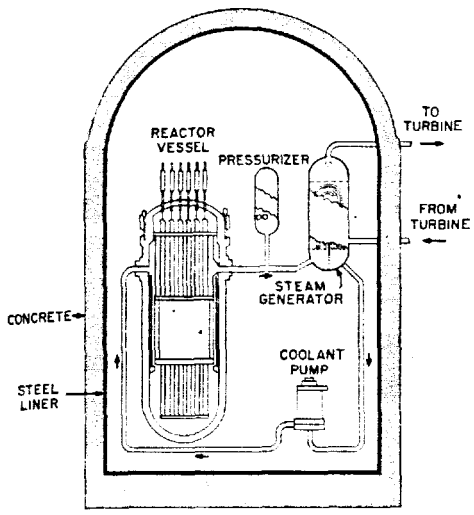
tric Corp. is the turnkey contractor, will have a net electrical output of about 873 megawatts obtained from a capacity of 2,758 Mwt. Construction completion is scheduled for June 1969. A public hearing before an atomic safety and licensing board was held on September 14–15 at Buchanan, N.Y. Pursuant to the board's initial decision of October 3, a provisional construction permit was issued on October 14. (See "Commission Adjudication" for additional information.)



Indian Point No. 2. This simplified schematic diagram of the reactor building for Consolidated Edison's 873-Mwe nuclear electric generating unit No. 2 under construction at Indian Point, Buchanan, N.Y., shows the 4½-foot thick concrete cylindrical wall and 3½-foot thick concrete dome which, with its steel liner, will entirely surround the reactor and heat exchanger equipment. The diagram shows only one of four heat exchangers. The reactor will be located in the center of the building. It, and the four heat exchanger loops, will be surrounded by additional concrete walls. All welds of the steel liner will be covered by steel channels which will be pressurized to prevent leakage out of the building and will provide a means of monitoring any leaks that might develop in the welds. The core (shown as center square in reactor vessel) of the Westinghouse-built reactor will be approximately 12 feet long and 12 feet in diameter. Cooling water will be circulated through the core and four steam generators by four 90,000 gpm primary coolant pumps.

Dresden Nuclear Power Station Units 2 and 3

Pursuant to an atomic safety and licensing board's initial decision, Commonwealth Edison Co. was issued a provisional construction permit on January 10, 1966, for Dresden Unit 2, a single-cycle, forced-circulation, boiling water reactor to be located at the Dresden Nuclear Power Station in Grundy County near Morris, Ill., where the original Dresden reactor has been in operation since 1959. The facility, which is being built by the General Electric Co., is designed for initial operation at 2,300 Mwt and production of 715 net Mwe, with an expected ultimate capacity of 793 net Mwe. Construction is expected to be completed by the fall of 1968.

Subsequently, on February 10, Commonwealth Edison filed an application to construct and operate Dresden Unit 3, also to be located at the Dresden Nuclear Station, about 50 miles southwest of Chicago. A public hearing on the application was held September

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27–28, at the Grundy County Court House in Morris, Ill., before an atomic safety and licensing board. Following the board's initial decision of October 4, a provisional construction permit was issued on October 14. The General Electric Co. is also handling this turnkey project. Also a single-cycle, forced-circulation, boiling water reactor, the unit will have a design capacity of about 2,600 Mwt, but will be operated initially at about 2,300 Mwt with a net output of 715 Mwe. The plant is slated for initial operation in 1969 to meet anticipated power demands in the company's service area of Chicago and northern Illinois.

Robert Emmett Ginna Nuclear Power Plant Unit 1

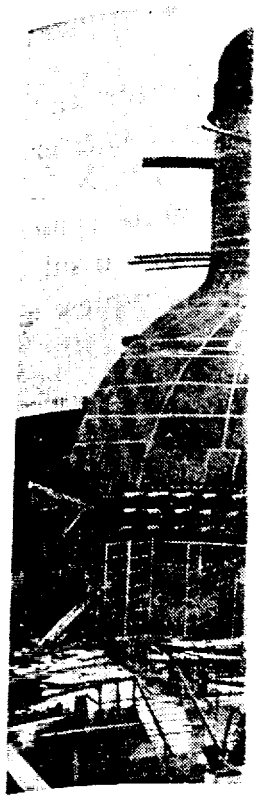
Following a public hearing April 5–6 at Ontario Center, N.Y., and an initial decision by an atomic safety and licensing board on April 14, a provisional construction permit was issued on April 25 to Rochester Gas and Electric Co. for a Westinghouse pressurized water reactor on the shore of Lake Ontario. Under construction in Wayne County, New York, 16 miles from Rochester, the plant (formerly called "Brookwood") is designed to operate at 1,300 Mwt and produce 420 Mwe net. Completion is scheduled by mid-1969, and at year's end construction was about 10 percent complete and on schedule.

Millstone Nuclear Power Station

An atomic safety and licensing board, following a public hearing on April 21 at New London, Conn., issued an initial decision on May 9 authorizing a provisional construction permit to Connecticut Light & Power Co., Hartford Electric Light Co., Western Massachusetts Electric Co., and Millstone Point Co. (an affiliate of the other three companies). The permit was issued May 19 for a 549-net-Mwe boiling water reactor which is being built by General Electric at Waterford, Conn. The estimated completion date is early 1969.

Nine Mile Point Nuclear Station

Construction is about 50 percent complete on Niagara Mohawk Power Corp.'s boiling water nuclear power reactor at Nine Mile Point on Lake Ontario near Scriba, N.Y., about 7 miles northeast of Oswego. An application for a provisional operating license for the 500-net-Mwe reactor, being built by General Electric, is expected to be filed in early 1967.



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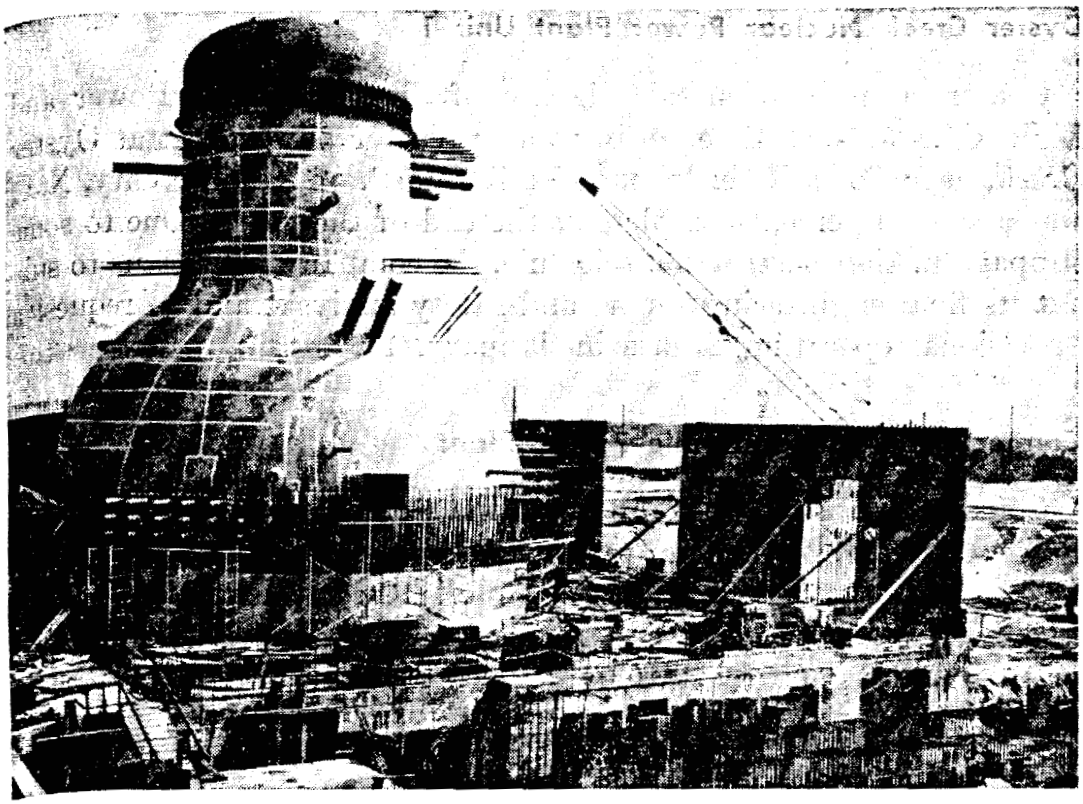
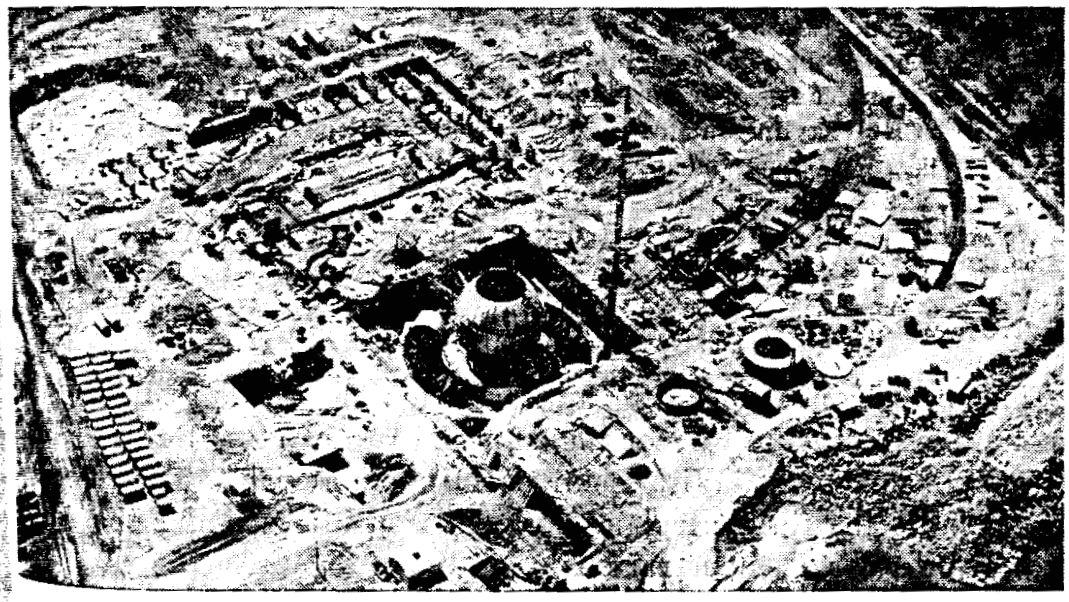


Two Types of Construction. The Oyster Creek Nuclear Power Plant Unit No. 1 (shown *above*), in Lacey Township, N.J., is being built for the Jersey Central Power & Light Co. (a subsidiary of General Public Utilities) by the General Electric Co. When completed the flask-shaped vapor containment shell for the reactor will be housed in a square structure. Scheduled date of operation of the plant is 1968 with an initial rating of 515 Mwe and an ultimate expected rating of 640 Mwe. Photo *below* shows the outer spherical containment building which will house the flask-shaped reactor containment shell of the Nine Mile Point Nuclear Power Plant, located near Oswego, N.Y., and under construction for the Niagara Mohawk Power Corp. by General Electric. The plant, when completed, will be rated at 500 Mwe initial output and will have an ultimate expected rating of 600 Mwe. December 1967 is the scheduled start of operation date. In October, Niagara Mohawk announced plans for a second nuclear plant, a 750-Mwe unit at Stillwater, N.Y.



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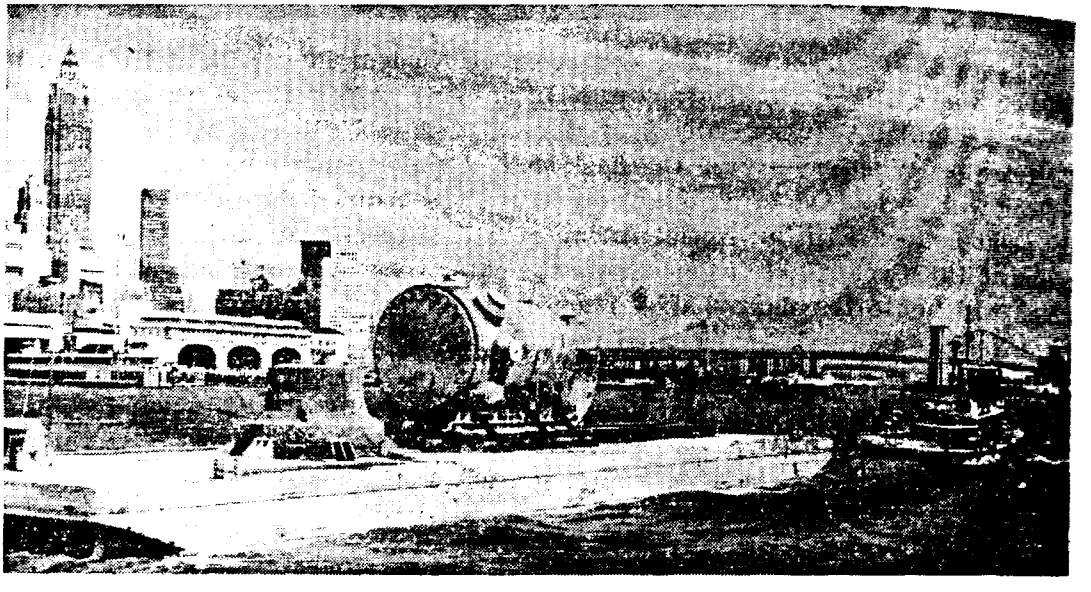
Oyster Creek Nuclear Power Plant Unit 1

Construction by General Electric of Jersey Central Power and Light Co.'s 515-net-Mwe boiling water reactor powerplant at Oyster Creek, near Toms River, about 40 miles north of Atlantic City, N.J., was about 40 percent complete at the end of the year. Due to some slippage in the construction schedule, the company now plans to submit its final engineering report and safety analysis, and to request a provisional operating license in January, 1967.

Connecticut Yankee Atomic Power Plant

Construction by Westinghouse of the Connecticut Yankee Atomic Power Co.'s 462-net-Mwe pressurized water reactor at Haddam Neck, Conn., is proceeding on schedule. The application for a provisional operating license was received in July, and is under review by the AEC regulatory staff and the Advisory Committee on Reactor Safeguards.



Water Journey. The 402-ton nuclear reactor vessel and its 71.5-ton head for the Connecticut Yankee Atomic Power Co.'s Haddam Neck, Conn., plant passed New York City's skyline on March 29. Built by Combustion Engineering at Chattanooga, Tenn., the components for the 462-Mwe pressurized water reactor were barged down the Tennessee River to the Ohio and Mississippi Rivers, then through the Gulf of Mexico and up the inland waterway from Florida to Connecticut.

LaCrosse Boiling Water Reactor

The provisional operating authorization requested by Allis-Chalmers Manufacturing Co. for the 50-net-Mwe LaCrosse Boiling Water Reactor near Genoa, Wis., is currently under review. The reactor is being built for the Dairyland Power Cooperative under the AEC's Power Reactor Demonstration Program.

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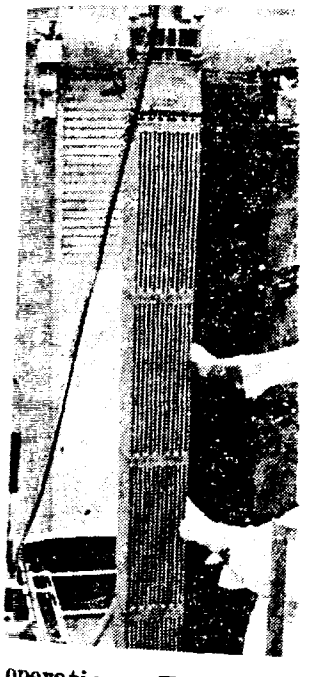

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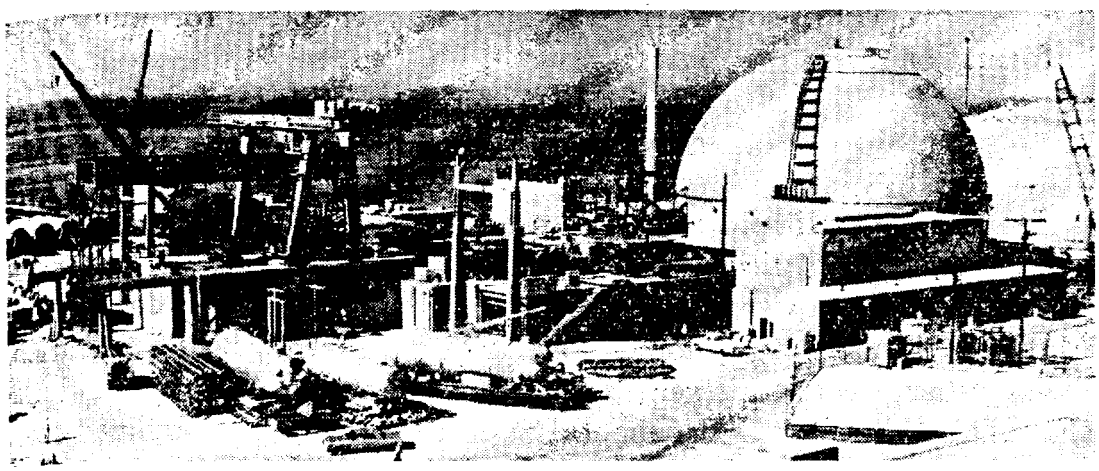
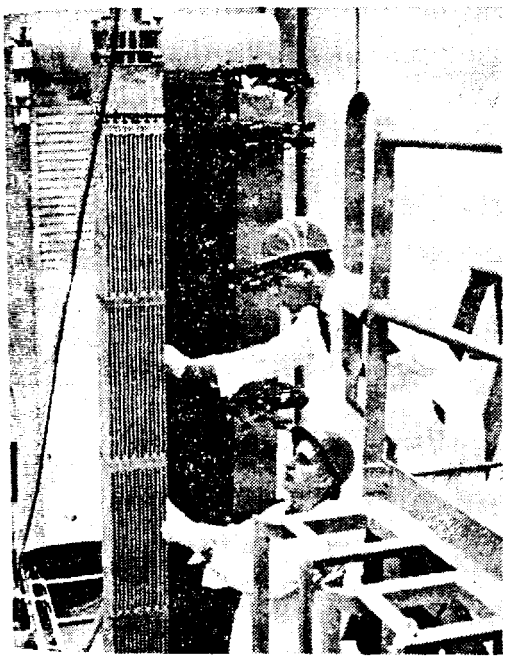
San Onofre Nuclear Generating Station

Construction was completed and pre-operational testing began on the San Onofre Nuclear Generating Station at Camp Pendleton in southern California, in late 1966. The Southern California Edison Co., San Diego Gas and Electric Co., Bechtel Corp., and Westinghouse Electric Corp., in December 1965 filed the final safety analysis report and applied for a provisional operating license. The application is under review. The loading of fuel for initial criticality is expected to begin early in 1967. The reactor is a 1,347-Mwt pressurized water unit designed to produce 430 net megawatts of electricity.





San Onofre. Photo, *above*, shows the San Onofre Nuclear Generating Station, located on a coastal site about 5 miles south of San Clemente, Calif., which will eventually generate 430 megawatts of electricity—enough to meet the needs of a city of more than a half-million population. The initial rating will be 375 Mwe when the plant begins operation in early 1967. The nuclear plant is owned 80 percent by Southern California Edison Co. and 20 percent by San Diego Gas & Electric Co. The AEC contributed approximately $9,500,000 for the research and development phase of the project and will waive the rental charge ($5–6,000,000) on the fuel for the first 5 years of commercial operation. The AEC no longer provides such financial support for light water (boiling or pressurized) reactor plants. Photo, at *left*, shows the first "fuel assembly" for San Onofre being unpacked and inspected by nuclear engineers before being stored in one of the steel racks in the foreground, to await loading in the reactor. The first loading will consist of 157 such assemblies, each containing 180 hollow steel tubes filled with nuclear fuel pellets—or a total of 28,260 rods which, if laid end-to-end, would extend 55 miles.

Technical specifications (license conditions) for this reactor were the first for a power reactor drawn up on the basis of the interim guidance provided by the proposed new system published in the *Federal Register* of August 16, for a 120-day comment period (see Chapter 1—Licensing and Regulating the Atom).

SEFOR Facility

An amended provisional construction permit was issued on March 18 for the Southwest Experimental Fast Oxide Reactor (SEFOR) to Southwest Atomic Energy Associates (SAEA) and General Electric Co. (see "Commission Adjudication," this chapter, for additional information).

Reactors in Operation

During 1966, 15 power reactors either continued or began operations under AEC licenses and authorizations. Of these, 12 central station nuclear powerplants have produced a cumulative total of more than 20 billion kilowatt hours of electricity since they began operation. Two other electric power experimental reactors (Saxton and the ESADA-Vallecitos Experimental Superheat Reactor) continued operations, and the N.S. *Savannah* continued its successful commercial operations. Beginning low-power operation under a provisional license during 1966 was the Philadelphia Electric Co.'s Peach Bottom Atomic Power Station Unit 1, at Peach Bottom, Pa. Two of the 15 operating power reactors, both prototypes, experienced significant operating problems during the year. These were the AEC's organic reactor at Piqua, Ohio, and the Enrico Fermi fast breeder-type reactor at Lagoona Beach, Mich. The operating difficulties experienced by some of the other reactors were not considered serious. Licensing activities and operating experience for individual reactors are described in Appendix 4.

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COMMISSION ADJUDICATION

Proceedings for the licensing of nuclear power and test reactors and other licensed facilities are ordinarily heard by atomic safety and licensing boards whose initial decisions are subject to formal review by the Commission either on appeal by a party or on the Commission's own motion. It is the Commission's practice to conduct informal reviews of initial decisions in such licensing proceedings even when review is not sought by a party. In 1966, the Commission conducted informal reviews of initial decisions without making any order in the following matters: *Matter of Commonwealth Edison Company*

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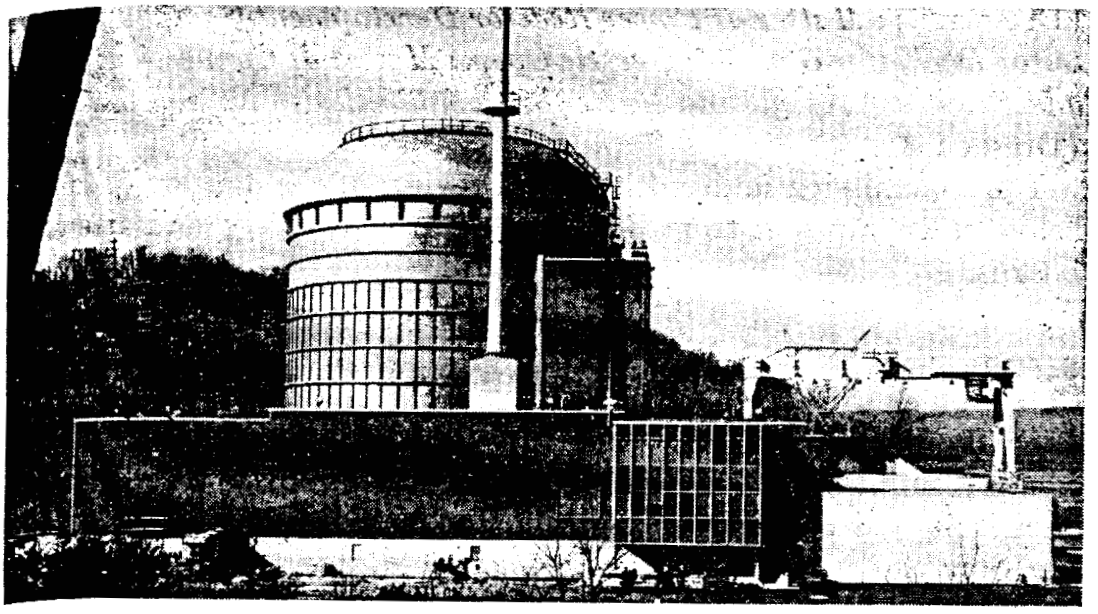
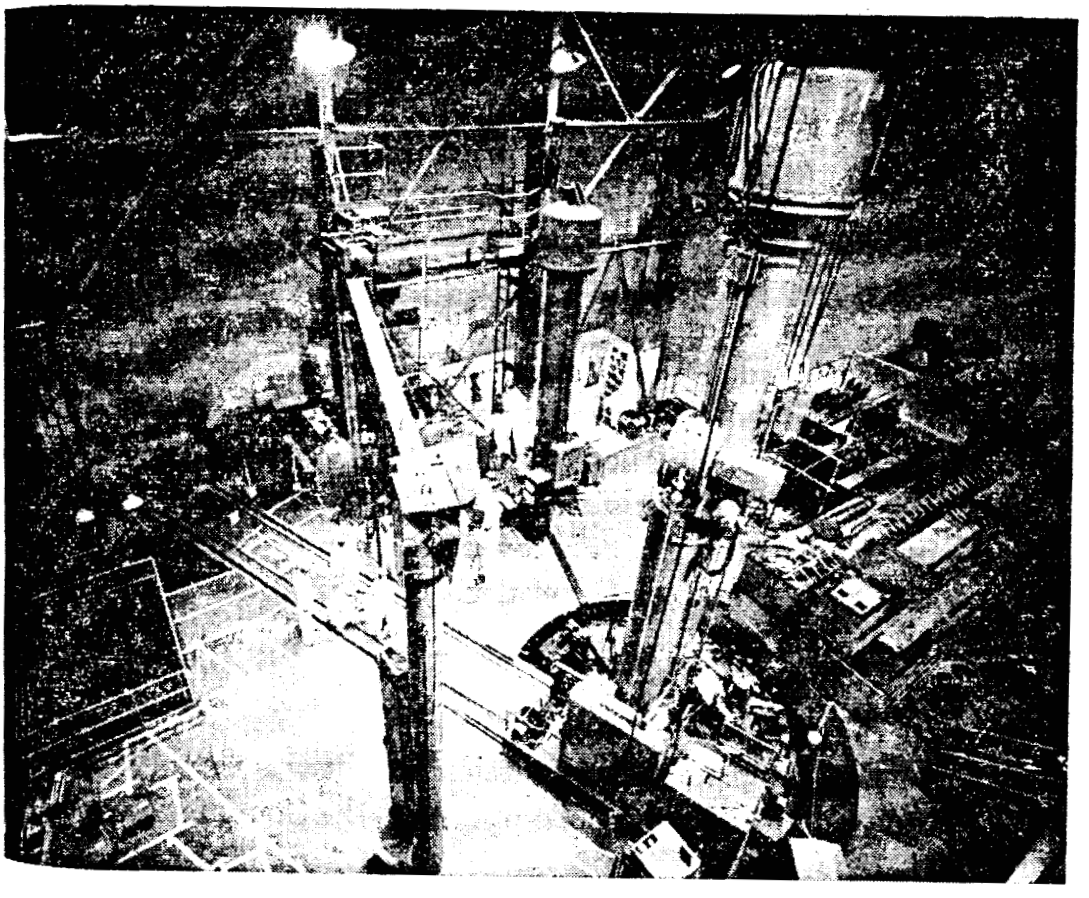


Peach Bottom. Photo *above* shows the 40-Mwe (40,000 ekw) High Temperature Gas-cooled Reactor (HTGR) nuclear powerplant built at Peach Bottom, Pa., for Philadelphia Electric Co. and 52 other U.S. electric utility companies comprising High Temperature Reactor Development Associates, Inc., as part of the AEC's Power Reactor Demonstration Program. The plant is expected to be ready for commercial operation during the spring of 1967. Photo, *below*, is a view of the reactor operating floor during loading of graphite-clad fuel elements in reactor core that uses HTGR reactor system developed by General Atomic Division of General Dynamics. It is the first gas-cooled power reactor to be put in operation by a U.S. utility.



(Dresden 2); *Matter of Power Reactor Development Company; Matter of Rochester Gas and Electric Corp.; Matter of Connecticut Light and Power Co., et al.;* and *Matter of Commonwealth Edison Company* (Dresden 3).

The Commission undertook formal review of the matters discussed below upon appeals from decisions of atomic safety and licensing boards.

SEFOR

On January 7, 1966, an atomic safety and licensing board (ASLB) issued a supplemental decision rescinding the provisional construction permit it had authorized conditionally on September 10, 1965, for the Southwest Experimental Fast Oxide Reactor (SEFOR). The action was taken on the basis that the project would be significantly and substantially under the control of a participating foreign corporation (Gesellschaft fur Kernforschung, m.b.H.—a West German firm), contrary to provisions of Section 104(d) of the Atomic Energy Act.

Cooperative project. Construction of the 20-thermal-megawatt sodium-cooled reactor had been started in the fall of 1965 at Cove Creek, near Fayetteville, Ark., by the General Electric Co. for the Southwest Atomic Energy Associates (SAEA), a group of 17 private power utilities from the Southwest and Midwest. Gesellschaft, which is associated with SAEA in the project, is a nonprofit corporation of the Federal Republic of Germany, and will make contributions to the project for itself and for the European Atomic Energy Community (Euratom). AEC support is provided in a contract with SAEA under which a research and development program is to be conducted as part of the AEC's fast breeder reactor program.

Board's decision reversed. The Commission granted the applicants' petitions for review of the ASLB's supplemental decision and on January 11 suspended the decision pending review. The Commission's decision, issued on March 7, reversed the holding of the board's supplemental decision on alien control. After reviewing the evidence, the Commission concluded: ". . . within the meaning of Section 104(d) of the Act, the Commission does not know or have reason to believe that SAEA and/or General Electric are owned, controlled or dominated by an alien, a foreign corporation, or a foreign government, and that the issuance of the construction permit will not be inimical to the common defense and security. . . ."

An amended provisional construction permit was issued March 18 to SAEA and General Electric Co. pursuant to the Commission's decision.

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Malibu Nuclear Plant Unit 1

Pursuant to exceptions filed on September 1, 1966, by the AEC regulatory staff and three intervenors, the Commission had before it for formal review an atomic safety and licensing board's initial decision on the application by the Los Angeles Department of Water and Power (LADWP) to construct a power reactor at Corral Canyon, near Malibu, Calif.

Extensive hearings. The board had conducted 41 days of hearings during 1965 at Santa Monica, Calif., ending on November 5, 1965. In addition to the applicant and the regulatory staff, five intervenors participated in the proceeding which was marked by extensive presentations on matters of geology and seismology. Following submittal of proposed findings and conclusions and supporting briefs in the spring of 1966, the board convened a posthearing conference on May 19.

Initial decision. The initial decision issued by the ASLB on July 14, authorized LADWP ". . . to construct the facility in accordance with the application, the evidence and representations entered in the record at the hearing, provided and on condition that the design criteria be modified and be supplemented to include adequate provision for permanent ground displacement at the reactor site from earthquake activity, and that such modification and supplement to design criteria be made available for such review procedures as the Commission may provide. . . ."

Decision exceptions filed. The AEC's regulatory staff excepted to the ASLB's holding that the probability of permanent ground displacement is sufficiently high so that the proposed design criteria must be modified to include adequate provision for permanent ground displacement. The regulatory staff asked, however, that if the Commission upholds the board's decision that the facility be designed to withstand permanent ground displacement, the proceeding be remanded to the board to determine the amount of ground displacement which must be accommodated and the adequacy of the design criteria which may be proposed by the applicant in this respect. The intervenors—Marblehead Land Co., Malibu Citizens for Conservation, and Lester T. (Bob) Hope—supported the board's holding on the necessity of design against permanent ground displacement but filed exceptions contesting present issuance of a conditional permit. The applicant filed no exceptions, but expressed support for the staff position that the design criteria need not provide for permanent ground displacement. It opposed, however, the positions of the staff and the intervenors with regard to present issuance of a conditional permit. The matter remained under Commission review at the end of the year.

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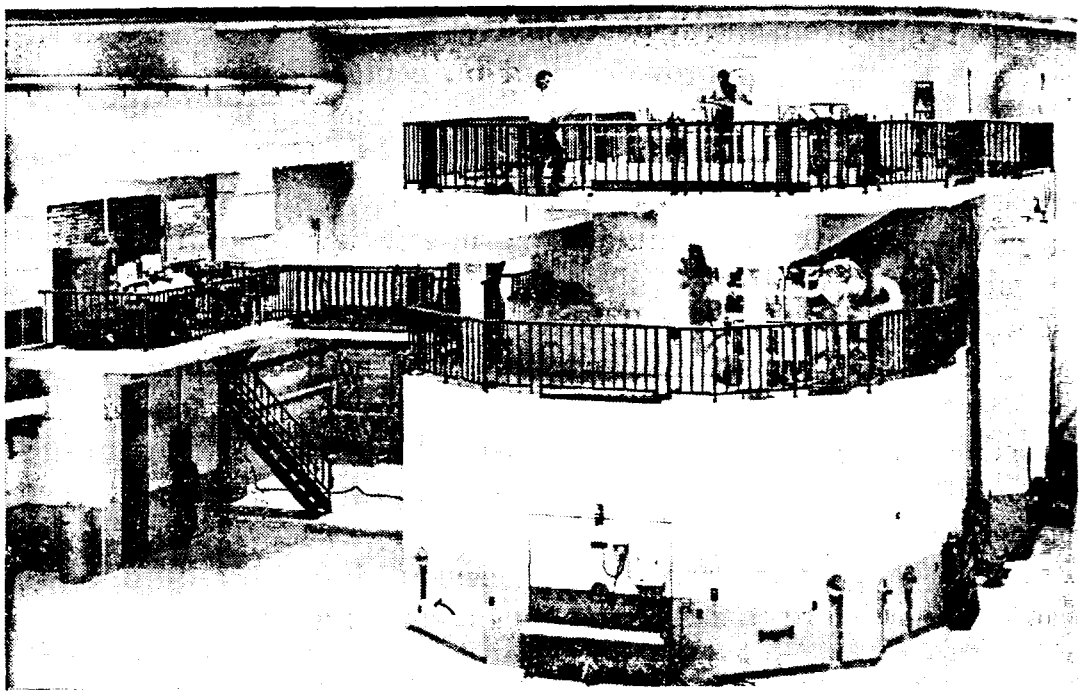
Indian Point Station Unit 2

Following issuance of the atomic safety and licensing board's initial decision authorizing a provisional construction permit to Consolidated Edison Co. for Indian Point Station Unit 2, the Conservation Center, Inc., filed exceptions to the decision contesting the board's denial of the Center's petition for intervention and the substance of certain of the board's safety findings. The AEC's regulatory staff and the applicant filed replies in opposition to the Center's exceptions. On Dec. 20, 1966, the Commission issued a memorandum and order denying the appeal of the Conservation Center, Inc.

RESEARCH REACTORS

Four new applications to construct, and four to operate research reactors were received by the AEC during 1966. Five construction permits had been issued by year's end, making a total of 8 construction



New Research Reactor. A TRIGA Mark III nuclear research reactor began operation August 10 as the central facility at the new $2-million neutronics laboratory on the University of California (U. of C.) campus at Berkeley. Installed by General Atomic Division of General Dynamics, the reactor has a steady-state operating power of 1,000 thermal kilowatts and can be repetitively "pulsed," for fractions of a second, to peak powers of approximately 2,000,000 kilowatts. These self-limiting pulses produce intense fluxes of neutron and gamma radiation for specialized research. The University of California TRIGA is one of 38 TRIGA reactors in operation or soon to be placed in use around the world. The new reactor at Berkeley, which will be operated by the U. of C. Department of Nuclear Engineering, was funded jointly by the university, the National Science Foundation, and the AEC. The reactor incorporates advance-type TRIGA fuel elements with stainless steel cladding and has a movable core.

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permits in effect on that date, covering 12 research reactors. Five operating licenses were issued during this period. Among these was one for the University of Missouri's reactor at Columbia, which has a design power level of 10 thermal megawatts—the largest university research reactor in the country.

The transfer of a reactor from the AEC's Sandia Laboratory in Albuquerque, N. Mex., to Louisiana State University, Baton Rouge, made it subject to future licensing for installation and operation. Operation of the Radiation Effects Reactor was transferred from the U.S. General Services Administration to Lockheed Aircraft Corp. at Dawsonville, Ga.

At year's end, 70 research reactor operating licenses were in effect.

OTHER PRODUCTION AND UTILIZATION FACILITIES

Because of the nature of the processes, the quantities of material, and the safety considerations involved, some nuclear material plants are subject to licensing procedures similar to those established for nuclear reactors. These procedures include the issuance of construction permits and operating licenses, and establishment of financial protection levels, indemnity fees, and special operator licensing programs for each new type of facility.

Isotope Recovery

Fission Products Conversion and Encapsulation Plant

An application was received in June from Isochem Inc.—a firm jointly owned by Martin Marietta Corp. and the U.S. Rubber Co.—for AEC authorization to construct and operate a Fission Products Conversion and Encapsulation (FPCE) Plant at the AEC's Hanford operations near Richland, Wash. The plant would process to usable forms strontium 90, cesium 137, promethium 147, and americium 241 from the highly radioactive fission product wastes resulting from the Hanford plutonium production operations. Design capacity calls for an annual production capability of 40 megacuries of strontium 90, 40 megacuries of cesium 137, 38 megacuries of promethium 147, and 8.6 kilocuries of americium 241. (See also Chapter 4—Source and Special Nuclear Materials.)

A prehearing conference on the Isochem application was held on December 14 before an atomic safety and licensing Board at Richland, and a public hearing was scheduled to begin on January 3, 1967, at the same location.

Fuel Processing Plants

Nuclear Fuel Services, Inc.

A provisional facility operating license was issued on April 19 to Nuclear Fuel Services, Inc., and the New York State Atomic and Space Development Authority authorizing operation of the irradiated nuclear fuel processing facility completed near West Valley, N.Y. Construction of the plant was authorized by an AEC construction permit issued April 30, 1963. (See also Chapter 4—Source and Special Nuclear Materials.)

General Electric Co.

An application was received on November 22 from the General Electric Co. requesting authority to construct and operate an irradiated nuclear fuel processing facility at Morris, Ill., adjacent to the site of the Commonwealth Edison Co.'s Dresden reactors. General Electric expects the plant to be operable by mid-1970. (See also Chapter 17—Industrial Participation.)

OPERATOR LICENSING

Operator and senior operator licenses for persons who manipulate controls of production and utilization facilities are issued pursuant to the regulation 10 CFR Part 55.

During the 12-month period ending November 30, the AEC issued 350 operator licenses and 375 senior operator licenses. These were for 313 new licenses, 48 amended licenses, and 364 renewed licenses. During the same period 99 license applications were denied. Including previously issued licenses, 923 operator licenses and 600 senior operator licenses were in effect on November 30.

Early in 1966, the fuel reprocessing plant of Nuclear Fuel Services, Inc., became the first nonreactor facility whose personnel received these licenses.

During the year, the AEC issued "Operators' Licenses, a Guide for the Licensing of Facility Operators, Including Senior Operators,"[2] to assist applicants and licensees in connection with this program.

[2] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 40 cents.

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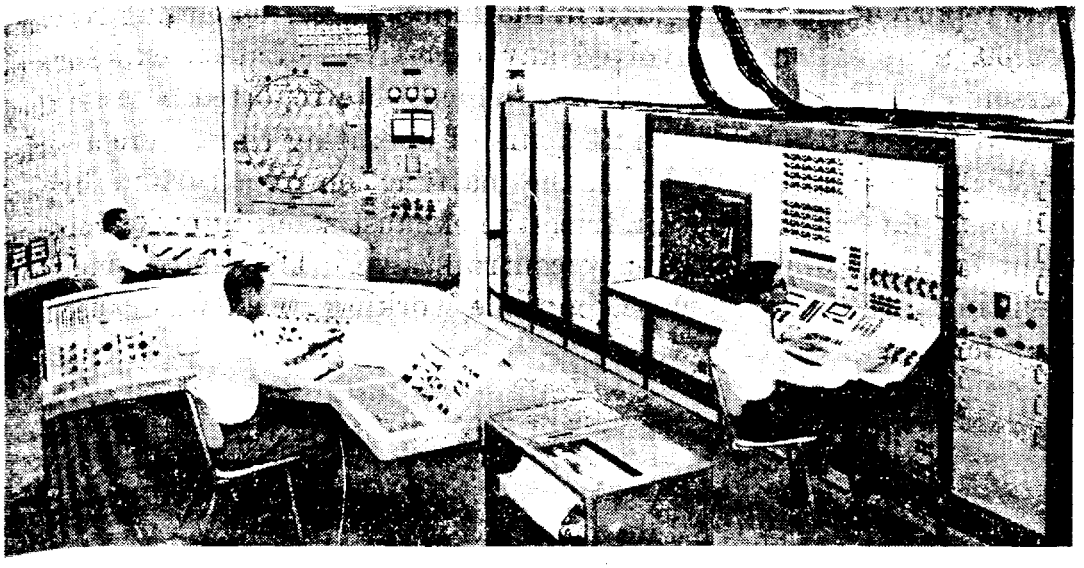

Operator Training. Photo shows a power reactor training simulator built by General Atomic Division of General Dynamics to duplicate the operating characteristics of the High Temperature Gas-Cooled Reactor nuclear powerplant at Peach Botton, Pa., on the system of Philadelphia Electric Co. The trainer-simulator is used in reactor operator training programs to qualify personnel for AEC licenses as operators and senior operators.

INSPECTIONS OF FACILITIES

Inspections by the AEC's regulatory staff of a licensed nuclear facility begin shortly after the start of construction and continue throughout the lifetime of the facility. Through the inspection of premises, records, and operations of licensees, the status of compliance with AEC requirements is determined and any safety problems which may need correction are identified.

353 Inspections During 1966

With the addition of 8 new facilities in 1966, a total of 127 reactors and other nuclear facilities became subject to inspection by compliance personnel. During the 12-month period ending November 30, a total of 353 compliance inspections were made in the following categories: power reactors, 131; test reactors, 29; research reactors, 142; critical assemblies, 23; N.S. *Savannah*, 9; and the Nuclear Fuel Services' irradiated fuel processing plant, 19.

AEC regulation 10 CFR Part 20 requires licensees to report to the AEC certain types of operating incidents.[3] Incidents at four reactors

[3] Types of incidents required to be reported are listed on page 302, "Annual Report to Congress for 1965."

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were reported and investigated in the 12-month period ending November 30, none of which involved any excessive radiation exposure to personnel. Three of the incidents, which were reported because they caused the loss of more than 24 hours of operating time, were a series of steam generator tube leaks, the malfunction of a turbine bypass valve, and a backflow of air from the exhaust stack into the containment building due to a faulty control valve. The fourth incident, resulting in the loss of more than one working week, was caused by fuel failure.

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THE REGULATION OF RADIOACTIVE MATERIALS

The expanding use of radioactive materials, particularly radioisotopes, continued to be reflected in Federal and State licensing and regulatory activities during the year. Highlights included: (*a*) the assumption of certain of the AEC's regulatory authority over atomic energy materials by four more States, (*b*) a continuing increase in the total number of licenses administered in the combined Federal and State programs, and (*c*) execution of a Memorandum of Understanding by the AEC and the Interstate Commerce Commission setting forth the manner in which the two agencies will exercise their authorities with respect to the safe transport of radioactive materials.

STATE RELATIONS AND AGREEMENTS

The Atomic Energy Commission is authorized [1] to enter into an agreement with the Governor of any State for the transfer of the AEC's regulatory authority within the State over byproduct material, source material and less-than-critical quantities of special nuclear material (*i.e.*, too small to achieve a chain reaction). The basis of each agreement is a determination by the Commission that the State's radiation control program is adequate to protect the public health and safety, and is compatible with the AEC's program for regulation of radioactive materials. All of the agreements contain a provision that the AEC and the agreement States will exercise their "best efforts" to maintain compatible programs.

[1] Public Law 86–373, effective September 23, 1959, added section 274 to the Atomic Energy Act of 1954, as amended. See pp. 266–267, "Annual Report to Congress for 1959"; pp. 375–376, "Annual Report to Congress for 1961."

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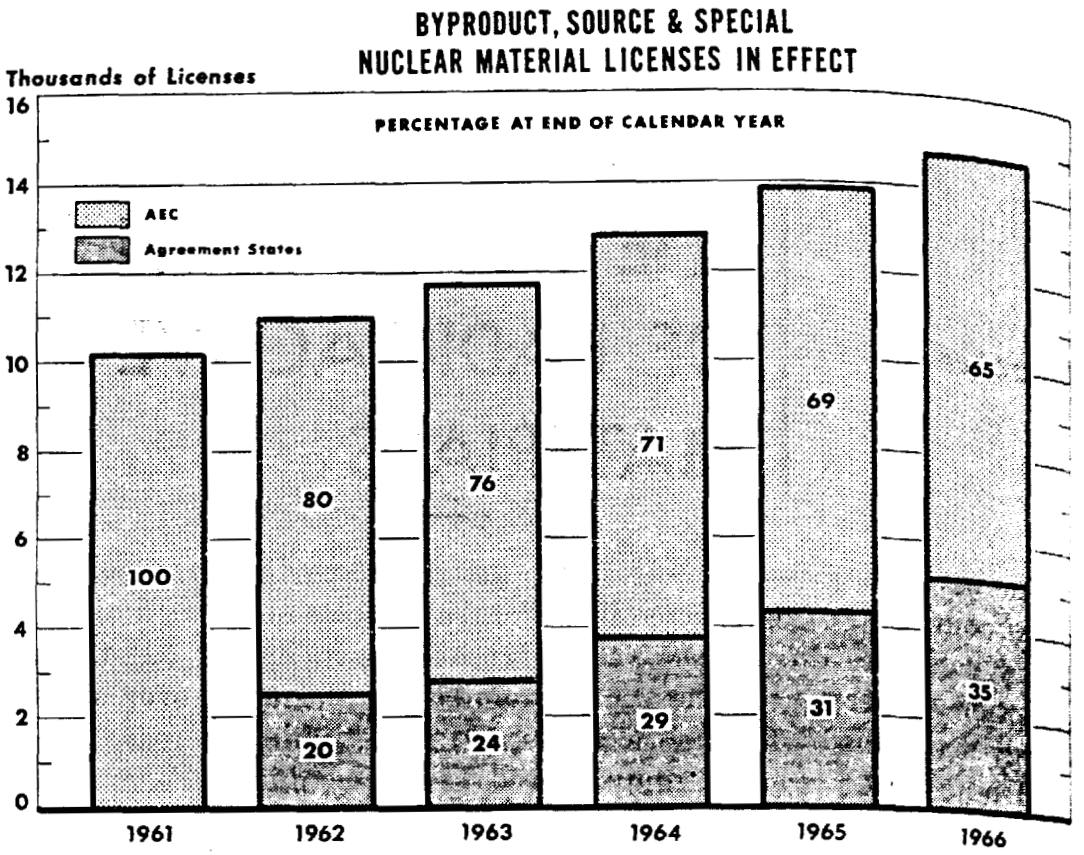

Licensing Growth. Licenses for byproduct, source, and special nuclear materials continued to climb during 1966 as the chart indicates. At the end of the year, the 15 agreement States administered approximately 5,200 licenses and the AEC administered 9,454. The chart and other statistics in this report understate to some degree the growth in the licensed use of radioactive materials. Several hundred specific licenses, reflected in the totals for earlier years, have been eliminated by consolidation under single, broad AEC licenses at several institutions which conduct extensive radioisotope programs. Some States also have instituted broad licensing systems.

AGREEMENTS

During 1966, the AEC transferred regulatory control over some 550 licenses to the States of New Hampshire (May 16), Alabama (October 1), Nebraska (October 1), and Washington (December 31). These four States join Arkansas, California, Florida, Kansas, Kentucky, Mississippi, New York, North Carolina, Oregon, Tennessee, and Texas in the agreement State program. A proposal by Louisiana for an agreement was under study at year's end.

Licenses Increasing Eight Percent Annually

At the end of 1966, the 15 agreement States administered approximately 5,200 licenses for byproduct, source, and special nuclear ma-

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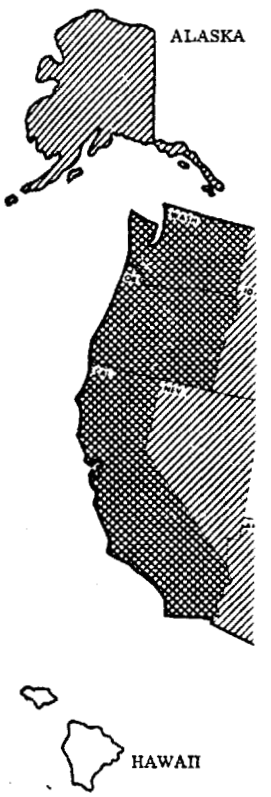

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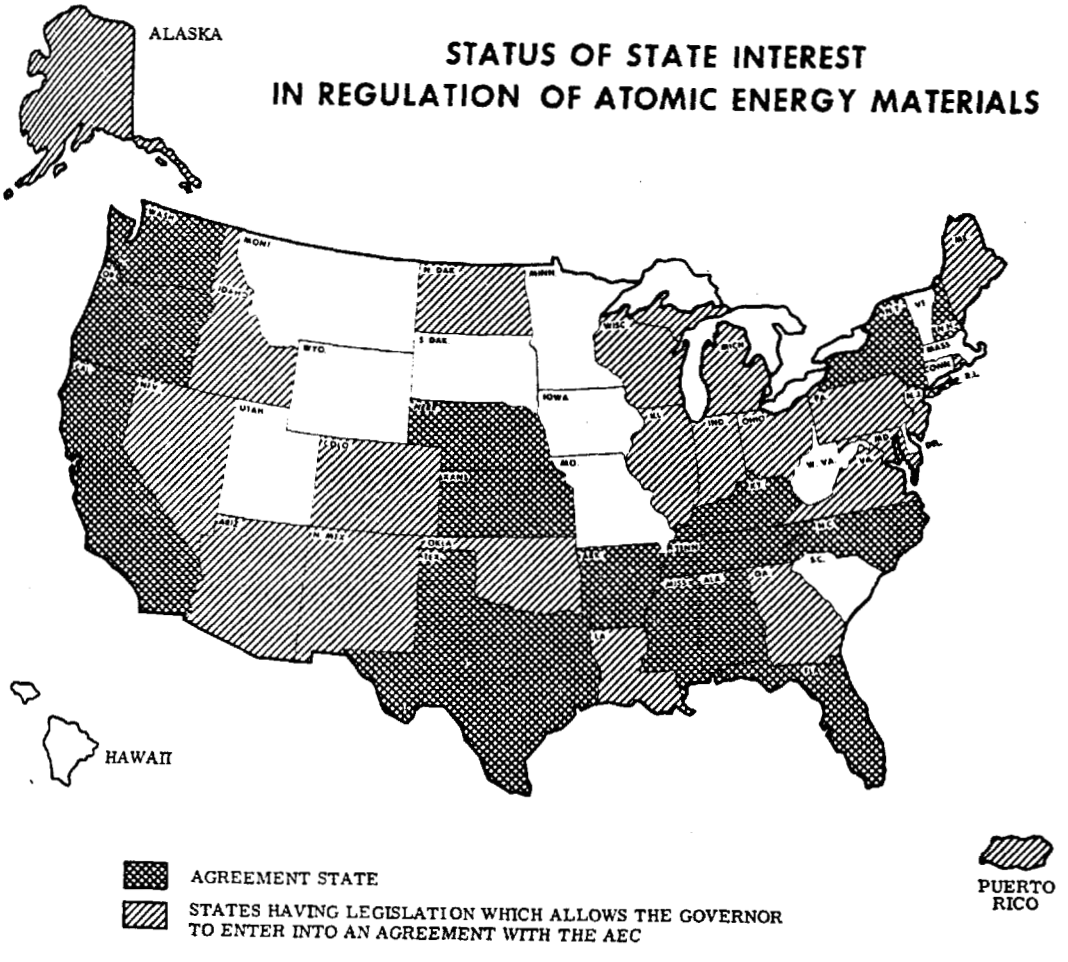
terials, compared with 9,454 effective AEC licenses for similar materials. The bar graph shows the change in the number of effective licenses and the percent of the total under AEC and under agreement State control at the end of each year since 1961. It is interesting to note that the total number of licenses in the Federal-State programs has increased an average of about eight percent annually over the past five years, even though multiple licenses issued to a given institution in many cases have been combined into a single license.

More Agreements Foreseen

It has been necessary for most States to enact new legislation authorizing the Governor to enter into a formal agreement with the AEC. Such a measure was enacted by Pennsylvania in 1966. In addition to the existing 15 agreement States, 22 States now have enacted appropriate new legislation or have determined that they have authority under existing law to enter into an agreement with the AEC. Several of these are actively progressing toward an agreement.



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Continuing Compatibility of Agreement State Programs

The Commission announced, during 1965, a policy of making formal annual redeterminations of compatibility of the regulatory program in each agreement State. Substantially similar, but not necessarily identical, State and AEC regulatory standards and policies constitute "compatibility."

The first redetermination of compatibility was made in January, 1966. The Commission found that the regulatory programs of the 11 States then participating continued to be adequate to protect public health and safety and were compatible with the AEC's program for the regulation of agreement materials.

Cooperative Activities

To assist States in obtaining an adequately trained staff, essential to the conduct of an adequate program under an agreement, the AEC cooperatively conducts various radiological health training and informational courses for State and local government personnel, and maintains a continuing exchange of information.

1966 Training Courses

Seventeen people representing 14 States participated in the annual 10-week radiation protection course conducted by the Oak Ridge Associated Universities.[2] Special university courses were conducted during the 1965–66 school year at Rutgers University, New Brunswick, N.J.; at the Nashville Extension of the University of Tennessee; at the University of Nebraska, Lincoln; and at the Louisiana State University, Baton Rouge, with a total enrollment of 61 students. Two orientation courses in AEC regulatory practices and procedures were given during the year at the AEC's Bethesda, Md., office with 33 participants representing 21 States. At the request of the Florida State Health Department, a pilot course was given at the University of Miami to provide State regulatory personnel with current information on the various types of industrial radiography equipment, radiation protection problems associated with the use of such equipment, and specialized licensing and inspection problems.

[2] On January 1, 1966, the corporate name of the Oak Ridge Institute of Nuclear Studies (ORINS) was changed to Oak Ridge Associated Universities (ORAU). The Institute (ORINS) continues as a major operating unit (Medical Division, Information and Exhibits Division, and Special Training Division) and serves as the avenue through which the sponsoring institutions of the Association participate in and support the Nation's nuclear energy programs.

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Exhibit Showings

A joint AEC–U.S. Public Health Service exhibit illustrating the status of State radiation control programs and Federal assistance to the States in radiation control was shown at five meetings of national professional organizations. The AEC exhibit, "Regulating the Atom," was displayed at the Southern Branch, American Public Health Association annual meeting. Approximately 10,000 persons had an opportunity to view these exhibits.

Exchange-of-Information Program

In order to keep both the agreement States and the AEC currently informed of each other's regulatory activities, the AEC maintains an extensive exchange-of-information program covering AEC and State licensing and inspection procedures and criteria, new or unusual licensed uses or license conditions, enforcement actions or procedures, and changes or proposed changes in regulations. In addition, upon request, technical or other consultation in the administration of specific State programs is provided by the AEC.

THE AEC MATERIALS LICENSING PROGRAM

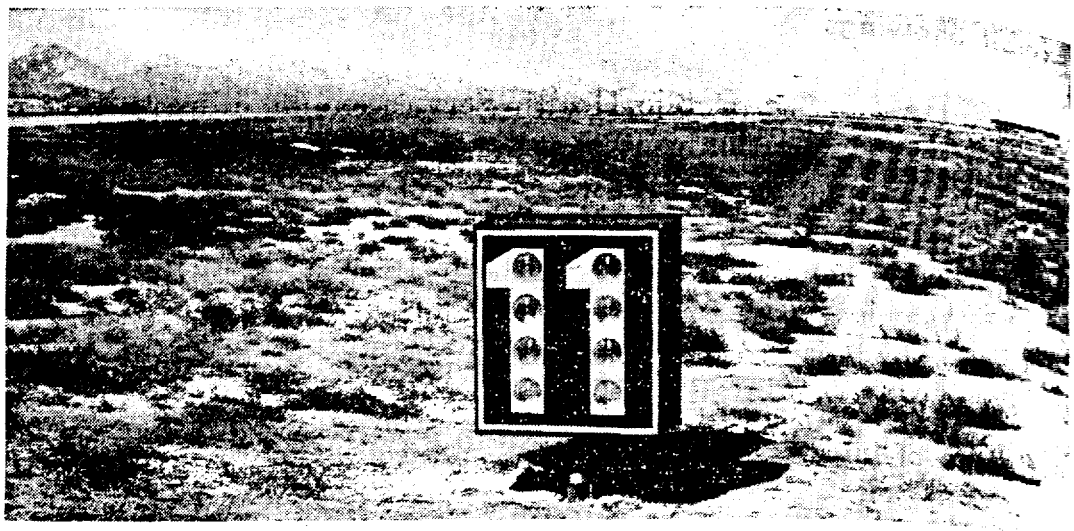
As of November 30, 1966, there were 9,454 AEC materials licenses in effect, consisting of 8,431 byproduct material licenses, 439 source material licenses, and 584 special nuclear material licenses.

SIGNIFICANT 1966 LICENSING ACTIONS

Of particular interest during the past year were the greatly increased use of radioisotopes in the development of self-luminous light sources and the first commercial sale of an isotopic power unit.

Isotopic Markers

License requests for using radioisotopes in self-luminous devices have included proposals for prototype highway signs; markers for mine tunnels, airport runways, and heliports; and sources in photometers, switch markers, instrument dials, and aircraft safety devices. The radioisotopes used in these items include krypton 85, hydrogen 3 (tritium), promethium 147, and carbon 14. Airport and highway



Self-Luminous Signs and Markers. The first self-luminous airport markers and street signs employing radioisotopes were installed under AEC licenses in the fall of 1966 at Tucson, Ariz. In photo *above*, a pair of runway distance markers is shown at Tucson's International Airport, mounted so they will collapse without being destroyed if struck by aircraft. The units face in opposite runway directions 1,000 feet from the end of a 12,000-foot runway, and read "11," and "1," respectively. Using enriched krypton 85 gas in sealed modules, the markers display figures 24 inches high with a stroke dimension of 5 inches wide. Light emission color is green, and each module contains 500 millicuries of krypton 85. Tucson Airport Authority is the licensed user, and the American Atomics Co., of Tucson, the manufacturer, will maintain and periodically inspect the equipment. The Tucson *Daily Citizen* photo at *left* shows prototype self-luminous street sign installed by the City of Tucson. It is mounted 16½ feet above the ground, contains 90 small sources—each of 100 millicuries of krypton 85—and has a life expectancy of 10 years. Height of the letters is eight inches.

authorities have shown interest in the proposed use of self-luminous markers to identify streets or highways and as distance markers for airport runways. A license has been issued for the prototype testing and evaluation of these markers in Tucson, Ariz., where an overhead street sign has been mounted in the city and four runway distance markers have been installed at the city's International Airport. These markers contain sealed capsules of radioactive krypton 85 gas as the activating agent in the light source.

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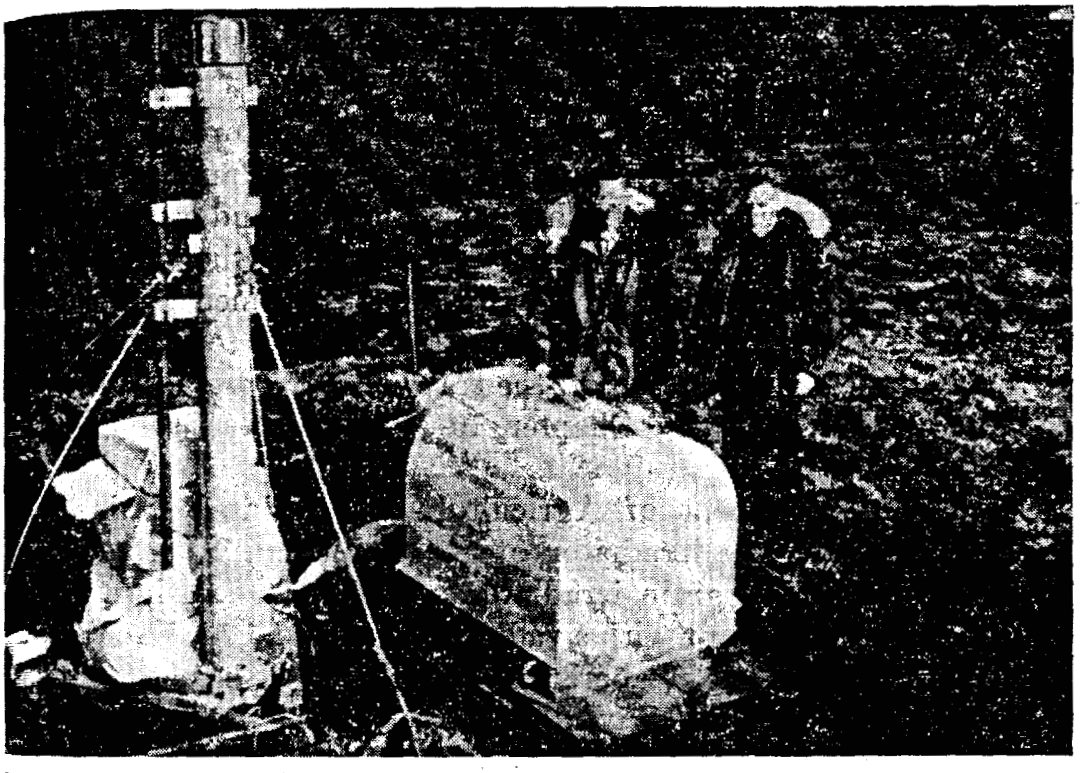
New Pharmaceutical Compounds

With the assistance of the AEC's Advisory Committee on Medical Uses of Isotopes (see Appendix 2 for list of members), evaluations were made of two new radioactive pharmaceutical products for routine use by licensed physicians in diagnostic scanning procedures to detect malignancies. (Through use of radiation detection and recording devices, this procedure graphically portrays the existence and location of a diseased organ or area.) Technetium 99^m as the labeled pertechnetate has been approved for brain scans. Iodine 131-labeled colloidal microaggregated iodinated human serum albumin has been approved for liver scans.

Thermoelectric Generators

AEC licenses were issued in July to Martin Marietta Corp., Middle River, Md., authorizing for the first time the demonstration of two models of strontium 90-powered thermoelectric generators developed and manufactured by the firm for the commercial market. One model, containing 125,000 curies of strontium 90, has a nominal



First Isotopic Generator on High Perch. The world's first commercially developed isotopic-powered, thermoelectric generator is shown being installed for unattended operation atop Fairway Rock, a lonely Eastern Bering Strait island with sheer cliffs rising 600 feet above sea level. Developed by Martin Marietta Corp., Middle River, Md., the 25-watt generator will power an oceanographic telemetry system, transmitting information from underwater sensors to a U.S. Naval Electronics Laboratory (NEL) field office at Cape Prince of Wales, Alaska. The demonstration of the strontium 90-powered generator was licensed by the AEC in July.

power output of 25 watts; the other model, which contains 25,000 curies, generates 3 watts.

Subsequently, the U.S. Navy was licensed to use a 25-watt unit purchased from Martin Marietta for powering an oceanographic telemetry system installed for unattended operation atop Fairway Rock, a small Eastern Bering Strait island with sheer cliffs rising approximately 600 feet above sea level. Underwater oceanographic sensors electronically measure salinity, water speed, current and temperature, and mass water transport. These sensors are linked by cable to the programming and telemetry system atop the island. The data are then automatically transmitted to a U.S. Navy Electronics Laboratory field station about 15 miles to the east at Cape Prince of Wales, Alaska, and recorded there for computer processing at San Diego.

Irradiator Applications

Operation of three large facilities to irradiate products by intense gamma radiation was authorized, and another licensing action authorized replacement of irradiator sources with new, more efficient sources of higher specific activity.

The U.S. Department of Interior's Fish and Wildlife Service (Pascagoula, Miss.) was licensed on June 15 to use a 35,000-curie cobalt 60 irradiator aboard the motor vessel *Oregon* operating out of St. Simons Island, Ga. The irradiator was used on an experimental basis for the preservation of freshly caught shrimp and other seafood. This was the second vessel equipped and operated by the U.S. Department of Interior for such operations. The Department's Bureau of Commercial Fisheries was licensed on February 2 to use a 30,000-curie cobalt 60 irradiator aboard the trawler *Delaware* operating out of Gloucester, Mass. (see Chapter 10—Isotopic Radiation Applications).

The U.S. Department of Agriculture was licensed to install a 30,000-curie cobalt 60 irradiator at its facility in Savannah, Ga. This pilot plant bulk grain irradiator is designed to disinfest 5,000 pounds of grain per hour with a radiation dose of 25,000 *rads*.[3]

The U.S. Army Natick Laboratory, Natick, Mass., has been authorized to replace its present inventory of cobalt 60 sources (1,000,000 curies) originally loaded in its food irradiation facility. The irradiator will be reloaded with cobalt sources of higher specific activity, thus providing greater utilization efficiency of the irradiator with less self-absorption of the radiation in the sources.

[3] *Rad* stands for absorbed radiation dose; the basic unit of absorbed dose of ionizing radiation. One *rad* is equal to the absorption of 100 ergs of radiation energy per gram of matter.

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Radioactive Waste Burial

California Nuclear, Inc., of Pleasanton, Calif., was licensed to receive, package, and store radioactive waste at a site near Sheffield, Ill. The firm's application for authority to bury radioactive waste at this site was under review at year's end. The company had been licensed in 1965 to operate a similar burial facility near Richland, Wash. Other privately operated radioactive waste burial facilities are located in Nevada, Kentucky, and New York, the latter two licensed by the respective State authorities.

Commission Decisions

The Commission considered one petition for leave to intervene in a materials licensing action during the year. Also of interest was a court decision upholding a Commission decision in a license renewal case.

Hamlin Testing Laboratories

On March 25, the United States Court of Appeals for the Sixth Circuit sustained the decision of the Commission which had reversed a hearing examiner's decision and denied renewal of a byproduct material license because of the licensee's repeated violations of the AEC's regulations. The Court held that denial of an application for renewal of a license did not constitute "withdrawal" of the license within the meaning of Section 9(b) of the Administrative Procedure Act which requires prior notice and an opportunity to comply. The court found that there had been no violation of due process of law on the part of the staff in the proceeding.

Atcor, Inc.

On May 13, notice was published in the *Federal Register* that the AEC was considering the issuance of a license to Atcor, Inc., for receipt and transportation of packaged waste radioactive material. Long Island Nuclear Service Corp. and Madeline La Grua filed a joint petition seeking leave to intervene or, in the alternative, an investigation into alleged unlawful acts of the applicant. On June 17, the Commission denied leave to intervene and ordered the Director of Regulation to make an investigation of the charges. The investigation revealed no violation of the Atomic Energy Act or of AEC regulations and the license was issued to Atcor in September.

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Broad Licenses

The AEC's regulatory staff continue to review applications from licensees conducting varied and large-scale activities with the view of issuing broad licenses which permit the necessary flexibility to adjust operations to meet changing or new research and development or production objectives.

New Licenses

Among the broad licenses issued in 1966 were those to Battelle Memorial Institute for its private work [4] at the AEC's Pacific Northwest Laboratory, Hanford, Wash.; Westinghouse Electric Corp., Waltz Mill, Pa.; and the General Electric Co., San Jose, Calif. The Battelle license authorizes a broad range of research and development activities. The General Electric and Westinghouse licenses cover activities other than nuclear reactor operation at the firms' Vallecitos and Waltz Mill laboratories, respectively. In order to provide for the varied activities and conditions of operations covered by these three licenses, special license conditions in the form of broad technical criteria have been incorporated with respect to avoidance of accidental criticality in using and storing special nuclear material, and for radiological safety. In issuing such broad licenses, the AEC carefully evaluates the licensee's administrative controls and in-house competence for carrying out safe operation.

A number of other licensees, particularly universities, hospitals, and research organizations, consolidated their respective radioisotope activities under single broad AEC licenses providing for flexibility in operations and centralized control by the institution of the procurement and safe use of radioisotopes. Such new broad licenses issued in 1966 totaled 14, replacing 26 previously in effect covering the same programs.

TRANSPORTATION OF RADIOACTIVE MATERIALS

A Memorandum of Understanding was completed March 21 between the AEC and the Interstate Commerce Commission (ICC) setting forth the manner in which each agency will exercise its authority in assuring safety in the transport of radioactive materials.

[4] Under its contract for operating the AEC-owned Pacific Northwest Laboratory, Battelle is authorized to conduct research for other Government agencies and industry on a private basis in the laboratory; Battelle is also constructing a $19 million research center in nearby Richland.

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Objectives of the agreement were to minimize duplication and provide maximum interagency consistency in regulations and requirements, assuring that all shipments of radioactive materials within the jurisdiction of the two agencies are regulated by either the AEC or the ICC. The AEC will develop standards for the preparation for shipment of fissile material and large quantities of radioactive material, while the ICC will adopt appropriate regulations and requirements applicable to the majority of shipments of radioactive materials. AEC performance standards for its areas have been developed and incorporated into the regulation 10 CFR Part 71, "Packaging of Radioactive Material for Transport," which became effective on August 21.

COMPLIANCE AND ENFORCEMENT

Compliance personnel performed 1,875 inspections of operations being conducted under AEC specific materials licenses over the 12-month period ending November 30. In only about four percent of the inspections was it necessary for Compliance Regional Offices to transmit recommendations to AEC headquarters for enforcement action under the Commission's regulations.

Radiation Incidents

In response to the AEC requirements in 10 CFR Part 20 [5] for the reporting of all significant radiation incidents, 20 such incidents were reported to the AEC by materials licensees and investigated during the 12-month period that ended November 30.

Seven of these incidents involved radiation exposures in excess of the limits prescribed in the AEC's regulations to a total of nine persons. Of these, five incidents occurred during radiography operations, one incident was in a plant engaged in the manufacture of tritiated compounds, and the other incident occurred in a plant engaged in the processing of samples containing fission products. The highest whole-body exposure resulting from the radiography incidents was a dose of about 40 *rems*,[6] and the highest extremity exposure was about 400 *rems*.

[5] Types of incidents required to be reported by AEC licensees are listed on page 302, "Annual Report to Congress for 1965." Licensee reports on all such incidents are filed for public inspection in the AEC's Public Document Room, 1717 H Street, NW., Washington, D.C. 20545.

[6] *Rem* stands for roentgen equivalent man. For purposes of radiation protection, the dose equivalent measured in *rems* is equal to the absorbed radiation dose in *rads* multiplied by the appropriate modifying factors.

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In the two plant incidents, one person received a whole body radiation dose of about 5 *rems* while preparing a multicurie tritium labeled compound, and two persons received doses on the order of 99 *rems* and 47 *rems*, respectively, to the hands while handling samples containing fission products.

None of the 13 other incidents reported by material licensees involved radiation exposures for which a report is required by Section 20.403 of 10 CFR Part 20. Eleven of these required reporting because they caused the closing of the facilities for more than 24 hours, and the other two were the accidental releases to the atmosphere of 25 curies and 2 curies, respectively, of krypton 85 gas.

Lost Radioactive Materials

Certain losses of radioactive materials also are required to be reported to the AEC. Licensees reported 43 losses, some of which were temporary, during the 12-month period ending November 30.

Eight of these losses were caused by detachment of the radioactive source from logging gear during oil well logging operations. Three of the sources were subsequently recovered, and the five sources which could not be retrieved were either cemented in place or covered with steel housing to eliminate any radiation hazard during subsequent drilling operations.

In 14 of the other 35 cases of reported loss, the missing material was subsequently recovered. In the remaining cases it appeared that either the material had been disposed of inadvertently as refuse in a manner that would not result in any significant hazard, or that no significant radiation hazard was present because of the circumstances of the loss or the amount of material involved.

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Chapter 4

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[1] See pp. 12–15, "An
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Chapter 4

SOURCE AND SPECIAL NUCLEAR MATERIALS

During the year, steps for implementing the 1964 Private Ownership Act were taken that will assist in planning and making the transition to a normal industrial base. The uranium industry picture brightened as utilities and companies supplying nuclear fuel began placing orders for concentrates to be used in producing fuel for the growing number of power reactors. The effects of the 1964–1965 production cutbacks in plutonium and enriched uranium for national defense purposes continued to be felt in the AEC's production operations; however, the demand for old and new types of radiosotopes continued to grow. Steps were initiated to strengthen domestic safeguards over special nuclear material in the interest of the common defense and security.

PRIVATE OWNERSHIP ACT IMPLEMENTATION

Upon passage of the Private Ownership of Special Nuclear Materials Act of 1964 [1] domestic private ownership of special nuclear material became permissive and will be mandatory for power reactor fuels after June 30, 1973. During the year, the AEC continued to work on implementation of the new law and its many ramifications. The prime actions in 1966 were to establish the criteria for the processing, for a fee, in AEC-owned facilities of privately owned uranium to produce enriched uranium and the establishment of post-1968 policies on sale and lease of enriched uranium.

[1] See pp. 12–15, "Annual Report to Congress for 1964;" and pp. 91–92, "Annual Report to Congress for 1965."

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CRITERIA AND POLICIES

After receipt of public comments and consultation with a committee representing the Atomic Industrial Forum, the AEC made a number of significant changes in the draft criteria and contracts for uranium enrichment services before they were formally submitted to the Joint Committee on Atomic Energy (JCAE) on July 1, 1966. The AEC also proposed a set of policies on the sale, lease, and toll enriching of enriched uranium after 1968. These policies were outlined in a press release of July 25, 1966, and were discussed on August 2–4 at JCAE hearings on the criteria for uranium enrichment services. Representatives of industry, in testimony on August 16 and 17, generally gave strong support for the AEC proposals. The Commission formally established the criteria by publication in the *Federal Register* on December 23.

Criteria for Uranium Enrichment Services

Key elements of the criteriar are: (*a*) the AEC will sign contracts of up to 30 years' duration; (*b*) the contracts will specify a ceiling charge of $30 per kilogram of separative work but subject to escalation; (*c*) two types of contract will be available, a "firm quantities" type which will specify feed and product assays and amounts or, alternatively, amounts of separative work, and a "requirements" type which will commit the AEC to supply (subject to a ceiling) and the customer to take (subject to cancellation rights) the enriching services required by a specified reactor or group of reactors; (*d*) quantities of feed uranium to be delivered by the customer and the amount of enriching services purchased by the customer will be determined by reference to a "Standard Table of Enriching Services" to be published by the AEC; (*e*) customers will have an option to acquire tails material (depleted uranium at an assay set by the AEC) equal to the weight of uranium feed delivered to the AEC less the weight of enriched product received from the AEC, less a correction for losses; and (*f*) uranium of foreign origin may not be delivered to the AEC for enrichment where the enriched material is intended to be used in a domestic utilization facility.

Post-1968 Policies on Sale, Lease, and Enriching

In response to the desire of the nuclear industry to be able to estimate the relative economics of lease, sale, and toll enriching, the AEC established a set of policies on those activities that will be followed after 1968:

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(1) The natural uranium component of the AEC schedule of charges for lease and sale of enriched uranium will continue to be based upon a price of $8 per pound of uranium concentrate (U_3O_8) at least through June 30, 1973.

(2) Toll enrichment is the preferred method of distributing enriched uranium. Except where provisions for long-term sales agreements are made in Agreements for Cooperation with foreign nations, any AEC sales of enriched uranium will be on the basis of single transactions. A further exception will be made in the case of distributions to domestic customers of enriched uranium to be used in a research and development program involving production of uranium 233 (U^{233}) when lease is not available and during the period when a guaranteed purchase price is in effect for U^{233}. In Agreements for Cooperation providing for supply of enriched uranium via toll enriching, the AEC will also agree to furnish, for an appropriate charge, the natural uranium for a toll enrichment transaction where the foreign party has determined that the required natural uranium is not reasonably available to him.

(3) Beginning January 1, 1971, enriched uranium on lease may be converted to private ownership by a mechanism, called "*in situ*" toll enriching, under which the lessee would furnish to the AEC specified amounts of uranium feed and dollars and would thereby acquire ownership of the leased material.

(4) The transition to private ownership of all material held or being procured by licensees for power reactor use will be accomplished by AEC's terminating distributions of such material by lease on December 31, 1970, and terminating outstanding leases for such material on June 30, 1973. These are the same dates which are already applicable under the Act to distribution of such material to power reactor operators. However, AEC will, on a case-by-case basis, consider requests by fabricators for deferred payment of enriching service charges on toll enriched material—at an interest charge on the unpaid balance equal to the then-current use charge rate—during a fabrication period of up to one year.

(5) The AEC is unable at this time to specify quantitative criteria on the disposition of AEC's available uranium feed; however, it does not plan to sell its available uranium until this can be done in a manner that will not damage the domestic uranium industry. It is expected that, once the industry attains viability, the AEC distributions will be based on an appropriate sharing of the market growth beyond the point of viability.

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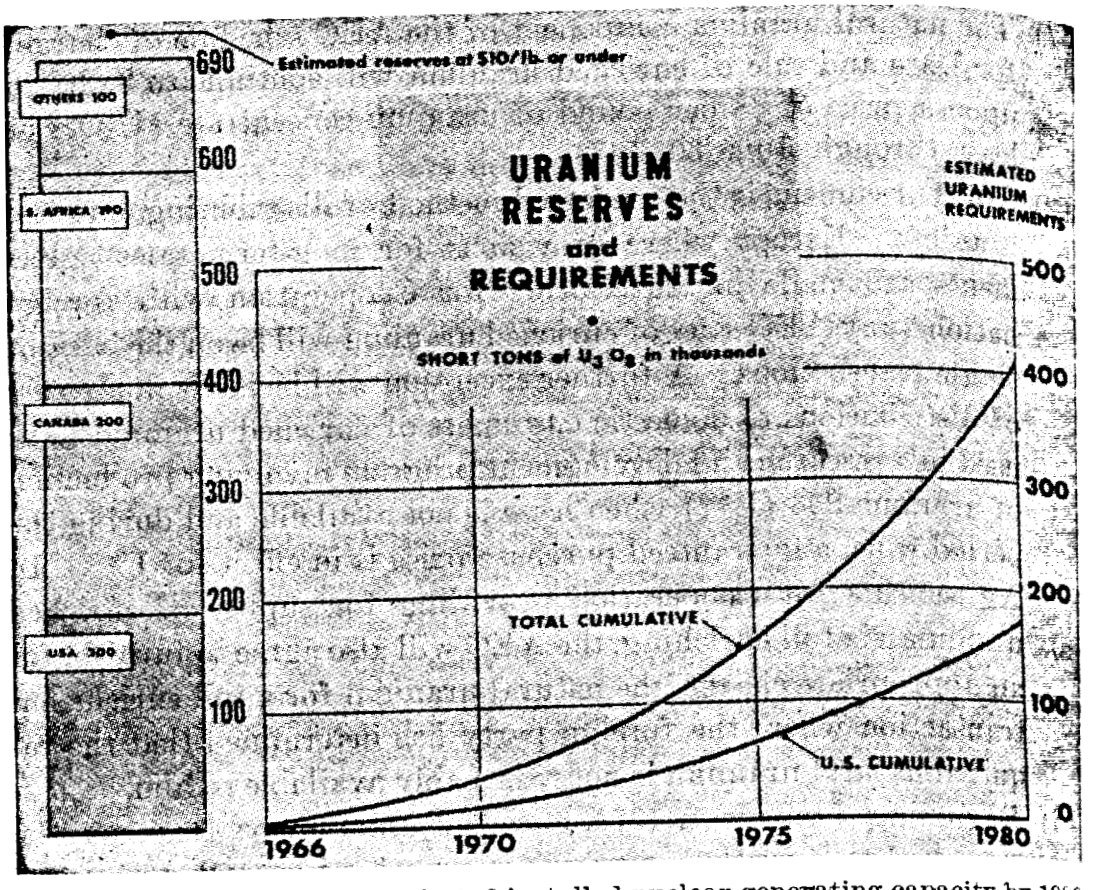

Uranium Requirements. Projected installed nuclear generating capacity by 1980 of 95,000 Mwe in the United States (median of estimated 80–110,000 Mwe range) and 130,000 Mwe in other countries (excluding U.S.S.R., China, and Eastern Europe) totals 225,000 Mwe. On this basis cumulative U.S. and total world requirements for uranium to that date are estimated at about 170,000 tons U_3O_8 and 400,000 tons U_3O_8 respectively. The present annual production rate of uranium in the non-Communist world—about 18,000 tons (U_3O_8)—will have to be nearly doubled by 1975 and more than tripled by 1980 to meet the forecast annual requirements for nuclear fuel.

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[3] See pp. 69–70, "A
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RAW MATERIALS

During 1966, the near-term future of the domestic uranium industry brightened with the announcements of expanded plans for nuclear powerplants; present U.S. uranium reserves are adequate for near-term needs, but new ore body discoveries are needed for the future.

URANIUM PROCUREMENT

Foreign uranium procurement by the AEC terminated at the end of 1966 with the expiration of the Canadian and South African contracts.

The AEC's uranium purchases in 1966 were 1,566 tons less than in 1965. The following table shows the sources and amounts received in the past two years:

	Tons of U_3O_8	
	1965	1966
U.S.A.	10,442	9,476
Canada	717	720*
South Africa	1,932	1,329
Total	13,091	11,525

*Includes 50.9 tons produced in 1966 under contract, but not delivered at year's end.

Domestic Uranium Production

AEC Procurement of Concentrate

Commencing January 1, 1967, uranium concentrate (U_3O_8) purchased by the AEC will be material the delivery of which was deferred by milling companies and by some independent mining companies from the 1963–1966 period, plus that derived from ores produced from eligible small mining properties, in accordance with the domestic stretch-out program announced in November 1962.[2]

On November 10, 1966, the AEC announced that it would contract with milling companies serving isolated areas for the purchase in 1967–68 of concentrate derived from ores from eligible small mining properties not served by stretch-out mills. The owners of several mills in isolated areas have requested arrangements with AEC to treat ores from eligible small properties. These and one or two other companies

[2] See pp. 69–70, "Annual Report to Congress for 1965;" and pp. 210–211, "Annual Report to Congress for 1962."

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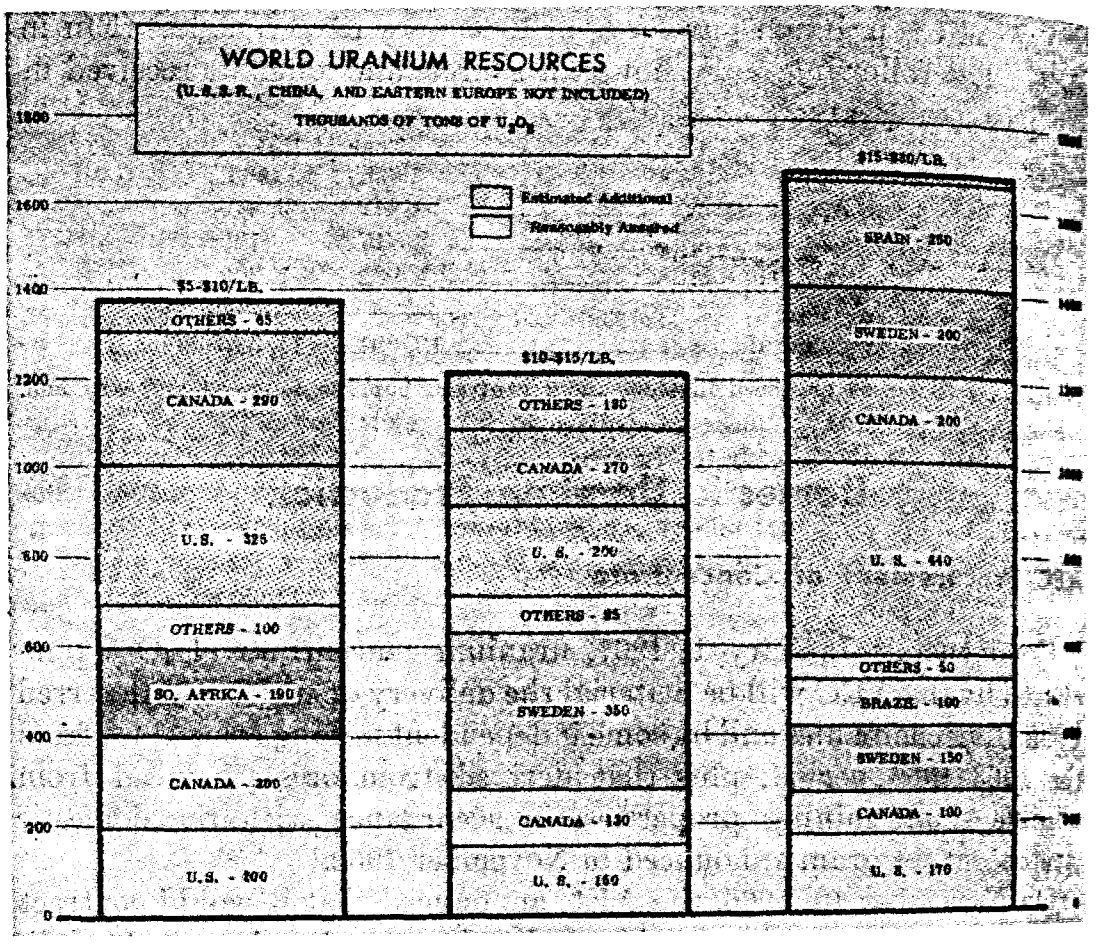
plan to continue operation after 1966 for production of uranium and other metals.

The mill of the El Paso Natural Gas Co. at Tuba City, Ariz., discontinued operations during the year after completion of production under its AEC contract.

Table 1 lists the locations of uranium concentrate producing plants operating under AEC stretch-out contracts, and the status of operations.

Industry Begins Private Procurement

Several producers have announced sales of concentrates for use in producing fuel for nuclear power installations. The orders are esti-



Uranium Resources. Forecasts of the cumulative requirement for uranium for the non-Communist world by 1980 focus attention on the question of available supply. As shown in the chart, the "reasonably assured resources" in the $5–$10 per pound U_3O_8 cost range (*left*) will more than meet the projected 1980 requirements; and, the known amount at this cost level may be doubled if exploration in known uranium-producing areas, or in areas of similar geologic favorability, fulfills the "estimated additional" expectations. Reactor engineers confidently predict improvements in fuel cycle costs and advances in reactor design which could make the use of uranium costing more than $10 per pound of U_3O_8 economic if reliance on the higher cost material should eventually prove necessary.

TABLE 1.—

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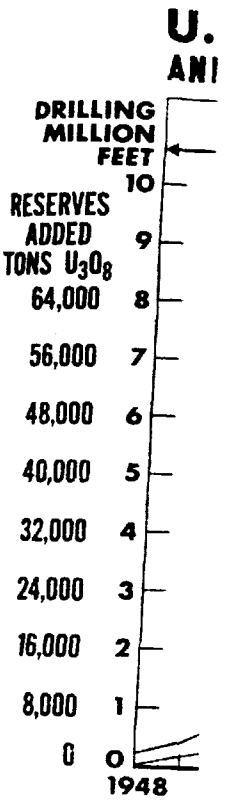

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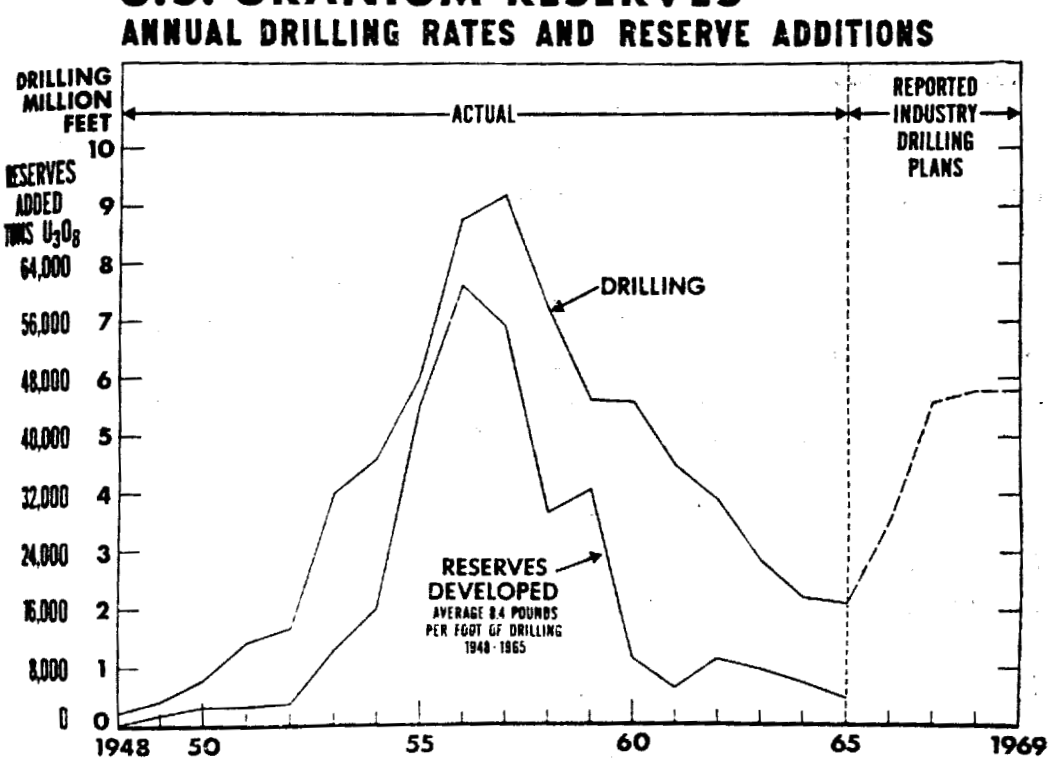
TABLE 1.—URANIUM CONCENTRATE PRODUCING PLANTS

Company (Contracts extended through 1970)	Mill Location	Estimated tons of U_3O_8 to be delivered under AEC contracts from January 1, 1967
Anaconda	Bluewater, N. Mex	3, 000
Atlas Corp	Moab, Utah	3, 800
Federal-Radorock-Gas Hills Partners.	Fremont County, Wyo	1, 450
Homestake-Sapin Partners	Grants, N. Mex	4, 360
Kerr-McGee Corp	Grants, N. Mex	6, 050
Union Carbide Corp	Natrona County, Wyo	760
Union Carbide Corp	Rifle & Uravan, Colo	3, 600
United Nuclear Corp	(Ores treated in Homestake-Sapin mill).	3, 840
Utah Construction & Mining Co	Fremont County, Wyo	2, 160
Vanadium Corp. of America	Shiprock, N. Mex	1, 340
Western Nuclear, Inc	Jeffrey City, Wyo	2, 140



U.S. Uranium Reserves. Industry has renewed its interest in uranium exploration. Although current reserves of low-cost uranium are adequate to fuel projected nuclear power installation through 1980, significant new discoveries will be necessary to supply longer term requirements. Chart shows the past relationship of additions to uranium reserves and annual drilling rates. Projected plans for industry exploration through 1969 indicate that drilling activity will expand substantially during the next few years.

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mated to amount to about 20,000 tons for current and future delivery through 1975. The rapid increase this year in utility company commitments for nuclear power installations resulted in an upward revision of estimates of uranium requirements for this purpose. The graph entitled "Uranium Reserves and Requirements" illustrates the current estimates for the United States and the non-Communist World.

The AEC program for procurement of uranium concentrates expires December 31, 1970. After that date, the producers will market their uranium exclusively through private sales, primarily for nuclear powerplant requirements. (See also "Private Ownership Act Implementation" summary at beginning of this chapter.)

Ore Reserves

The AEC was represented at the Paris conferences in May of the European Nuclear Energy Agency in a study of the uranium production capability of the world (not including U.S.S.R., China, and Eastern Europe). The report of the conferences has not yet been released, but is expected shortly.

U.S. Reserves

U.S. uranium ore reserves at the beginning and end of 1966, calculated at $8 a pound of uranium concentrates, were:

	Tons of Ore	Percent U_3O_8	Contained Tons U_3O_8
Estimated reserves Jan. 1, 1966	61, 600, 000	0. 235	145, 000
Estimated reserves Jan. 1, 1967	61, 000, 000	0. 23	141, 000*
Decrease in estimated reserves	600, 000	----	4, 000
Shipments to mills in 1966	4, 200, 000	0. 23	9, 800

*Reserves available at up to $10 a pound of U_3O_8 are estimated to be 200,000 tons.

There were approximately 1,850 tons of U_3O_8 in ore stockpiles, and 3,150 tons in process and finished product, making a total inventory at the mills of 5,000 tons at the end of the year.

Net additions to $8 reserves during the year were approximately 5,800 tons of contained U_3O_8, only partially offsetting production and delivery to mills of about 9,800 tons.

Free world resources. The estimated total of reasonably assured world uranium resources available at up to $10 per pound of U_3O_8 is now estimated to be approximately 690,000 tons compared to 640,000 tons at the end of 1965, due mostly to an increase in the estimate of South African reserves.

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New Discoveries Needed

The presently estimated U.S. reserves are adequate for near-term needs, but in view of large projected requirements for nuclear power, significant new discoveries will be needed in the 1970's to maintain sufficient reserves to supply long-range needs. There is evidence that the needed exploration activity will be undertaken by industry. Exploration and development drilling in the last half of 1966 was at a rate more than double that of the two preceding years, and industry plans for the next few years are for an even greater activity. The mining companies' exploration plans as reported to the AEC in mid-1966 for the 3½-year period through December 1969, are shown on the chart together with curves showing past drilling rates and annual ore reserve additions.

To supplement these efforts, the AEC plans to support a topographic and geologic mapping program in favorable areas through the U.S. Geological Survey, and carry out a series of studies directed toward the development of improved geologic and geochemical guides for exploration, new geophysical exploration methods and tools, and regional geologic evaluation.

Thorium Resources

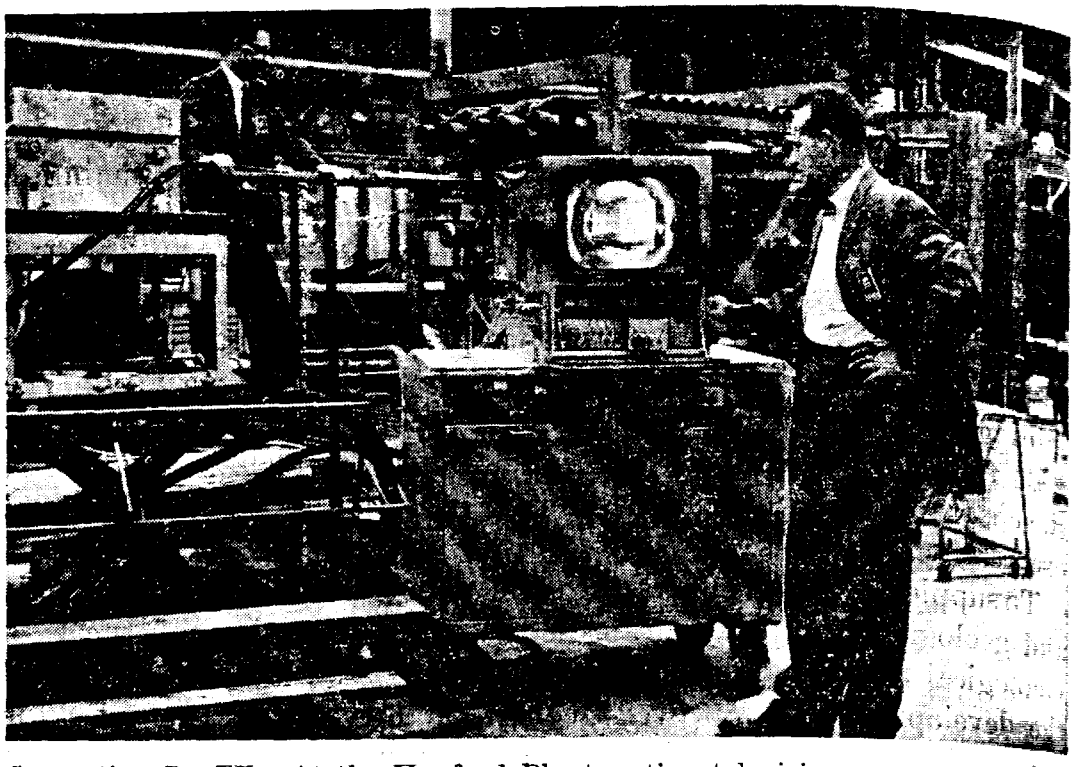
There has been no indication of early large requirements for thorium as a nuclear fuel. The estimate of reasonably assured resources in the United States available at a price of $10 a pound of ThO_2 remains at about 100,000 tons as reported last year.

NUCLEAR MATERIALS PRODUCTION

Special nuclear materials production during 1966 was sufficient to meet all scheduled requirements for military and civilian programs. Production has been at reduced levels since the decreased need for these materials was first announced by the President in his State of the Union Message on January 8, 1964.

PRODUCTION REACTORS AND FACILITIES

Built primarily for producing plutonium, the large production reactors at the AEC's Hanford and Savannah River Plants are also being used for other purposes. One is not only providing steam for an adjacent electric power station, but will also be demonstrating the production of tritium. A shut-down reactor is being used for a demon-



Inspection By TV. At the Hanford Plant, a tiny television camera is used to inspect the insides of a "N" reactor process tube. As the television probe is pushed through the process tube, the inside surfaces are displayed on a television screen. The General Electric Co.'s "N" reactor staff worked more than two years developing the probe which can measure scratches as slight as .00025-of-an-inch deep. Prior to this development, process tubes of the world's largest dual-purpose (production and power) reactor could not be inspected for damage.

stration on safe-guarding against clandestine operation of a reactor that has been closed down by international agreement. Some capacity is being used for production of radioisotopes and the conduct of scientific experiments on man-made elements. The production system began to feel the full effects during 1966 of the 1964–1965 cutbacks in production.

Hanford "N" Reactor

Reactor operation. Operation of the "N" plutonium production reactor[3] at Hanford was essentially normal for the entire year following the attainment of full design power of 4,000 thermal megawatts in December 1965. The tie-in of a sixth primary coolant loop to improve quality of the steam to be used in the adjacent Washington Public Power Supply System (WPPSS) powerplant was completed in early June after a five week shutdown. The only other

[3] The "N" reactor, formerly called the "NPR" (New Production Reactor), is a dual purpose plant—producing plutonium as its primary product with the steam generated in these operations being used in the turbines of the adjacent WPPSS electricity generating plant. As such, it is currently the world's largest nuclear power reactor in operation.

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outage of consequence was due to the strike against two Hanford contractors which essentially shut down all production facilities for about six weeks during July and August (see "Collective Bargaining" discussion in Chapter 18—Administrative and Management Matters). Early in 1967, fuel and target elements are scheduled to be charged to the reactor for a co-product demonstration of tritium (hydrogen 3) and plutonium production.

Power generation project. Construction of the inter-connected 786 electrical megawatt (Mwe) powerplant by WPPSS was completed during 1966 and much of the year was spent in startup and testing programs prior to full power output. Initial power generation using steam produced in the "N" reactor began on April 8. Full power operation of 786 net Mwe (800 gross Mwe) was achieved on December 9, 1966, following completion of operational stability testing. However, on December 10, failure of a high voltage transformer (230/500 kilovolts) in the Bonneville Power Administration's transmission system made it necessary to reduce the full-power output. At year's end, the WPPSS plant was generating at the 400 Mwe-level. Full power operation cannot be resumed until repairs are made to the special-type transformer—estimated to be six to eight months.

Savannah River Reactors

At the Savannah River Plant, the versatility of the plutonium production reactors was further developed and demonstrated. A high-flux demonstration, which attained sustained neutron flux levels never reached before (6.1×10^{15} n/cm^2-sec.), provided an opportunity for scientific teams from several laboratories to conduct experiments not heretofore possible. It also resulted in the production of the world's most highly radioactive—700 curies per gram—cobalt 60 source. These operations are summarized in the "Radioisotope Production" section of this chapter.

The Savannah River reactors continued to be used, in addition to production of materials for nuclear weapons, for irradiating target materials to produce heat-source isotopes of usefulness to the Nation's space program (see Chapter 9—Isotopic Heat and Power Applications) and transuranium elements that will be used for research and production purposes at the new National Transuranium Center at Oak Ridge (see Chapter 13—Research Facilities and Projects).

VERIFICATION SYSTEM FOR SHUTDOWN REACTORS

During the year, a simple, reliable, and unobtrusive system to verify non-operation of a nuclear reactor that had been shut down under

international agreement was demonstrated to delegates to the United Nations General Assembly at a shutdown Hanford production reactor.

Presidential Announcement

In his January 21, 1964, message to the 18-Nation Disarmament Committee, the President had announced that the United States was prepared to ". . . accept appropriate international verification of the reactor shutdown already scheduled in our country . . ."[4] Within the U.S. Government, the AEC undertook the development of a system, for use by an international verification group, to assure that a production reactor that was shut down had not been operated between verification visits. The primary responsibility for developing the system was given to the General Electric Co., contract operator of the AEC's Hanford Plant at that time. The work has been continued by Battelle Memorial Institute and Douglas United Nuclear, contractors that have since taken over portions of the Hanford operations for the AEC.

"Fingerprinted" System

The system makes use of a bimetallic tape in which the core has a lower melting point than the jacket, *i.e.*, aluminum core, and copper or stainless steel jacket. Because of the difference in melting points of the two metals, any attempt to rejoin a cut in the tape is immediately apparent. The tape itself is "fingerprinted" with randomly-distributed particles of an X-ray opaque material, *i.e.*, scattered, irregularly shaped tungsten filaments, and thus presents a unique pattern under X-rays. Any substitution of a tape would be evidenced by comparing X-ray photographs of the tape taken at the time of installation with those taken by inspectors at a later time. Also incorporated in the wire is a small amount of cobalt which, if exposed to the neutron flux of an operating reactor, would become radioactive. The cobalt would become sufficiently radioactive upon exposure to even a low density neutron flux to disclose, upon the wire's removal months or years later, the occurrence of a chain reaction.

In application, the tape would be threaded through the shutdown reactor, and the ends fixed by specially developed "fingerprinted" seals, utilizing random particles of an X-ray opaque material in epoxy resin. During later inspections, the seals would be checked—

[4] In his State of the Union address of January 1964, President Johnson had announced that the U.S. intended to curtail production of fissionable material for use in weapons. That action entailed shutting down four plutonium production reactors and decreasing the production of enriched uranium.

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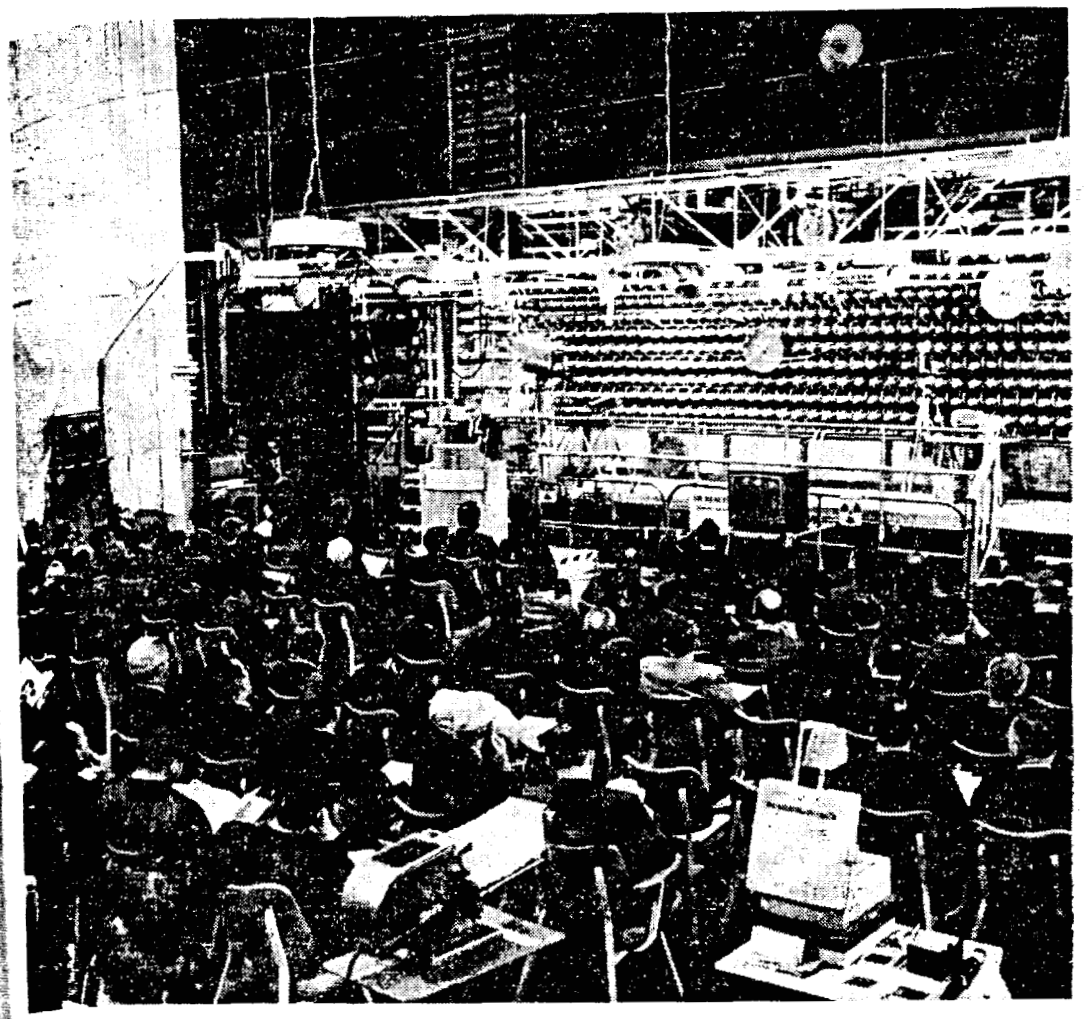

International Demonstration. Forty-eight representatives of United Nations delegations from 42 countries attended the November 16 demonstration of the AEC-developed system designed to verify that production reactors shut down under an international agreement have not been operated between visits of inspectors. Photo shows the visitors listening to Dr. Charles Harrington, President of Douglas United Nuclear, Inc., explain the system. In the background is the front face of the shutdown "F" reactor on which the system was demonstrated.

comparison of X-ray and other photographs—for any signs of tampering and the tape would be withdrawn and checked for authenticity and radioactivity.

International Demonstration

In April 1966, the U.S. delegation to the 18-Nation Disarmament Committee meeting at Geneva, Switzerland, submitted a working paper on the system developed by the AEC and its contractors at Hanford for verifying the status of shutdown reactors. This was followed by an August briefing of the system for members of the disarmament conference delegations by an employee of Douglas United

Seal Installation. Photo shows technicians installing a "fingerprinted" seal, to which the "telltale" tape it attached, on the "F" Reactor at Hanford during the demonstration of the verification system for United Nations delegates who visited Hanford on November 16.

Nuclear. At that time, the United States invited the member governments of the 18-Nation Disarmament Committee and other interested governments to send representatives later in the year to a demonstration at Hanford of the system. Later, on November 4, 1966, in New York City, this invitation was extended by the U.S. delegation to all members of the United Nations General Assembly.

The demonstration took place at Hanford on November 16 with 53 representatives from 45 nations and international organizations attending.

CUTBACKS IN PRODUCTION

As a result of the Presidential announcement[5] to cut back plutonium production, four of the AEC's 14 production reactors were shutdown in 1964 and 1965. The full impact of these shutdowns was being felt at other AEC facilities during 1966.

[5] The first reduction was announced by the President in the State of the Union message on January 8, 1964—see pp. 17, 18, and 44, "Annual Report to Congress for 1964"; and p. 7, "Annual Report to Congress for 1965."

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Separations Facility Closed

At the Hanford Plant, where three of the four closed reactors are located (the other one is at Savannah River, S.C.), the Redox plant—the older of two chemical separations plants in the plutonium production complex—is being shut down. The plant was constructed in 1951, and was the first large-scale solvent (Hexone) extraction-type plant built in the United States for the recovery of plutonium from irradiated uranium fuel. Dissolution of irradiated uranium fuels was terminated on December 31, 1966. During the first six months of 1967, the plant will be flushed to remove residual amounts of uranium and plutonium and then placed in "standby" condition. The Purex plant, also using a solvent extraction system, has been modified to permit its processing irradiated fuel discharged from the Hanford reactors.

Gaseous Diffusion Plants

During 1966, the electric power usage at the AEC's gaseous diffusion plants (Oak Ridge, Tenn.; Portsmouth, Ohio; and Paducah, Ky) was reduced by 715,000 electrical kilowatts (ekw), as follows: 300,000 ekw at Portsmouth supplied by Ohio Valley Electric Corp., 325,000 ekw at Paducah supplied by Electric Energy, Inc., and 90,000 ekw at Oak Ridge supplied by TVA. These reductions, which will result in annual savings of about $25 million, are part of the steps taken to reduce the total power usage to two million ekw by January 1, 1969.

On December 29, the AEC announced it was undertaking studies on the possible desirability of selling or leasing to private industry one or more of the three gaseous diffusion plants. Built for national defense purposes at a cost of $2.3 billion, the plants also provide enriched uranium for use as fuel in civilian reactors. With the reductions in defense requirements, civilian reactors are expected to become the primary market for enriched uranium in the future. The plants are operated for the AEC by private contractors (see also Chapter 17—Industrial Participation Aspects).

PRODUCTION OPERATIONS

During the year, the AEC consolidated some of its feed materials activities and, after an independent study, decided to continue its heavy water production operations. The recovery of bulk quantities of heat-producing radioisotopes from chemical processing wastes is discussed under the "Radioisotope Production" section of this chapter.

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Weldon Spring–Fernald Consolidation

In April 1966, the AEC announced that the Weldon Spring, Mo., feed materials plant (operated by Mallinckrodt Chemical Works) would be shut down as part of a program to consolidate the feed materials production operations at the Fernald plant near Cincinnati, Ohio. Fernald is operated by the National Lead Co. The two plants had been operating at reduced levels as a result of the plutonium and enriched uranium production cutbacks. The plant shutdown was completed at year's end.

Expressions of interest were solicited from industry for possible commercial use of the Weldon Spring facilities. The nature of industry interest will, in large measure, determine whether proposals will be formally requested.

Consolidation of facilities. The consolidation of the feed materials activities at Fernald required the reactivation of some of the plant units at that site which had been in a standby condition. The concentrate sampling and storage activities which had been handled at Weldon Spring were transferred to the Grand Junction Office. In addition, Mallinckrodt Chemical Works had conducted a process development program at Weldon Spring directed toward reducing the costs of feed materials production. This program was combined with similar efforts at the Fernald plant and the necessary equipment for the activity transferred to Fernald from Weldon Spring.

Weldon Spring library. The Technical Library from the Weldon Spring Plant was turned over to the University of Missouri for use in the school's St. Louis Branch. The university will keep the library intact and make the information available to the public (see also Chapter 15—Informational Activities).

Storage Site Disposal

St. Louis Airport. All uranium-bearing residues (with the contained recoverable elements) at the St. Louis Airport Storage Site were sold to the Continental Mining and Milling Co. Removal of these residues, which contain other recoverable elements, was completed on November 1. The land will be turned over to GSA for disposal as Government surplus.

Middlesex. All materials stored at the Middlesex, N.J., Storage Site were removed and complete decontamination of the facilities for unrestricted disposal should be completed during 1967.

Boron 10 Production

The AEC-owned boron 10 plant at Model City, N.Y., operated by Nuclear Materials and Equipment Corp., Apollo, Pa., continued to supply material for Government-wide uses and small commercial

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Heavy Water Production

Change-over study. At the request of the AEC, an Atomic Industrial Forum *ad hoc* committee was appointed in 1965 to study the feasibility and interest of industry in producing heavy water on a commercial basis.

After a careful study of the heavy water production operation and projected requirements, the committee forwarded a report of their study to the AEC in the spring of 1966 which concluded that ". . . because of the limited domestic market and competition from government-assisted foreign production plants, it seems unlikely that a private company would be willing to assume the risk of building new heavy water production facilities in the United States at the present

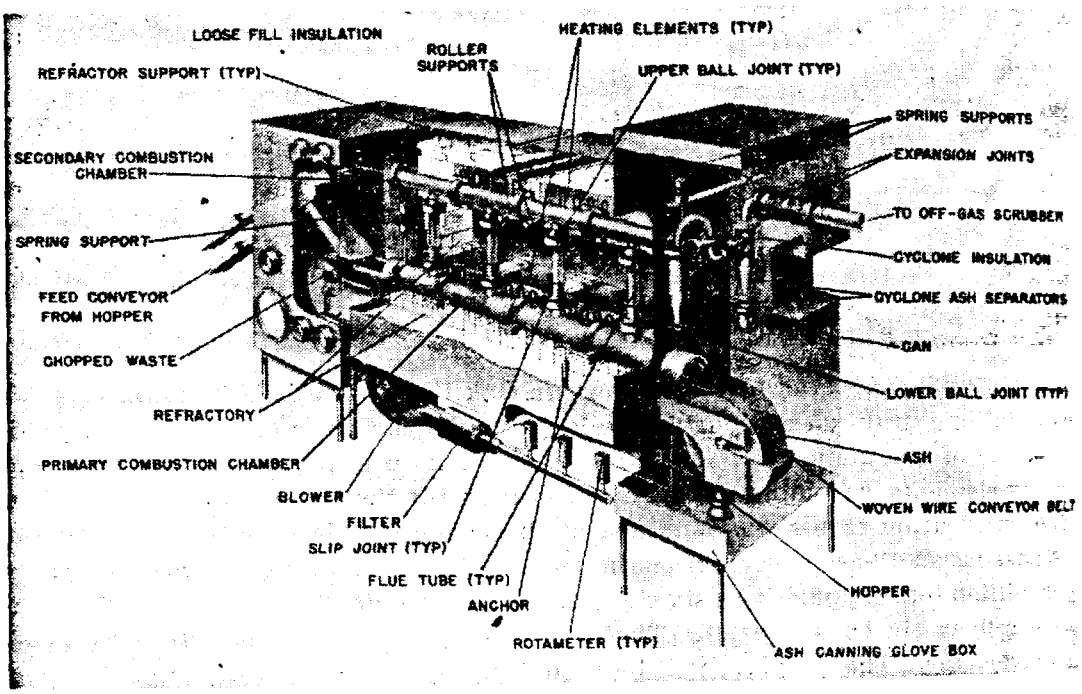
Unique Products. Photo on *left* shows an Oak Ridge, Tenn., Y–12 Plant chemist examining a uranium rod purified to less than 50 parts per million total impurities, one of the highest refinements known. This was the summation of 75 impurity elements, assuming the maximum values for the lower limits of detection. The purification factor was obtained at the Union Carbide Corp.-operated plant by passing an 18-gram portion of the rod—which originally contained 900 parts per million total impurities—six times through a standard electron-beam floating-zone refiner (in background). The purity was verified by a spark-source mass spectrometer. The uranium will be used for research purposes. Photo on *right* shows a Hanford product that has been produced in metal button form for the first time. It is a button of neptunium which was produced in the Hanford Plutonium Chemistry Laboratory by Isochem Inc. Operation of the AEC-owned chemical separations facilities was taken over at the start of 1966. The neptunium is being used by the Pacific Northwest Laboratory for metallurgical studies. Previously all neptunium recovered from irradiated uranium fuel elements at Hanford was processed to nitrate solution or oxide form. The silver-dollar-sized button weighs 123 grams.

time or in operating the Savannah River facilities. . . ." In view of the AIF committe's study report, the AEC decided to continue operation of the Savannah River plant at one-third capacity and to continue to watch closely the heavy water market.

Sales increase. Production of heavy water at Savannah River in 1966 amounted to 186 tons. Heavy water sales to U.S. customers totaled 7.3 tons—an increase over 1965 sales. Foreign sales during the year totaled about 232 tons which was almost a nine-fold increase over 1965, due principally to the 127-ton sale to France for the EL-4 reactor. Foreign leases, principally to Canada for the remainder of the heavy water needed for the first CANDU reactor at Douglas Point in Ontario, totaled 94 tons. Domestic loans and leases in the United States totaled 38.4 tons.

Plutonium Scrap Recovery

Operations at the Hanford Plutonium Reclamation Facilities, for the recovery of plutonium from solid scrap and waste solutions, were increased in March from a 15-shift week to a 21-shift week to expedite the recovery of plutonium from the scrap backlog. The $3.2 million reclamation plant [6] has been in operation since 1964.



Plutonium Recovery. Diagram shows the incinerator, which was completely rebuilt in 1966, that is used for burning combustible scrap, such as papers, cardboard, and rags, contaminated with plutonium at the Hanford Plant. The ash, containing the plutonium, is then treated in the Hanford Plutonium Reclamation Facility.

[6] See p. 51, "Annual Report to Congress for 1964."

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New Arrangements for Small Lots

It is AEC policy to use commercial services for processing all AEC-generated plutonium scrap—other than that generated from the plutonium production and the weapons fabrication programs.[7] However, individual AEC operations and contractors may have nonproduction and/or nonweapons plutonium scrap in amounts too small to justify separate commercial scrap processing arrangements. In May, the AEC's Richland Operations Office was given the responsibility to act as an agent for handling such amounts by combining them into suitably segregated and sized processing lots, and arranging for commercial recovery of the plutonium and other nuclear materials that can be recovered economically from the scrap.

Production Planning

Five-Year R&D Planning

The future demand for weapons material has decreased, thus making it possible to use the production reactors to produce increasing quantities of other useful products. A long-range process development program has been established to reduce costs of a variety of new isotopes for commercial and space applications (see Chapter 9—Isotopic Heat and Power Applications). The approved program has broadly based objectives to: (*a*) provide data regarding likely availability of non-weapon reactor products, (*b*) provide a base upon which to establish future, more complete, technology as specific requirements materialize, (*c*) minimize interference with the weapons mission, (*d*) incorporate flexibility to adjust rapidly to mission priorities, and (*e*) avoid, insofar as possible, potential future "crash" programs.

Investigation of Resonance Reactors

A resonance reactor has been suggested by the Savannah River Laboratory as an attractive method for converting uranium 236 into the neptunium 237 target material needed to meet the anticipated plutonium 238 demand over the next 15 years. One possible conversion of a Savannah River production reactor involves displacing 80 to 90 percent of the heavy water (D_2O) moderator with materials such as

[7] See p. 82, "Annual Report to Congress for 1965."

aluminum or magnesium—which neither moderate nor absorb neutrons to any large extent—while retaining the present lattice configuration of the reactor. Another concept to achieve a more efficient configuration of a resonance reactor would involve the creation of a compact and relatively homogeneous mixture of fuel, D_2O moderator, and controls. The compact core design would require extensive modifications of the present control system, moderator circulation, safety systems, etc., and could be constructed either in an existing reactor tank or in a closely adjacent new tank at about the same cost. The compact core design would have a significant productivity advantage, but would cost considerably more. Both the technical feasibility and the economic evaluation of the two concepts are under study.

RADIOISOTOPE PRODUCTION AND SALES

Radioisotopes being used, or under study for potential uses, as thermoelectric power sources are either man-made by irradiation of selected target materials with neutrons, or are recovered as byproducts (fission products) from chemical processing of "spent" reactor fuels. The increasing interest in certain radioisotopes for isotopic heat applications has stimulated technological development of cheaper and better methods for irradiating target materials in the AEC's production reactors. At the same time, chemical processes are being developed for economical recovery of highly purified isotopic products on a larger scale than previously. The current and potential uses of radioisotopes in space, terrestrial, and marine systems, and the development of the fuel sources for these uses, are discussed in Chapter 9—Isotopic Heat and Power Applications.

NEUTRON ADDITION PRODUCTS

Originally, the AEC's production reactors at Hanford and Savannah River were built specifically to provide fissionable material for the Nation's defense. However, because of their large size and wide range of neutron flux these reactors offer significant advantages for the production of special radioisotopes. This can be done by neutron irradiation of specific target materials, generally over a period of several months, and in some cases, years. The desired isotope ordinarily must be chemically separated from the target material after the irradiation period. The more important of the heat-producing isotopes being made directly by neutron addition reactions at Savannah River are

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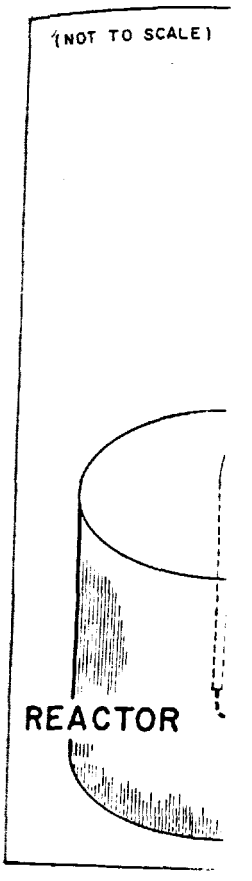

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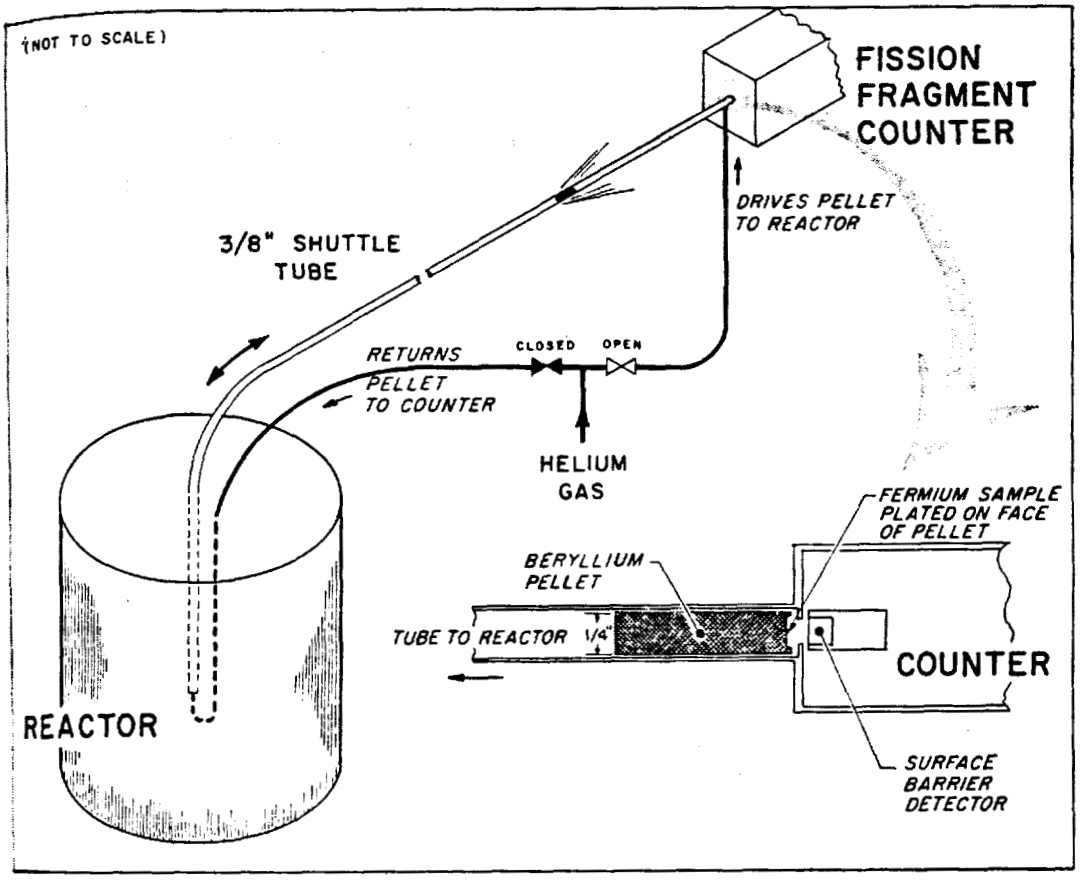
curium 244, plutonium 238, cobalt 60, and polonium 210. Also being produced are unique heavy element radioisotopes, such as americium, berkelium, and californium which are of scientific interest.

HIGH-FLUX OPERATION

A successful one-year demonstration of very high flux operation, for scientific as well as technical purposes, was completed at the Savannah River Plant (SRP) in February 1966. During this program, stable reactor operation was demonstrated at neutron flux levels up to 6.1×10^{15} (six quadrillion) neutrons per square centimeter per second (n/cm^2-sec.)—the highest sustained flux ever attained in any



Sample Irradiation. Diagrams show a pneumatic device for rapidly moving a sample from the center of a reactor core to a counting facility that has been developed by E. I. du Pont de Nemours & Co. engineers at the AEC's Savannah River Plant to take advantage of the high thermal neutron flux (5×10^{15} n/cm^2-sec) available in the production reactors. The sample, coated on the end surface of a pellet (see *lower right*), is irradiated in the reactor and then transported in about one second through a 75-foot-long shuttle tube for counting at a detector. The high-speed pneumatic facility was used by scientists from the Lawrence Radiation Laboratory to irradiate fermium 257 to produce fermium 258. The results have not yet been reported. Consideration is being given to using this device for additional tests during future high flux operation at Savannah River.

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reactor in the world—and at heat fluxes up to 2.66×10^6 (2.66 million) BTU per hour per square foot, and specific powers of 226 kilowatts per gram of uranium 235.

Scientific Experiments

During the SRP high-flux demonstration, research samples containing over 150 nuclides of 66 elements were irradiated for several universities and various AEC national laboratories. Irradiation of cobalt 59 produced the world's most concentrated cobalt 60 source—containing 700 curies/gram and generating 96 watts/cc of heat—for fundamental studies at the Savannah River Laboratory. Also, during this program in 1966, more sophisticated tests than those accomplished in 1965 were completed at the reactor site by scientists and engineers from the Lawrence Radiation and Savannah River Laboratories to measure the half-life of fermium 258 (see below); new isotopes from double neutron capture in stable targets were produced and tentatively identified at the reactor site by scientists from Argonne National Laboratory; an experiment confirming the hard texture of the moon observed in the Surveyor I landing was completed by scientists of the Brookhaven National Laboratory; and many other scientific experiments, the results of which are still being developed by experimentors from various universities and AEC laboratories, were completed.

Fermium Half-Life Finding

A series of irradiation tests, begun by Lawrence Radiation Laboratory scientists in 1965 in an attempt to measure the half-life of fermium 258 (Fm^{258}) was continued in 1966. While no evidence was obtained for the formation of this nuclide, the high neutron fluxes attained made it possible to set an upper limit of about 10 seconds for its spontaneous fission half-life.

The stability of Fm^{258} and Fm^{260} (158 and 160 neutron subshells, respectively) toward spontaneous fission is of key significance in determining the upper limit of nuclear stability as atomic number increases. Because of the perturbation introduced by the 152 neutron subshell, theoretical extrapolations of spontaneous fission half-lives for nuclei with neutron numbers above 156 are contradictory and allow the possibility of a recovery of stability at this level. Experiments, however, had shown a trend toward shorter spontaneous fission half-lives above the 152 neutron number.

The extremely short spontaneous fission half-life limit for Fm^{258} determined in the Savannah River experiments suggests that the recovery of stability after the 152 neutron subshell is unlikely, although

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similar measurements of Fm^{260} will be necessary before reaching a final conclusion. As a consequence, theories on much of the recent spontaneous fission systematics are in danger, and equally so are the possibilities of creating heavier nuclides. Neutron capture by a rapid process such as occurs in thermonuclear explosives may lead to new odd-mass nuclei, but formation by prolonged neutron irradiation in reactors will be severely limited because of losses of key nuclides through spontaneous fission decay.

Special Reactor Products

The demand for the man-made transplutonium isotopes, especially curium 244 and plutonium 238, continues to grow as new uses for them in the space programs (see Chapter 9—Isotopic Heat and Power Applications) are found and with the opening of the National Transplutonium Program Center at Oak Ridge (see Chapter 13—Research Facilities and Projects). Efforts are continuing at Savannah River to increase the production rate for transuranium radioisotopes as well as such other special reactor products as cobalt 60 and polonium 210. Shortly after the completion of the high-flux-operation demonstration, the plutonium target elements which are being used to produce curium 244 were charged to the reactor. In addition to producing curium 244, other isotopes—polonium 210 and cobalt 60—are being produced, and numerous special irradiations are being carried out at a flux of approximately 10^{15} n/cm^2-sec.

Curium 244

Production of curium 244 (Cm^{244}) is a multistep, multiyear process. During 1966, the last irradiation step in a pilot production program which began in 1963, was underway with the irradiation scheduled for completion early in 1967. During the year, it was also found possible to increase the planned output by 50 percent at a low incremental cost by minor modifications to the irradiation schedule.

Curium 244 is being produced in a production reactor by irradiating plutonium 239 (Pu^{239}). The portion of the starting plutonium not lost through fission is converted to heavier isotopes by successive neutron capture. The plutonium thus produced, rich in the plutonium 242 isotope, is separated and irradiated further to produce americium and curium. In the current production program, the irradiation of plutonium 239 was started in 1964, and the irradiation of the plutonium 242-rich fraction was started in 1965.

Residuals reused. In the scheduled high-flux irradiations, 4.5 kilograms—instead of the previously planned 3 kg.—of curium 244 will

be produced by April 1967. Starting in September 1967, this curium 244 will be separated and purified in temporary facilities being provided at the Savannah River Laboratory. Residual plutonium 242 and americium 243 (Am^{243}) will be separated; these materials can then be used to produce additional quantities of curium 244 which has a 17.6-year half-life. The purified product will be used to characterize curium 244 as an isotopic heat source and will be available for other research needs. The work to develop curium compounds suitable for isotopic power applications supplements and is coordinated with the curium heat source work at the Oak Ridge National Laboratory. The irradiation will also produce about 20 milligrams of californium 252 (CF^{252}) as a byproduct. Californium 252 is currently being evaluated for possible use for neutron radiotherapy of cancer. Californium and berkelium (Bk), another isotope formed in the irradiation, are valuable raw materials for the production of heavier elements.

Facilities being designed. New facilities are being designed at the Savannah River Laboratory to handle quantities as large as 100 to 1,000 grams of curium 244 to permit the necessary support work on manufacturing processes for fuel form and encapsulation. The facilities are expected to be located in a new wing designated as the Isotopes Process Development Laboratory (IPDL) to the major Research and Development Building at Savannah River. The curium 244 facilities envisioned for the IPDL will permit the development of all processes up to, and including, the encapsulation of curium 244 for use in power sources.

Plutonium 238

During 1966, studies were completed of various alternatives available to the AEC to increase the long-term production of the plutonium 238 isotope. However, because the production process is lengthy and complex, little can be done to increase near-term production significantly.

Useful heat source. Plutonium 238, with an 87-year half-life, is a very attractive radioisotope for heat source purposes, especially where long service and minimum shielding requirements are needed. Plutonium 238 is made in production reactors by irradiating neptunium 237 (Np^{237}) with neutrons. Neptunium 237, however, is currently obtained only as a byproduct from thermal reactors; therefore, its present availability is dependent on large-scale manufacture of other isotopes. Alternative methods were developed to enhance neptunium 237 production. With these alternatives, significantly more plutonium 238 can be produced over extended periods, although little can be done to increase plutonium 238 availability in the near term.

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Although forecasted demand for plutonium 238 may exceed its availability for irradiation of neptunium 237 from the production reactors, large amounts of plutonium 238 may be derived from by-product neptunium 237 recovered from spent power reactor fuels after the mid-1970's. This target material could be advantageously converted to plutonium 238 in the production reactors because of their relatively high neutron flux, short irradiation cycles, and available irradiation space. Thus, the production reactors may complement power reactors to provide a more abundant and inexpensive supply of plutonium 238.

Plutonium 238 oxide. When plutonium 238 (Pu^{238}) was first produced at the Savannah River Plant, it was shipped off-plant as a solution of plutonium nitrate. A new facility was started up in July 1965 to produce plutonium oxide in an easier-to-handle powder, rather than in liquid form. Now, plutonium oxide is shipped in a container (see illustrations) that can withstand an internal pressure of 825 psig, a temperature of 925°C., and an impact equivalent to a drop of 35 feet.

Cobalt 60

Of all the radioisotopes currently being produced, the market for cobalt 60 (Co^{60}) is the greatest. Already widely used—because of its strong gamma radiation—in industry, medicine, and research, the use of cobalt 60 for irradiation processing of foods and the possible use as a heat source now indicates a need for even more production in the future. Until 1966, the Savannah River Plant and the General Electric Co. (Pleasanton, Calif.) have been the Nation's major domestic sources of high specific activity Co^{60}.

In May, the AEC approved a request of Consumers Power Co. of Michigan to produce Co^{60} in the Big Rock Point Nuclear Power Plant in Charlevoix County, Mich. Production of Co^{60} will be incidental to the continued operation of the Big Rock Point plant as a power-producing reactor (see Chapter 17—Industrial Participation).

Cobalt 60 has a half-life of 5.3 years and is made by irradiating natural cobalt, which is 100 percent cobalt 59, in a nuclear reactor. Pure cobalt 60 would have a specific activity of 1,140 curies/gram and a total energy release rate of 17.7 watts (thermal) per gram, but high concentrations of cobalt 60, *i.e.*, high specific activities, are difficult to obtain except at very high reactor fluxes. Cobalt 60 at low specific activity (up to 50 curies/gram) has been made in large quantity in the past for applications where the gamma rays were used for radiography and product irradiation. However, there are advantages to using cobalt 60 at a high specific activity (100 to 400 curies/gram) in heat producing applications. During 1966, significant quantities of

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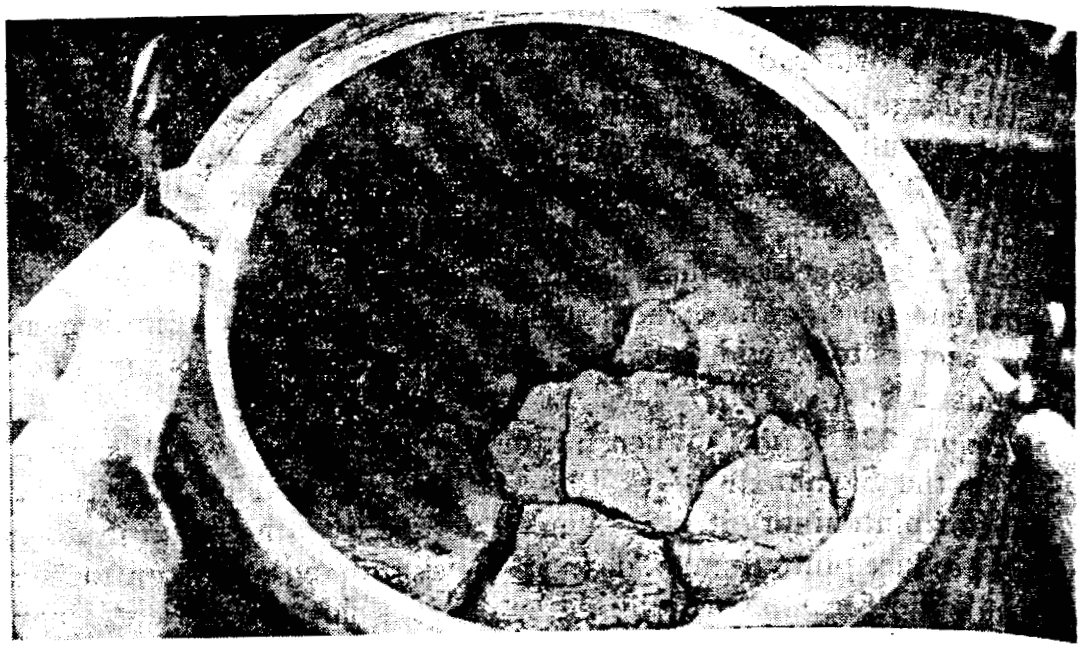
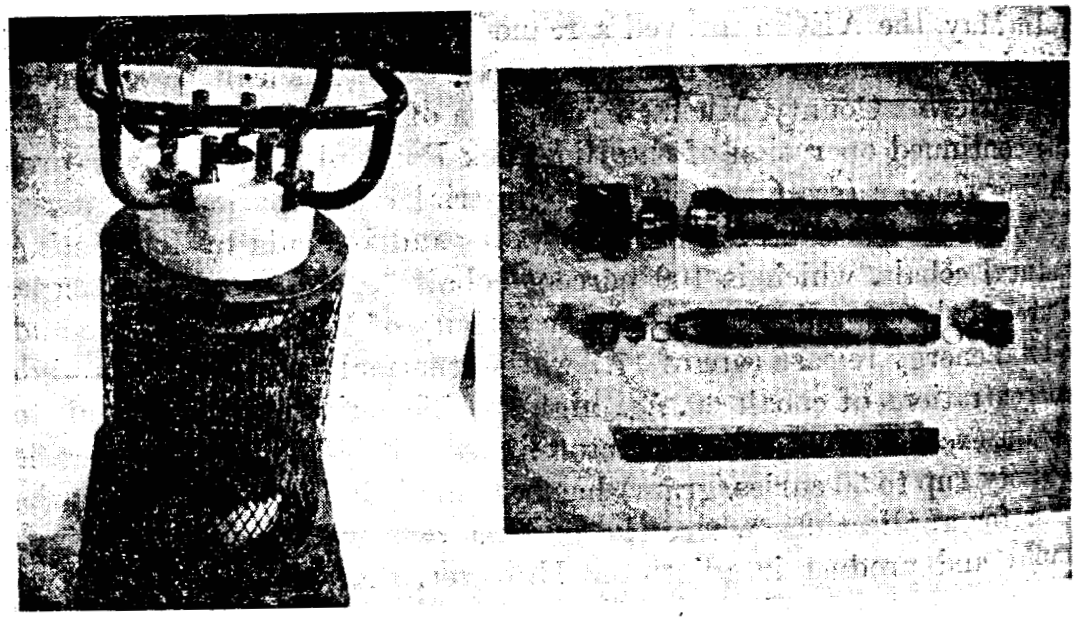


Plutonium 238. Plutonium 238 is a man-made radioactive material produced at the AEC's Savannah River Plant (SRP) near Aiken, S.C. Among other things, it is useful as a heat and power source for space vehicles. The material is shown *above* in cake form at the SRP chemical processing area. The material is shipped to a fabrication facility off-site, where it is prepared for the ultimate user. Photos *below* show the SRP-developed container for the plutonium oxide which is actually three containers in one. Oxide is loaded into the inner container (*bottom right*) a stainless steel tube, which is then sealed on both ends with metal plugs, caps, and gas-filled O-rings. The inner container is then loaded into a stainless steel can, which is then sealed with a stainless steel cap and a "Silastic" gasket. The can is then decontaminated and loaded into an outer stainless steel container (*bottom left*) which is covered with a layer of polythene through which radial metal fins protrude. The stainless steel and the polythene absorb neutron radiation and the metal fins dissipate heat. The 15-pound container, is about 16½ inches high.



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cobalt 60 at high specific activity were made in the Savannah River reactors, to be used for investigating the metallurgical properties and to provide physical data for engineering designs. In addition, a small sample (about 1⅓ grams) of cobalt was irradiated to a record specific activity of 700 curies per gram for similar experimental purposes. Such concentrated sources of penetrating energy could have uses in the radiography industry.

The technology of producing and using cobalt 60 as a heat-producing isotope continues to advance. Cobalt 60 promises to be among the cheapest of the heat producing isotopes. However, because the energy from Co^{60} primarily is a very penetrating gamma ray, its use as a heat source will require heavy shielding. The weight of the latter will probably limit Co^{60} applications to terrestrial or marine uses. These could be for the heat content alone, as in space heater ("pot bellied stove") applications at remote locations—such as the Antarctic—or in undersea laboratories.

World's "Hottest" Cobalt. Photo on *left* shows a cobalt 60 wafer smaller than a dime and which emits 7.5 watts of energy. This wafer, having a record-breaking specific activity of 700 curies per gram, was produced in the Savannah River Plant's high-flux demonstration program during which the highest sustained neutron flux (6.1×10^{15} n/cm^2-sec.) ever attained in a reactor was achieved. Photo on *right* shows a 3-inch long cobalt 60 heat source capsule that produces 260 watts of heat and readily boils the water in the beaker. The capsule, which contains 57,000 curies of cobalt 60, is the first ever made to obtain heat from cobalt. The cobalt 60, which was produced in the high-flux demonstration program, is in the form of 57 wafers, each of which has a specific activity of 120 curies per gram.

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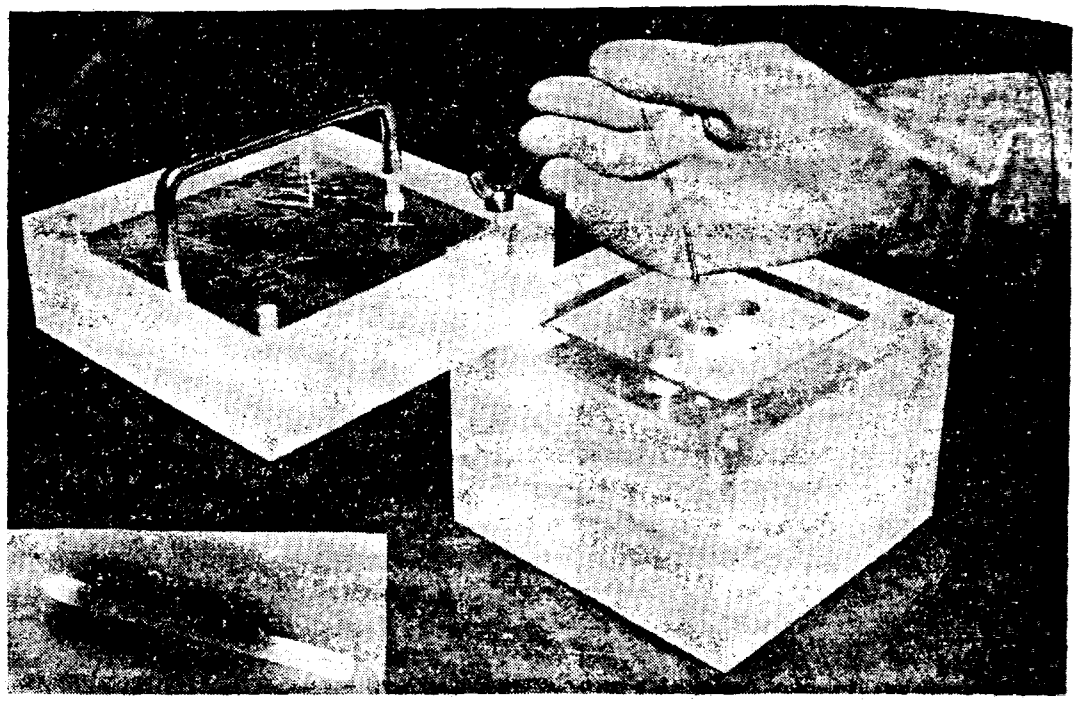
Polonium 210

The irradiation process for polonium 210 (Po^{210}) manufacture is well established. Bismuth, which is the target isotope for Po^{210} manufacture, has a very low cross-section and is not readily converted by neutron capture. Thus, large amounts of bismuth are required in a reactor at any one time for polonium 210 production. During 1966, the irradiation being conducted at Savannah River, primarily for curium 244 manufacture (discussed previously), was such that a number of reactor channels were unused, and the opportunity was taken to fill these channels with bismuth. The polonium 210 from this material will be used in process and device development activities at Mound Laboratory.



Californium Needle. By spontaneous fission, californium 252 emits neutrons that may be used for therapeutic purposes. A needle slightly over an inch long has been loaded with 1.4 micrograms of man-made californium 252 by special electrodeposition techniques at the AEC's Savannah River Laboratory and is being used to determine dose distribution in material equivalent to human tissue. In the autoradiograph (*inset photo*) the dark area was produced by radiation from the californium 252 which emits 3.4 million neutrons per second by spontaneous fission. The outline of the needle was obtained by exposing the film to X-rays. It has been proposed that the needle could be placed directly in a malignant tumor. This treatment would expose the tumor to a high concentration of neutrons, particles which have not been thoroughly investigated for cancer therapy in the past because of the difficulty of depositing neutrons specifically in the tumor. Heretofore, too much intervening healthy tissue was exposed. So far, neutron irradiation for cancer treatment has been possible only by placing the patient in close proximity to a nuclear reactor or a cyclotron. Considerable work in this field has been done at the AEC's Brookhaven National Laboratory. The treatment is costly and is limited by the availability of reactors and cyclotrons.

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To meet anticipated requirements for larger quantities of polonium 210, which has a 138-day half-life, for heat source applications, Hanford, Mound, and Savannah River are evaluating processes for the recovery and purification of polonium 210 from irradiated bismuth. Vacuum distillation has been demonstrated to recover relatively pure polonium from bismuth and is expected to make the bismuth immediately available for re-irradiation. However, a special facility would be required for such a process. To meet increased requirements at an earlier date, solvent extraction with diethyl carbitol could be applied in an existing solvent extraction facility to separate polonium from the bulk of the bismuth, with correspondingly reduced total expenditures for the process.

Thulium 170 and 171

Oak Ridge National Laboratory has completed a study of the nuclear reaction cross sections that are important in determining the effective reactor production rates of the thulium 170 and 171 radionuclides. Thulium 170 could be produced by irradiation of naturally occurring monoisotopic thulium 169. Three modes of reactor production of thulium 171 were studied: (*a*) successive neutron captures in thulium isotopes beginning with thulium 169; (*b*) neutron irradiation of isotopically enriched (96%) erbium 170; and (*c*) irradiation of naturally occurring erbium. The study will be extended to determine the practical modes of production for these two radioisotopes, purity of the products, biological shielding requirements, and economic factors relevant to costs of isotopic power fuel forms.

Uranium 233 Recovery

Production of uranium 233 (U^{233}) by irradiation of thoria (ThO_2) continued during the year at both Hanford and Savannah River to supply high-purity uranium 233 for reactor and fuel cycle development needs. For research and development purposes, high purity uranium 233 with a low (4 to 6 parts-per-million) uranium 232 content is desired because its low radioactivity is more conducive to direct handling and fabrication without the use of heavy shielding. Hanford recovered high purity uranium 233 in the Purex plant; Savannah River recovered high purity uranium 233, using a similar process which normally processes highly enriched uranium-aluminum alloy fuels. About 200 kilograms of this high-purity uranium 233 was produced for the Light Water Breeder reactor (LWB) physics critical experiments at the Bettis Atomic Power Laboratory (see Chapter 7—Reactor Development and Technology). Some uranium 233 was transferred to the Oak Ridge National Laboratory research pool for storage and distribution.

FISSION PRODUCTS

Fission products are the nuclear fragments resulting from the splitting of a fissionable atom and constitute the highly radioactive (high-level) wastes from the chemical processing of irradiated ("spent") nuclear fuels. Many of the fission products are radionuclides having potential large-scale application as heat and radiation sources.

Hanford Prime Source

Currently, the prime source for fission-product radioisotopes is the recovery operation conducted at the AEC's Hanford, Wash., production complex; a secondary source could be the Savannah River Plant at Aiken, S.C. Detailed design work is continuing on the Fission Products Conversion and Encapsulation Plant at Hanford which is scheduled to begin a large-scale radioisotope recovery operation as a private commercial enterprise.

During the 1961–1963 period, facilities at Hanford had been modified and adapted for recovering and providing, as selected concentrates, the fission products strontium 90, cesium 137, cerium 144, and promethium 147 [8] that are required by other AEC programs. With the exception of cesium 137, these fission product radioisotopes are recovered from the currently generated high-level chemical processing wastes. The cesium 137 is recovered from stored aged high-level waste solutions. Since the initiation of recoveries in 1960, Hanford has made deliveries of fission products as shown in Table 1.

TABLE 1.—FISSION PRODUCT DELIVERIES, 1961–1966

Fission products delivered to	Kilocuries for CY's	
	1961/1965	1966
Strontium 90		
Oak Ridge National Laboratory	6,200	1,700
Martin Co., Quehanna, Pa	1,244	0
Cesium 137		
Oak Ridge National Laboratory	2,500	1,000
Cerium 144		
Oak Ridge National Laboratory	1,000	0
Promethium 147 (as 2.5-year aged)		
Oak Ridge National Laboratory	59	0
Pacific Northwest Laboratory	309	3,730

[8] See pp. 48–50, "Annual Report to Congress for 1963."

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[8] See p. 81, "Ann

Private Plant Being Designed

Fission product fractions of strontium 90 and rare earths—containing promethium 147—not required for scheduled deliveries, are being accumulated and stored for the decay of objectionable short-lived isotopes in Hanford's B-Plant facilties. These fractions are being accumulated as initial feeds for the Fission Products Conversion and Encapsulation (FPCE) Plant. The FPCE Plant is to be built on leased ground in Hanford's chemical processing areas as a private venture by Isochem Inc.[9] Isochem, as an AEC contractor, also took over the operation of the Government-owned chemical-separations facilities at Hanford at the beginning of 1966. The FPCE Plant, for which an AEC construction permit is now pending, is planned as a facility to obtain specification feeds of strontium 90, cesium 137, and a rare earth fraction from Hanford's waste management operations.

In addition to the fission products already mentioned, the Hanford high-level wastes contain trace amounts, although significant total quantities, of rhodium, palladium, and technetium, an element not found in nature but with chemical properties similar to rhenium. Techniques are being developed to recover and purify these potentially valuable elements.

The AEC's Savannah River operations has developed flowsheets to recover a crude promethium 147 concentrate in both of its irradiated fuel processing plants. The actual process steps would use existing equipment in each plant and could be performed with a minimum of interference to other plant processes. In October, a demonstration run in the Purex plant (F-Canyon) recovered from fresh wastes the equivalent of approximately two megacuries of 2.5-year aged promethium 147 which is being stored in existing tanks. From three to four years' lead time for preparation, concentrate accumulation, and aging for decay of the unwanted promethium 148 would be required for promethium 147 deliveries from Savannah River.

RADIOISOTOPE SALES

To meet the needs of the Government, industry, and science for radioisotopes, AEC facilities are used to produce, or recover in purified form from chemical reprocessing wastes, 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 private commercial producers, the AEC withdraws from the routine production and distribution of those isotopes.

[9] See p. 81, "Annual Report to Congress for 1965."

Cobalt 60 Sales Increase

During the 11 months ending November 30, 1966, a total of 2,516,978 curies of processed radioisotopes were distributed by Oak Ridge National Laboratory. This represents a 125 percent increase in unit sales over the same 1965 period, mainly from increased sales of cobalt 60 and promethium 147. A total of two million curies of cobalt 60 were sold representing 79 percent of the total curies distributed by ORNL. Significant shipments of cobalt were made to Brookhaven National Laboratory (792,000 curies) for use in its High Intensity Radiation Development Laboratory and to Atomic Energy of Canada Limited (477,000 curies) for re-sale to its commercial customers.

Production and Sales Withdrawals

The AEC withdrew from the routine production and sale of 19 more radioisotopes during the year: antimony 124, arsenic 76, arsenic 77, bromine 82, cadmium 109, cadmium 115, cadmium 115^m, copper 64, gold 198, gold 199, lanthanum 140, mercury 197, mercury 203, molybdenum 99, phosphorus 32, potassium 42, silver 110^m, sodium 24, and sulfur 35. This makes a total of 36 radioisotopes from which the AEC has withdrawn since May 2, 1961, as these isotopes became available from private industry. As a direct result of these withdrawal actions, the number of shipments made by ORNL during the first 11 months of 1966 fell to 5,044 from 7,907 in the same period in 1965, and 10,387 in 1964. The continuing withdrawals resulted in the need for the AEC to increase prices[10] on 13 products to achieve full-cost recovery for the production of cobalt 60 in solution, europium 152, hafnium 181, indium 114, irridium 194, iron 55 and 59 (in combination), osmium 191, rubidium 86, scandium 46, tantalum 182, tungsten 185, yttrium 90, and tritium (hydrogen 3) targets.

Other withdrawals. The AEC also withdrew from supplying the technetium 99^m generator which was developed by Brookhaven National Laboratory, but is now available at reasonable prices from at least five commercial firms.

The AEC had withdrawn from providing encapsulation service to the public for cobalt 60 sources in 1958, but continued to encapsulate its own sources. During 1966, a decision was made to have all cobalt 60 sources used by the AEC laboratories and contractors and other Federal agencies encapsulated by private industry, since competitive commercial service is now available at reasonable prices. As a result of this decision, the Brookhaven shipment mentioned above was commercially encapsulated by the Lockheed-Georgia Co., Marietta, Ga.

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

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New Products

A series of new radioisotopes became available from the AEC during 1966 as a result of the availability of enriched stable isotopes and high neutron fluxes. Included are six radioisotopes that are now being used in medical research: arsenic 74, cesium 131, copper 67, phosphorus 33, rhenium 188, and zinc 69^m.

FUEL PROCESSING AND RADIOACTIVE WASTES

Until 1966, the chemical processing of irradiated ("spent") fuels from reactors was done only in AEC facilities to recover the useful byproducts—radioisotopes, and uranium that is still usable in reactor fuel elements. With the opening of the first privately owned fuel processing facility and industry interest in building other such plants, the AEC reassessed its future plans in this area. Work continued to develop methods for reducing the highly-radioactive solutions, resulting from chemical processing, to solids for easier storage.

FUEL PROCESSING

On May 23, the AEC announced that as a result of its review with potential chemical processors, reactor manufacturers, and power utilities of the need for further improving the technology for chemical processing of irradiated fuel, the AEC will continue its development program on the fluoride volatility process. The AEC intends to give the appropriate industrial entities an opportunity to review and comment on its volatility development program as it progresses. It will also continue to evaluate the merits and need for a future cooperative program for the industrial demonstration of the fluoride volatility process, and will consider at a later date the possibility of providing a high enrichment fuel load for this purpose.

Second Base-Load

It was also announced that, on the basis of information it has been given on the forward steps planned by industry to construct new chemical processing plants (see below), the AEC considers that for the present, support in the form of a second base load of fuels, such as was furnished in establishing the first private plant, is not required to encourage the development of a competitive processing industry. The

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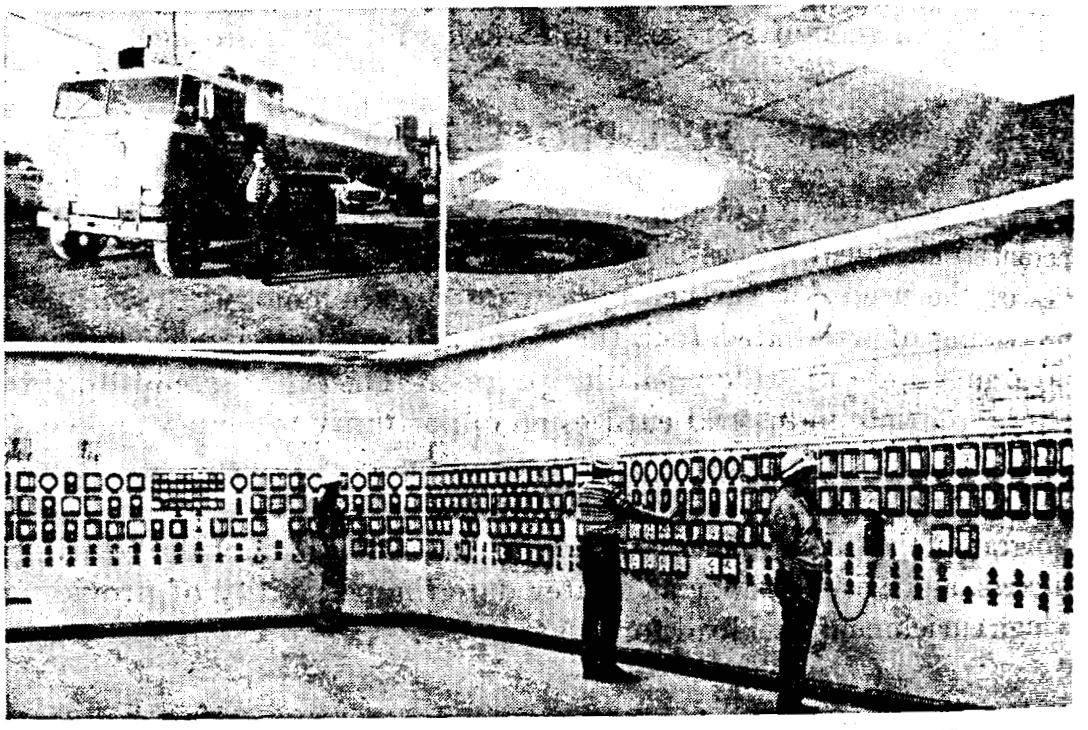
AEC will follow the progress by industry in the development of competitive processing services, and will reconsider its offer of a second base load of Government fuels if it should prove to be necessary or desirable.

Private facilities. The first private processing facility, Nuclear Fuel Services, Inc. (NFS), West Valley, N.Y., began operation in April with an initial load of "spent" fuel from Hanford's "N" reactor and Commonwealth Edison's Dresden reactor. During September, the General Electric Co. announced it would build a processing plant near Morris, Ill., with operation scheduled for mid-1970. Allied Chemical Corp. is continuing its studies directed toward eventual construction of a fuel processing plant. (See also Chapter 17—Industrial Participation Aspects.)

Increased Fuel Processing Capacity

The first uranium recovery process employing a dissolved neutron poison for criticality control has been successfully developed and put into operation at the AEC's Idaho Chemical Processing Plant



Private Processing. The first privately owned plant for the processing of irradiated reactor fuel went into operation during the year. The Nuclear Fuel Services, Inc., facility at West Valley, N.Y., began commercial separation of "spent" fuel to recover fissionable uranium on April 19. Photo shows the automated control room of the plant. The inset photo (*upper left*) shows the first shipment of uranyl nitrate solution leaving the plant on May 2, destined for the AEC's feed material plant at Fernald, Ohio. The shipment consisted of 39 metric tons of uranium recovered from the processing of spent fuel from the AEC's "N" production reactor at Hanford, Wash.

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(ICPP). The addition of dissolved boron (boric acid) to the hydrofluoric acid dissolvent for zirconium-based fuel permits a ten-fold increase in the quantity of uranium charged to the dissolver, and a corresponding increase in plant capacity. This can be done with only minor modification of equipment. Following development of the process to assure adequate solubility, stability, extraction, and corrosion control, the ICPP conducted a highly successful zirconium fuel processing campaign, achieving a processing rate of 765 kg of zirconium per day for a 30-day period. This new technique can be extended to many other fuel processing operations with similar significant cost savings.

Deliveries for Processing

The AEC's Idaho and Savannah River operations received "spent" fuel for processing from 3 domestic and 10 foreign reactors during the year. The deliveries are summarized in Table 2, below:

TABLE 2.—IRRADIATED ALUMINUM ALLOY FUEL DELIVERED DURING CY 1966 TO AEC FOR PROCESSING

Contracting party	Reactor	AEC receiving site	Type of fuel	No. of elements	Gross wt. alloy Kgs	As received		
						Total U Kgs	U^{235} Kgs	Percent U^{235}
General Electric Co	GETR	ID	U-Al	140	838	48.3	41.8	87
Industrial Reactor Laboratories, Inc.	Research Reactor	ID	U-Al	28	100	3.4	2.8	82
Japan	JRR-2	ID	U-Al	24	120	21.6	4.2	20
Sweden	R-2	SR	U-Al	108	399	13.0	10.8	83
Germany	FRM Munich, FRG Garching.	SR	U-Al	71	349	50.4	8.3	16
France	Minerve, Triton, Melusine.	SR	U-Al	72	361	11.4	9.4	82
AECL (Canada)	NRU	SR	U-Al	260	1,559	34.9	17.8	51
NASA	Plumbrook	SR	U-Al	168	782	23.9	19.4	81

RADIOACTIVE WASTE MANAGEMENT

Waste solutions containing the highly radioactive byproducts of nuclear fission from irradiated fuel processing facilities at Hanford, Savannah River, and the Idaho Chemical Processing Plant are stored in underground tanks.[11]

[11] See p. 56, "Annual Report to Congress for 1964."

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Concentration of Wastes

To conserve available tank space and make the maximum use of the present tanks, both Savannah River and Hanford are continuing to evaporate and concentrate aged stored wastes to the extent feasible.[12] In addition to its prototype unit that has been operated for about two years, Hanford is constructing two more in-tank solidification (ITS) units for evaporating tank stored waste to a salt cake. Savannah River has evaporated millions of gallons of water from the waste stored in its two tank farms during the past seven years. During October, Savannah River initiated operation of a facility in one of its tank farms to transfer concentrate from the pot evaporator to any of several tanks. Waste volume reductions of about 65 percent are expected. A similar facility is under construction in the other Savannah River tank farm.

Sluicing Techniques

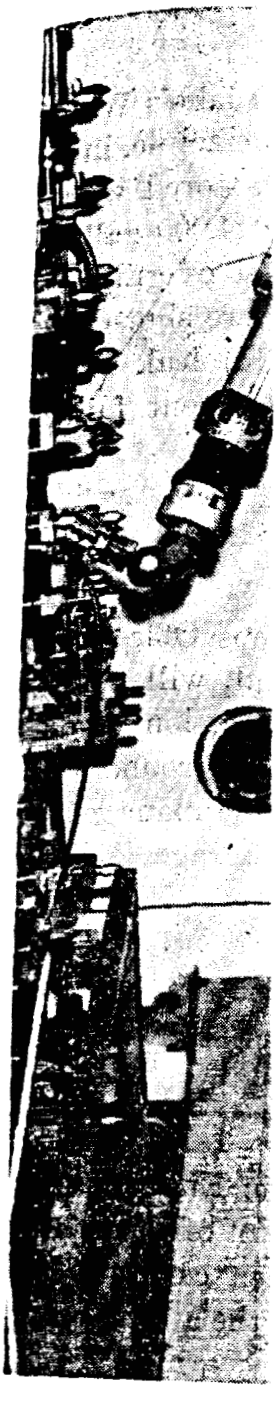
Removal by sluicing of waste sludges from the Hanford tanks, which are relatively free of inside impediments, has been demonstrated and used. However, 16 of Savannah River's tanks have internal cooling coils (approximately 4 miles of pipe in each tank) which increase the difficulty of tank sluicing for sludge removal. Nevertheless, in 1966, the Savannah River Plant demonstrated a sluicing technique in 2 of these waste tanks which successfully removed at least 90 percent of the sludges.

Solidification Project

Solidification of liquid radioactive wastes is also being demonstrated at the Pacific Northwest Laboratory. Actual high-level radioactive waste has been solidified in stainless steel containers 12 inches in diameter and 8 feet long. The conversion to a solid offered a much improved form for long-term storage, reduced the volume by approximately tenfold, and provided an immobile and encapsulated solid with a low solubility in water.

Actual demonstrations of radioactive solidification are being used to evaluate three processes—pot calcination, continuous spray solidification, and continuous phosphate glass. The demonstration climaxes a cooperative effort on the development of solidification processes by Brookhaven National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory. The project is designed to produce the needed technical, safeguard, and cost information for use by the rapidly expanding nuclear industry.

[12] See pp. 84–88, "Annual Report to Congress for 1965."



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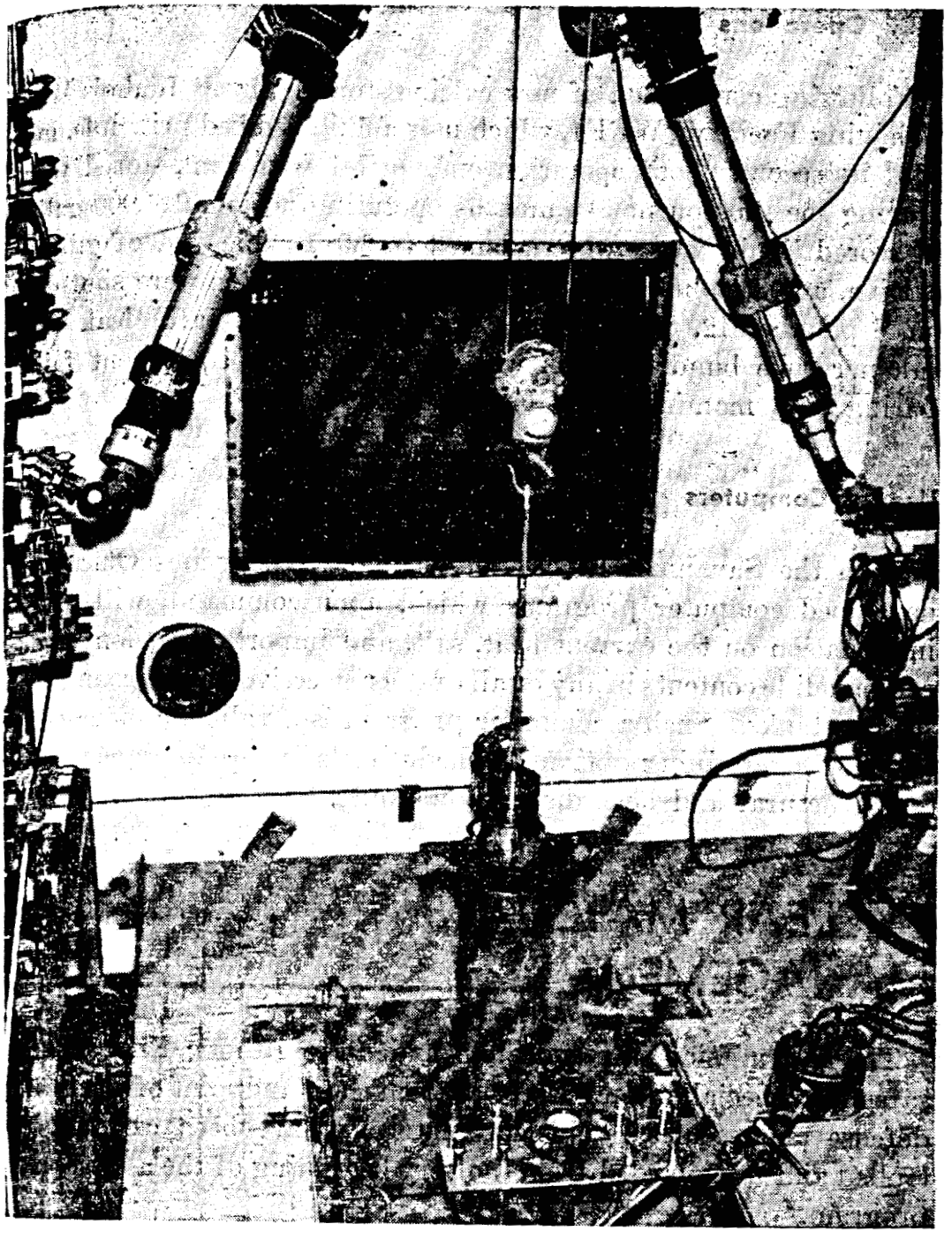

solidification Project. Working through a thick layer of lead-glass, a Pacific Northwest Laboratory (PNL) technician prepares a pot calciner for a "hot" run with high-level radioactive wastes as a part of the pilot plant studies on methods of solidifying liquid radioactive wastes. The pilot plant studies are underway in the new Chemical-Materials Engineering Laboratory of the PNL complex at Hanford. The Pacific Northwest Laboratory is contractor-operated for the AEC by Battelle Memorial Institute.

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WCF Operations

Following completion of new calcine storage bins,[13] Idaho's Waste Calcining Facility (WCF), which uses a fluidized bed principle, initiated its second "hot" operation on April 1 with tank-stored waste. During the subsequent 5½ months operating period, 244,000 gallons of stored liquid waste were calcined to 3,087 cubic feet of granular calcine, a 10.6 volume reduction factor. Operations were shut down on September 12, to repair a sodium-potassium (NaK) leak in the calciner tube bundle. This was the first major equipment failure during 15½ months of WCF operation.

Use of Computers

Both the Savannah River and Richland Operations Offices have developed computer programs which, upon command, will provide information on the current heat, salt, and important fission product radionuclide contents in any or all of the respective underground waste storage tanks. Such a computer program is a valuable management tool for determining optimum scheduling of waste storage facilities for structural and heat dissipation limits.

NUCLEAR MATERIALS MANAGEMENT

The Commission is responsible under the Atomic Energy Act to safeguard special nuclear material from the standpoint of the common defense and security. Nuclear materials have been carefully controlled and safeguarded from the very beginning of the atomic energy program.

DOMESTIC SAFEGUARDS

The administration of safeguards is complicated by the difficulty encountered in measuring nuclear materials in various mixtures and compounds. It has not been possible to measure these materials with the precision that is characteristic of many general chemical measurements.

[13] Shown on p. 87, "Annual Report to Congress for 1965."

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Problem Areas

The AEC has long recognized this measurement problem and has experienced instances where the measurement difficulty resulted in some material not being accounted for in nuclear material operations.

In the early years of the atomic energy program, all special nuclear material was in the hands of the Government and its contractors. With the enactment of the Atomic Energy Act of 1954, however, Government-owned special nuclear material was made available under lease for private use, and various controls, important to safeguards, were imposed, both through AEC regulations and the contractual terms of AEC lease agreements.

In implementing the regulatory provisions of the 1954 Act, the AEC adopted the policy of relying upon licensees' financial responsibility for the material to provide sufficient incentive to assure their accounting for, and protection of, the material, and upon the severe criminal penalties provided in the Act to prevent unlawful possession and diversion. In addition, the health and safety requirements imposed on licensees have been such that compliance with these requirements in the management of the material also has contributed to its protection. While the AEC continues to recognize the importance of the intrinsic value concept and the penalties imposed by law, it believes that the growth of the industry and the private ownership of special nuclear material will require greater reliance on safeguards requirements administered under its regulatory authority.

Improvements Proposed

The AEC published for public comment in the *Federal Registers* of March 29 and May 27, 1966, several proposed amendments to its regulations which would incorporate control mechanisms that have been carried out previously under contract arrangements with licensees and, for most of the requirements, under the lease agreements. These requirements include maintenance of appropriate records; submittal to the AEC of material transfer forms and periodic material balance reports; the performance of annual physical inventories; and submittal to AEC review of licensees' descriptions of their internal material control systems.

Improvements which have been made or proposed in the controls and safeguarding techniques employed by the AEC include:

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(*1*) Expansion and standardization of AEC safeguard surveys to include coverage of privately owned special nuclear material;
(*2*) A tightening of physical inspection procedures for independent AEC verification at licensees' plants with respect to special nuclear material destined for overseas use; and
(*3*) Computerization of quantity data needed to maintain knowledge of special nuclear material inventories, transfers, production, and losses, and to analyze those data.

Study Panel Appointed

On July 22, 1966, the Commission appointed an *ad hoc* Advisory Panel on Safeguarding Special Nuclear Material[14] to review and appraise current and proposed AEC policies and procedures in connection with the AEC's evaluation of the effectiveness of controls in this field. The Commission asked the panel to include in its review the U.S. program for safeguarding special nuclear material distributed abroad under the "Atoms for Peace" program. This material is safeguarded by an AEC bilateral system of on-site inspections, records and reports and, where appropriate, by the safeguards systems of Euratom or the International Atomic Energy Agency. (See Chapter 12—International Cooperation Activities.) The panel is expected to complete its report early in 1967.

AVAILABILITY OF SPECIAL NUCLEAR MATERIAL

The Atomic Energy Act of 1954, as amended (Section 41b), provides for Presidential determination of the quantities of special nuclear materials available for distribution to U.S. licensed users and to nations having Agreements for Cooperation with the United States. During 1966, the President determined the availability for distribution of an additional 100,000 kilograms of uranium 235 each for domestic and foreign use. AEC commitments for uranium 235 increased during the year by 77,500 kilograms for domestic licensees, and 89,250

[14] The panel members are: Dr. Ralph F. Lumb, Director, Western New York Nuclear Research Center, *Chairman;* Francis P. Cotter, Vice President, District of Columbia Office of Westinghouse Corp.; Gerald Charnoff, Attorney, Shaw, Pittman, Potts, Trowbridge and Madden, Washington, D.C.; Paul Grady, ex-partner of Price Waterhouse & Co., New York City; Aston J. O'Donnell, Manager of Development, Bechtel Corp., San Francisco; Louis Roddis, President, Pennsylvania Electric Co.; and Fred H. Tingey, Head, Operations Analysis Branch, Idaho Nuclear Corp. *Executive Secretary* to the panel is Vincent Vega, Director, Operational Safety Division, AEC, Albuquerque Operations Office; and the *Secretary* is Ralph G. Page, Chief, Enforcement Branch, Division of State and Licensee Relations, AEC Headquarters.

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kilograms for foreign nations. The status, in kilograms, of the determination as of December 31, 1966, was:

	U^{235}	Pu	U^{233}
Domestic licensees			
Presidential determination of availability	300, 000	207. 5	53. 6
AEC commitments	187, 900	115. 4	0. 6
Actual distribution	17, 300	115. 0	0. 6
Foreign nations			
Presidential determination of availability	250, 000	543. 0	45. 0
AEC commitments	194, 250	528. 0	32. 3
Actual distribution	13, 000	438. 3	1. 7

IMPROVED MATERIALS MANAGEMENT

As nuclear power capacity is expanded and as special nuclear material becomes privately owned, the need for accurate measurement techniques for uranium and plutonium in different forms become increasingly significant. The AEC is currently engaged in intensive research activities to improve measurement methods and to determine the predicted error of measurement associated with various methods.

Standard Reference Materials

To permit flexibility in chemical, isotopic, and impurity analysis, the AEC has long recognized the need for chemical compounds for use as primary standards of plutonium and uranium. An extensive search has revealed no chemical compounds of plutonium or uranium which meet the requirements imposed on a primary standard. Dicesium plutonium hexachloride (Cs_2PuCl_6) plutonium sulfate tetrahydrate ($PuSO_4 \cdot 4H_2O$) and uranium oxide (U_3O_8) will be used as working standards, to supplement the uranium and plutonium metal primary standards available from the National Bureau of Standards.

The AEC along with the National Bureau of Standards is participating with the United Kingdom Atomic Energy Authority in a joint verification program for a natural uranium isotopic standard. A sample of U_3O_8 from England's Capenhurst plant has been received by the National Bureau of Standards and is being prepared for certification analysis.

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Mixing Parameters Study

An Oak Ridge (Y–12 Plant) study of mixing parameters in excursion-safe cylindrical tanks (4″–6″ diameter, 10′–60′ length) has been completed. This work, utilizing a digital computer for complicated mixing techniques, provides reliable methods for predicting solution homogeneity, *i.e.*, guarantees a representative sample.

Calculations Verification

Calculations are being performed by Combustion Engineering, Inc., Windsor, Conn., to assist the AEC in verifying statements made by reactor operators regarding nuclear fuel depletion and plutonium production. Control rod settings and heat generation values from daily operating logs are used to determine the amount of special nuclear material in the operating fuel elements. Studies have been completed for 8 of the 17 power reactors being considered.

Laboratories as Measurement Umpires

The complexities of measuring special nuclear materials are such that qualified umpires are needed to settle differences when the AEC and another party cannot agree on the quantity of nuclear material transferred. To answer this need, the AEC is evaluating various industrial and private commercial laboratories, both in the United States and abroad, as potential uranium and plutonium measurement umpires. Eight AEC laboratories are participating in preparation and analysis of reference samples. Nine domestic and five foreign laboratories are participating in the umpire laboratory qualification program. Samples of uranium hexafluoride and uranyl nitrate have been sent to the domestic laboratories and results have been reviewed. Preparation of plutonium qualification samples has been initiated. The qualification program is being conducted for the AEC by the Idaho Nuclear Corp., Idaho Falls, Idaho.

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Chapter 5

THE NUCLEAR DEFENSE EFFORT

The AEC, in coordination with the Department of Defense (DOD), conducts the necessary research, development, testing, and production essential to the maintenance and improvement of the United States nuclear defense capability.

WEAPONS DEVELOPMENT, PRODUCTION, AND TESTS

During 1966, the AEC (through its three weapons laboratories—Los Alamos Scientific Laboratory, Lawrence Radiation Laboratory, Livermore, and Sandia Laboratory—Albuquerque, N. Mex., and Livermore, Calif.) continued the maintenance of the limited nuclear test ban treaty safeguards,[1] continued the development of devices and improved techniques for underground testing, and continued the development of weapons and components designed to meet DOD requirements.

WEAPONS DEVELOPMENT

The continuing development objective of improving the penetration capability of strategic misssile warheads—by further decreasing warhead vulnerability to nuclear environments generated by antiballistic missile countermeasures—has resulted in modification programs for some warheads in the stockpile. Nuclear tests in 1966 verified laboratory computations and designs for achieving improvements in hardness.

[1] The four safeguards announced as U.S. national policy by the late President John F. Kennedy and reaffirmed in April 1964 by President Johnson, 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.

Weapons Progress

Weapons tests related to nuclear safety, increased reliability, and increased efficiency were conducted in 1966. Development of improved devices for installation in nuclear weapons to prevent unauthorized employment continued.

The weapons development effort includes overall weapon improvements as well as advancements in individual component design with the resulting technology incorporated into specific weapon systems.

Progressive Laboratory Programs

The AEC weapons laboratories are continuing to function in a healthy and modern environment. The upgrading of facilities—part of one of the test ban treaty safeguards—is progressing as scheduled. Included in the upgrading program are scientific computer complexes at the laboratories which are vital to the development programs. Most projects have been completed with only a few of the larger projects still in the construction phase. The AEC budgets for fiscal years 1966 (ending June 30, 1966) and 1967 (first half ending December 31, 1966) provided for progressive laboratory programs in basic weapons technology and applied nuclear research and development oriented to stated military requirements.

A major facet of the laboratories research and development programs was the design and fabrication of test devices for use in the continuing underground test program at the Nevada Test Site. The laboratories continued to maintain and test their readiness capability to resume atmospheric testing, if authorized, in a minimum reaction time.

The facility improvement program, the continued maintenance of challenging research and development programs in all phases of nuclear technology, and the continuing underground test program have allowed the laboratories to continue to expand the "state-of-the-art" and also to retain and recruit the essential technical staff to conduct the assigned programs.

Nuclear Explosives As a Research Tool

Production of Heavy Elements

On May 5, 1966, a research team from Los Alamos Scientific Laboratory, assisted by Lawrence Radiation Laboratory, Livermore, and Argonne National Laboratory personnel, successfully conducted, as an adjunct to a weapons development event, the Cyclamen experiment.

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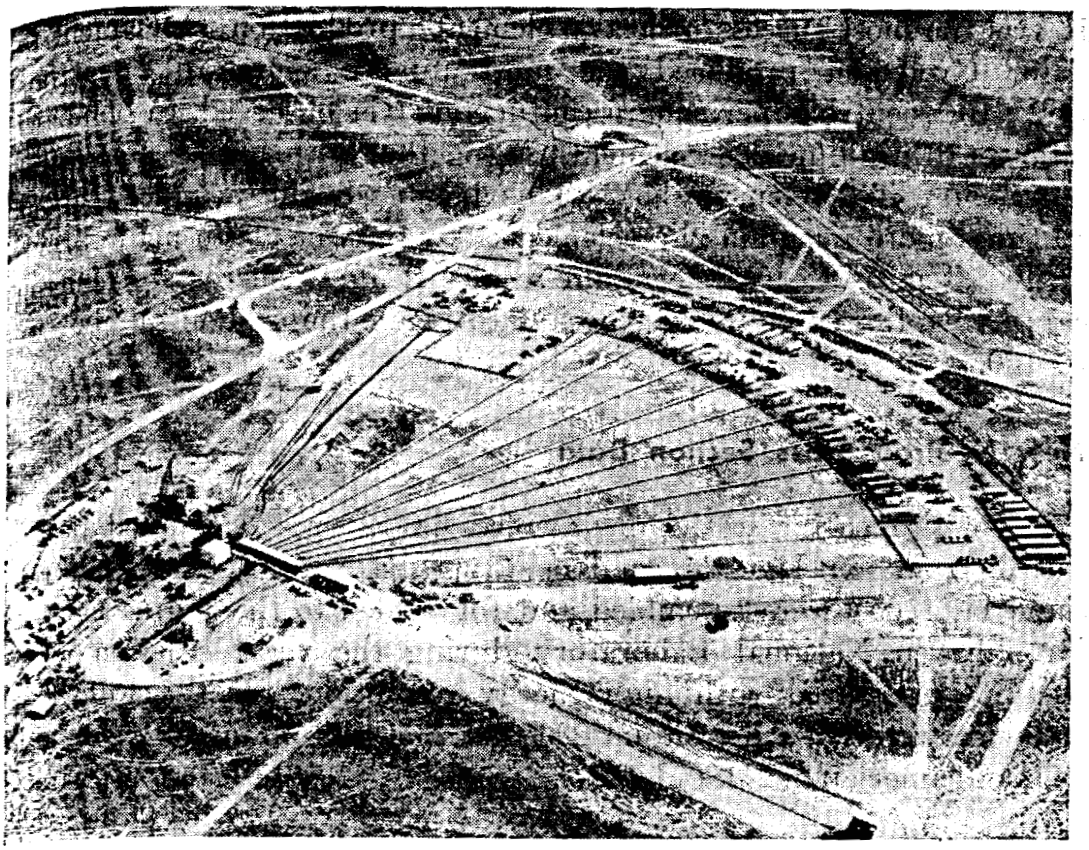

Experimental Array. Nuclear detonations are conducted at the Nevada Test Site not only as a part of the weapons development program, but also to provide needed information and data, *e.g.*, neutron cross-section or time-of-flight measurements, of use in other phases of the atomic energy program. The aerial view *above* shows the complex array of equipment that was used at a multi-purpose nuclear test during the year. The detonation point was hundreds of feet below the convergence of the signal cables; the instruments to record the test results were housed in the trailers to the right. Surface subsidences from two previous detonations are visible—left of center, and upper left of the photo. Photo at *left* shows how sandbags were used to protect cables for a Lawrence Radiation Laboratory, Livermore, electromagnetic add-on experiment during the year. The "snake-like" hose was not a part of the experiment, but was part of an air filtering system to prevent escape of radioactivity during the post-event sample recovery operations.

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It was the most successful heavy element [2] production experiment to date. Cyclamen produced the most intense source of neutrons (1.2×10^{25} neutrons per square centimeter) yet observed, to bombard a target of uranium 238 (element 92) together with a small amount of americium 243 (element 95). This bombardment produced about 10 times more fermium 257 (element 100) than has been made previously. This isotope of fermium results from 19 successive neutron captures followed by 8 beta decays to bring the atomic number up to 100.

New Neutron Cross Section Data

A comprehensive set of unclassified fission cross section data deduced from experiments conducted with a weapons test (Petrel, June 11, 1965) were assembled and forwarded to the Sigma Center, Brookhaven National Laboratory during the year. Fission cross sections, measured with high energy resolution, for the following nuclides were listed: uranium 233 and 235, plutonium 239, 240, and 241, and americium 241 and 242.

WEAPONS PRODUCTION

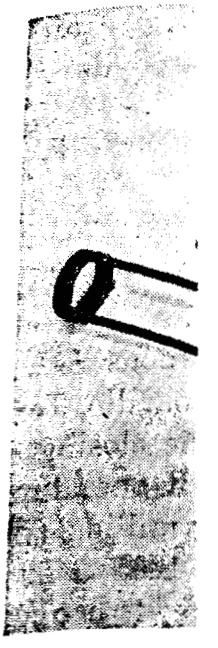
The AEC's production of nuclear weapons during the year, as directed by the President, continued to fulfill the Department of Defense's stated military requirements with no major production problems. The weapons production workload necessary to meet military requirements in 1966 was somewhat below the 1965 level.

Stockpile Improvement

Weapons production activity incorporated several design and technological improvements which contributed significantly to efficiency as well as to simplified maintenance procedures. Modification of the stockpile to incorporate the latest methods for the prevention of unauthorized use of weapons was continued.

Production activities include the fabrication and assembly of new weapons, factory and field modifications of existing weapons, and retirement and disposal of obsolete weapons. In the retirement of obsolete weapons, careful attention has been given to the recovery of re-usable components, both nuclear and nonnuclear, for use in current AEC production of weapons, or for use in research and development

[2] Uranium—element 92—is the heaviest naturally occurring element; all higher-numbered elements are man-made except for the minute amounts of plutonium which occur naturally when neutrons from cosmic radiation are captured in natural uranium 238. Such amounts of plutonium are so small that for all practical purposes, plutonium is considered a man-made element.



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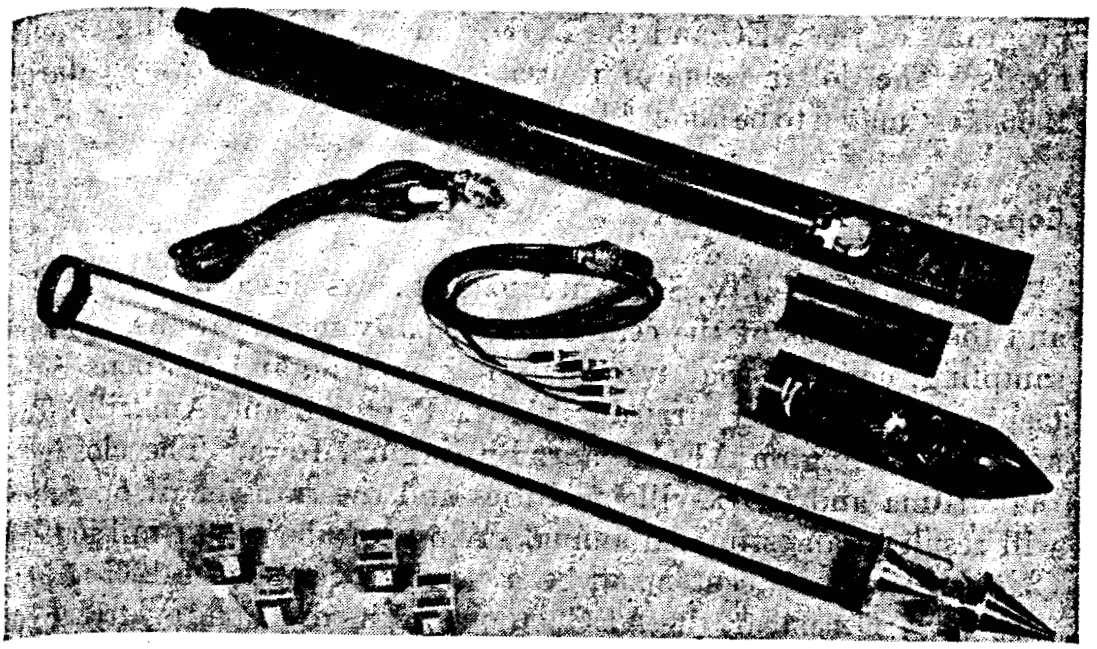
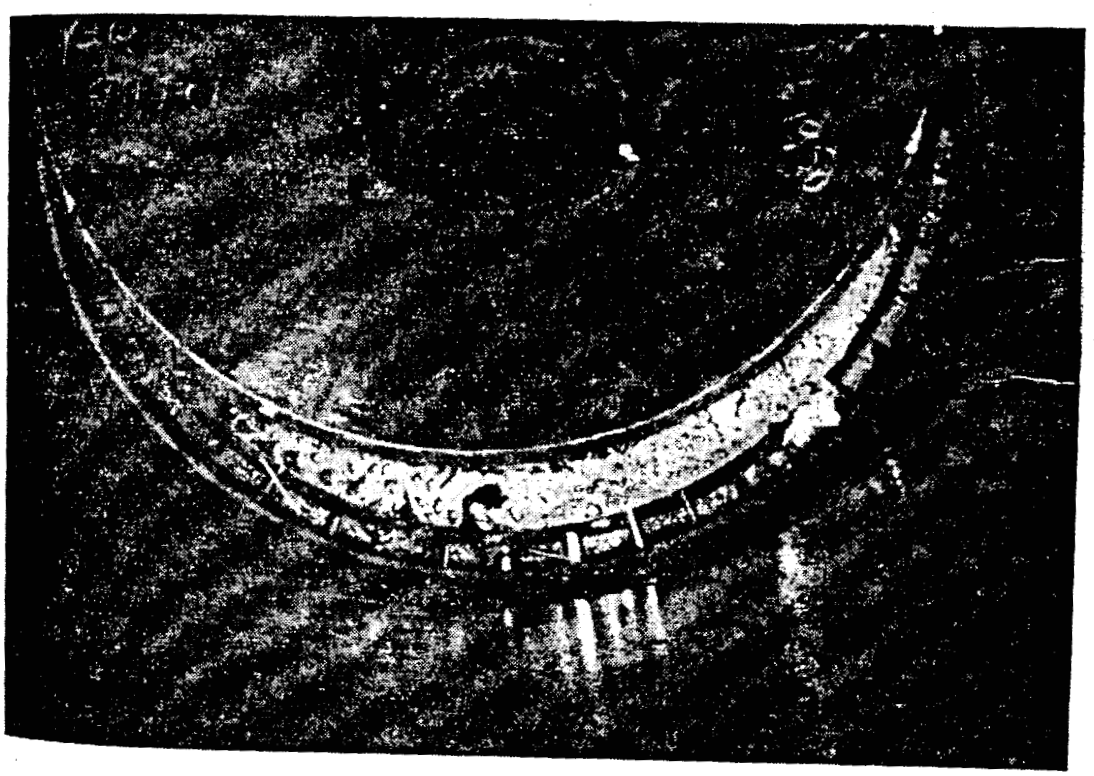


Downhole Camera. Many questions have been raised in the past at the Nevada Test Site as to what is happening down its many drilled detonation holes. To answer these questions a 35mm downhole camera was designed and built by Lawrence Radiation Laboratory, Livermore. The camera—its major components are shown *above*—is unique in design as it is a remotely operable, shutterless type, capable of taking photographs in either horizontal or vertical planes. Coupling a xenon strobe-light with conventional photographic techniques has yielded high resolution photographs in either color or black and white at depths beyond 2,000 feet—the photo *below* was taken at a depth of 1,680 feet. The use of this camera has made significant contributions to pre-shot and post-shot diagnostic efforts at the Nevada Test Site.



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programs of the AEC and the DOD, and for DOD training requirements. The dollar value of re-usable components recovered during 1966 is estimated to be about $4.6 million.

Consolidation of Facilities

The Medina Facility, San Antonio, Tex., was closed in early spring, and the functions of the center—principally modifications, stockpile sampling, new material system testing, repairs, and weapons retirement—are now being carried out at the Pantex Plant, Amarillo, Tex., and the Burlington AEC Plant, Burlington, Iowa. The closing of the Medina and Clarksville facilities and the transfer of operations will result in an estimated annual savings of about $3.1 million (the Clarksville, Tenn., center had been closed in September 1965).

In early December, the AEC announced its decision to further consolidate the production complex by reducing certain machining activities at the Kansas City Plant (operated for the AEC by the Bendix Corp.) and, beginning in the spring of 1967, gradually reducing and possibly eliminating the production workload at the South Albuquerque Works (SAW-operated for the AEC by ACF Industries, Inc.).

The decision follows a 2-year study of the weapons production complex to determine the facilities needed to meet continuing weapons production requirements. Annual savings resulting are estimated to range from $6 to $8 million. It is anticipated that these actions will be completed within two years with personnel reductions announced as far in advance as possible.

The plan for reduction and possible phasing-out of the Albuquerque plant includes a program to minimize the local impact. Consideration will be given to such alternatives as transfer or sale of the plant as a going concern—with possibly an AEC base workload—or other arrangements to sell or lease the plant on a special basis designed to meet the local situation and closeout of the plant, if necessary. A task force has been established to coordinate the development and implementation of a plan for disposal of the plant.

Consolidation of Development Work

It was announced in late 1965 that neutron generator development work, formerly carried out by General Electric Co. at Milwaukee, Wis., would be consolidated with closely related work at the AEC-owned, GE-operated Pinellas Plant at Clearwater, Fla. The integration of neutron generator development work with production activities was completed in early October.

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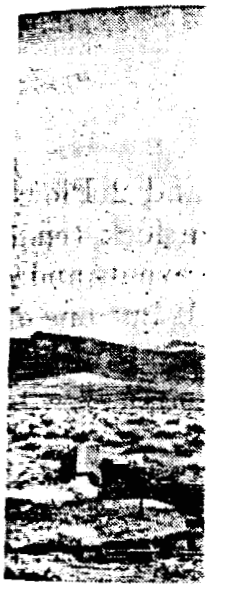

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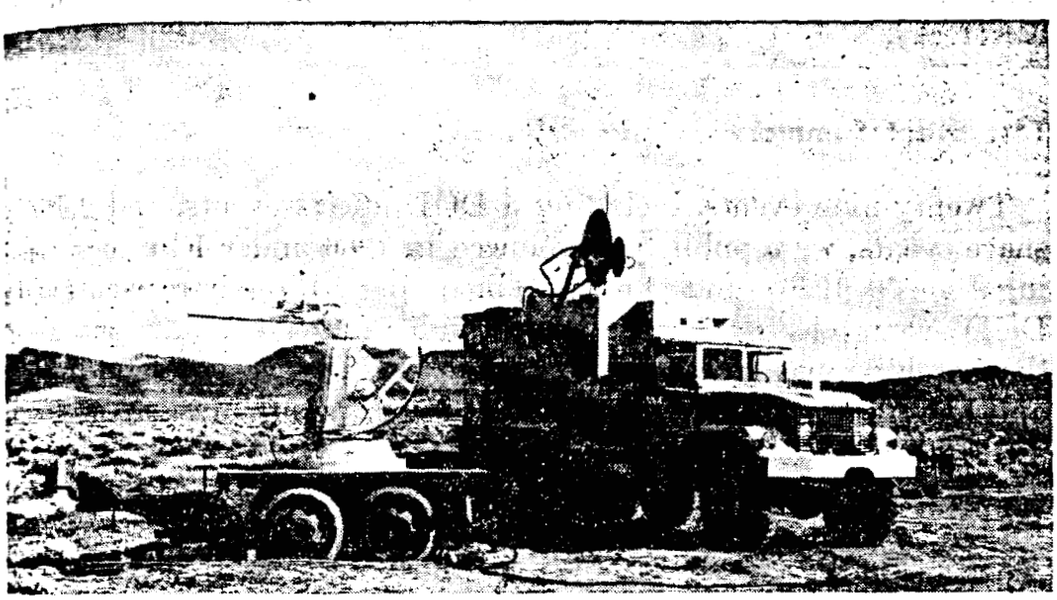
UNDERGROUND NUCLEAR TESTS

The AEC continued conducting an underground nuclear test program as called for in the first safeguard associated with the limited nuclear test ban treaty. A continuing, comprehensive test program has been conducted since the signing of the limited nuclear test ban treaty by the three principals (U.S., U.K., and U.S.S.R.) on August 5, 1963. As a result of the continuing tests, a unique capability to support a diverse range of full-scale AEC and DOD underground nuclear tests has been developed, maintained, and improved.

Flintlock-Latchkey Series

The current test series called Latchkey commenced on July 1, 1966, and will continue through June 30, 1967. The test series ending on June 30, 1966, was called Flintlock. The combined AEC–DOD test program was developed to pursue those aspects of nuclear technology considered most important to the maintenance of the national security.



"Sky Scanner." An instrument called the "Sky Scanner" has been developed by Lawrence Radiation Laboratory, Livermore, to define and measure the radioactivity in a cloud resulting from seepage or venting which may occur from underground nuclear tests at the Nevada Test Site. This instrument is a tightly collimated scintillation detector mounted on a surplus missile tracking pedestal. Elevation and azimuth control are actuated from the control point located 15 to 20 miles away. Data received by the instrument consist of a TV picture of the collimator sight path, the radiation intensity, and elevation and azimuth angle readouts. All data are transmitted between the instrument and the control point by radio link. Since the radiation detector sees only that activity of a radioactive cloud intercepted by the solid angle of the collimator, cloud dimensions can be defined with a fair degree of accuracy. The total activity in the cloud is estimated by measuring the quantity which is carried by wind currents past a preselected sight path.

The planned events of Latchkey, as approved in principle by the President are grouped in four broad categories: (*a*) AEC weapons and/or device development events: (*b*) DOD nuclear effects events; (*c*) joint AEC–DOD tests designed for research and development on improved detection methods and systems to enhance the U.S. detection capability (Vela program); and (*d*) AEC Plowshare—peaceful uses of nuclear explosives—experiments. Included in the first category are events to further weapons and device developments, investigate concepts and technologies, assure the reliability and safety of nuclear weapons, and investigate nuclear effects on materials and components. Certain nuclear events, with increasing magnitudes of yields from low intermediate (20–200 kt), to intermediate (200 kt-1 megaton), on a step-by-step basis, were planned and conducted in the Pahute Mesa area. The 1964 expansion of NTS operations [3] into the more remote, higher elevations of the Pahute Mesa has led to the drilling of deeper holes to accommodate higher-yield detonations.

Each nuclear event is reviewed and approved in accordance with AEC procedures, and the tests are executed only with the expectation that they can be conducted within the constraints of the limited test ban treaty.

Test Event Summary

Twenty-nine events, including 5 DOD effects events, and 2 Plowshare events, were publicly announced in 1966 under Flintlock (ending June 30, 1966), and 11 events (including 2 Plowshare events and 2 DOD events) have been announced under Latchkey. All but one of the Latchkey events were conducted at the NTS, five of the Flintlock and Latchkey events were conducted in the Pahute Mesa area.

Supplemental Test Site

The AEC has initiated a program to investigate and develop possible locations for a supplemental site in the vicinity of the present Nevada Test Site (NTS) so that the combined facilities available for underground testing will be more flexible and suitable. Initial exploration to determine surface and underground characteristics has begun.

The AEC is also exploring remote areas in Alaska, especially Amchitka Island, to determine the suitability of those areas for possible use in underground nuclear testing. Any use of these areas would not affect those programs now conducted at the AEC's Nevada Test Site.

[3] See p. 69, "Annual Report to Congress for 1964."

TABLE

Na
Flintloc
Maxwell
Lampblack
Dovekie
Plaid
Rex [2]
Red Hot [3]
Finfoot
Clymer
Purple
Templar [4]
Lime
Stutz
Tomato
Duryea [2]
Pin Stripe [3]
Traveler
Cyclamen
Chartreuse [2]
Tapestry
Piranha
Dumont
Discus Thrower
Pile Driver [3]
Tan
Puce
Kankakee
Double Play [3]
Vulcan [4]
Halfbeak [2]
Latchkey
Saxon [4]
Rovena
Derringer
Daiquiri
Newark
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Greeley [2]

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[4] Plowshare (Peacefu
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TABLE 1.—ANNOUNCED UNDERGROUND TESTS—1966

Name	Date	Type of yield [1]
Flintlock Series		
Maxwell	January 13	Low.
Lampblack	January 18	Low Intermediate.
Dovekie	January 21	Low.
Plaid	February 3	Low.
Rex [2]	February 24	Low.
Red Hot [3]	March 5	Low.
Finfoot	March 7	Low.
Clymer	March 12	Low.
Purple	March 18	Low.
Templar [4]	March 24	Low.
Lime	April 1	Low.
Stutz	April 6	Low.
Tomato	April 7	Low.
Duryea [2]	April 14	Low Intermediate.
Pin Stripe [3]	April 25	Low.
Traveler	May 4	Low.
Cyclamen	May 5	Low.
Chartreuse [2]	May 6	Low Intermediate.
Tapestry	May 12	Low.
Piranha	May 13	Low Intermediate.
Dumont	May 19	Low Intermediate.
Discus Thrower [3]	May 27	Low.
Pile Driver [3]	June 2	Low Intermediate.
Tan	June 3	Low Intermediate.
Puce	June 10	Low.
Kankakee	June 15	Low Intermediate.
Double Play [3]	June 15	Low.
Vulcan [4]	June 25	Low.
Halfbeak [2]	June 30	Intermediate.
Latchkey Series		
Saxon [4]	July 28	Low.
Rovena	August 10	Low.
Derringer	September 12	Low.
Daiquiri	September 23	Low Intermediate.
Newark	September 29	Low.
Simms [4]	November 5	Low.
Ajax	November 11	Low.
Cerise	November 18	Low.
Sterling [3] [5]	December 3	Low.
New Point [3]	December 13	Low.
Greeley [2]	December 20	Intermediate.

[1] Low yield, less than 20 kt; low intermediate yield, 20 kt to 200 kt; intermediate yield, 200 kt to 1 megaton (Mt).
[2] Conducted in the Pahute Mesa area of NTS.
[3] DOD event conducted with AEC laboratory assistance.
[4] Plowshare (Peaceful Uses of Nuclear Explosives) event.
[5] An underground detection event conducted in Mississippi.

The search in the Alaskan area involves finding sites of suitable geology where certain tests can be conducted with a minimum of local disturbance. The Arctic National Wildlife Range is excluded from this survey.

Surface survey teams working on Amchitka Island will soon be followed by crews drilling exploratory holes if the surface geology makes underground exploration appear desirable.

Individuals employed by the AEC and its contractors, the Department of Defense, and other Government agencies including the U.S. Geological Survey will be involved in the effort.

ATMOSPHERIC TEST READINESS CAPABILITY

The AEC continued to maintain the capability to resume nuclear testing in the test ban treaty prohibited environments (atmosphere, underwater, and in space) should the AEC be directed to test in the event of an abrogation of the treaty by others or in the interest of national security, within a minimum reaction period. This capability was first attained on January 1, 1965.

Summary of Readiness Capability

The readiness capability includes the maintenance of facilities, aircraft, and personnel capabilities in the continental United States and in the Pacific Ocean area (Hawaiian Islands and Johnston Atoll) for launching and diagnosing an atmosphere test series on short notice. The airdrop, missile launch, and diagnostic capabilities are maintained in a state of readiness by conducting full scale and abbreviated nonnuclear exercises in the Pacific area and in the continental United States.[4] Operation Windlass, an overseas exercise during September 1966, re-affirmed the U.S. readiness capability.

Diagnostic Aircraft Utilization

AEC policy permits use of the diagnostic aircraft for other appropriate scientific tasks on a non-interference basis with the readiness program and within current financial limitations. Within these limitations, two scientific expeditions with the aircraft were undertaken in 1966.

Cosmic ray study. A cosmic ray scientific study was conducted in early 1966 using the Sandia and Los Alamos-assigned NC–135 diagnostic aircraft. Flights were made from Roosevelt Roads, Puerto Rico, and Ezeiza Airport, Buenos Aires, Argentina during the period

[4] See pp. 102–103, "Annual Report to Congress for 1965."

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[5] See p. 104, "A

of February 10–23. The two aircraft were used to measure simultaneously the distribution and intensities of cosmic rays over wide ranges of latitude, with special emphasis on deviations around the equator.

Preliminary analysis indicated that very good data were obtained on nearly 100 percent of flying time. This was believed to be the first simultaneous airborne recording of cosmic ray activity ever carried out with the aircraft maintaining conjugate positions in the northern and southern hemispheres.

Solar eclipse study. The three weapons laboratories were authorized to use all three diagnostic aircraft for airborne experiments during the total solar eclipse on November 12 in the south Atlantic region. The 1966 eclipse expedition was similar in scope to that which was conducted in 1965.[5] The solar eclipse was observed by the diagnostic aircraft east of Buenos Aires, Argentina, with measurements being made of the sun's corona and other solar and astrophysical phenomena. In addition, Sandia and LASL conducted three Nike-Tomahawk rocket launches, above the atmosphere (about 200 miles), from a site near Rio Grande, Brazil to record X-ray emissions from the sun shortly before and during the eclipse. The rocket accumulation of data will be of direct benefit to the Vela satellite program.

PROJECT VELA

The joint AEC–DOD Project Vela research and development program is conducted to obtain data for developing a system, or systems, to increase the United States' capability to detect, identify, and locate nuclear detonations conducted underground or in space by other nations. The DOD (Advanced Research Projects Agency—ARPA) has the overall programmatic responsibility. The objective is to develop a system or systems capable of adequately monitoring any comprehensive nuclear ban. The Vela program has three subprograms: (*a*) detection of underground nuclear explosions; (*b*) detection, by means of satellites, of nuclear explosions in space; and (*c*) detection of nuclear explosions in space by ground equipment.

VELA UNIFORM PROGRAM

The Vela Uniform Program uses both nuclear and chemical explosions to provide data needed to evaluate: (*a*) the capability to detect underground nuclear tests of various yields and in various media; and (*b*) for studies of seismic wave generation by underground disturb-

[5] See p. 104, "Annual Report to Congress for 1965."

ances and how these waves are affected by different travel paths and geologic environments.

Ground Shock Measurements

Measurements of ground shock accelerations and other effects, and the operation of both short and long-range seismic recording stations, continued in conjunction with underground test events at the Nevada Test Site as a part of the Vela Uniform Program. The DOD has the administrative, funding, and technical responsibility for the program, and the AEC is responsible, in connection with approved nuclear events, for: (*a*) conducting the experiment within the provisions of the limited test ban treaty; (*b*) assuring the public safety; (*c*) construc-

Vela Satellite Hardware. AEC Commissioner Gerald F. Tape (*left*) listens to a description of some of the instruments used in the Vela Satellite Program from Dr. James Coon, Los Alamos Scientific Laboratory group leader. Coon is holding an X-ray detector for a Vela satellite. At *center* is Dr. Raemer Schreiber, LASL technical associate director.

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tion and firing; (*d*) determining the yield and conducting post-shot drilling; and (*e*) instrumenting for close-in measurements.

To date, four underground nuclear events have been conducted under the Vela Uniform Program. The first was Project Shoal, a nuclear detonation of about 12 kt in granite, conducted on October 26, 1963, near Fallon, Nev., to record seismic signals from a nuclear detonation for comparison with signals generated by a naturally occurring earthquake. The second was the October 22, 1964, Salmon event of Project Dribble, a tamped [6] event emplaced in salt at the Tatum Salt Dome, near Hattiesburg, Miss., directed at exploring tamped and decoupling [7] techniques. The third event was the Long Shot event conducted on October 29, 1965, on Amchitka Island in the Aleutian Chain, as an experiment designed to obtain a new set of seismic travel time curves from an underground disturbance in a high earthquake incidence area. The fourth event was Sterling, conducted on December 3, 1966, in Mississippi.

Project Sterling

An exploratory drill-back program through the emplacement casing into the Salmon cavity to establish the feasibility of the re-use of the cavity and emplacement hole was completed in late April and the hole and cavity were determined to be re-usable.

A 350-ton yield nuclear device was detonated in the center of the 110-foot diameter Salmon cavity as Project Sterling. The purpose of this event was to investigate the air-filled cavity concept of seismic decoupling in a "sprung" (detonation produced) cavity. This experiment was completely contained.

The theory of "decoupling" the explosive energy from a surrounding salt mass, and thereby reducing the earth shock or seismic signal, has been demonstrated by experiments conducted with chemical high explosives. The decoupling was accomplished by placing the explosive charges in the center of mined spherical cavities before firing them. The energy transmitted to the walls of the spheres ranged from $\frac{1}{100}$th to $\frac{1}{300}$th that transmitted when the same amount of explosive was tightly confined by the surrounding medium. However, less is known about the decoupling effects of a nuclear explosion at the center of a large sphere created by a previous detonation, and the main purpose of Project Sterling was to obtain information on such effects.

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

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

The difference in effects would stem from the fact that the walls of mined cavities are strong and relatively undisturbed, while explosion-formed cavities such as the Salmon cavity have walls that are strongly deformed and minutely fractured. An understanding of decoupling, as a possible concealment technique, would be important in relation to a more restrictive test ban treaty.

Preliminary analysis of data shows that decoupling ratios were in the vicinity of 200 for frequencies of one cycle per second and lower, and in the vicinity of 100 for frequencies of 10 cycles per second and higher. It is expected that all data will have been analyzed by April 1967.

Unmanned Seismic Observatory (USO)

A prototype USO, developed by Sandia Laboratory, was installed in a 90-foot borehole in late April near Fairbanks, Alaska, to evaluate the effects of permafrost on the observatory. It is planned that the USO will be evaluated for a 12-month period in the permafrost environment. The unit was tested for about 2 months at an Albuquerque site before being shipped to Alaska for further evaluation in an arctic environment. A second USO was emplaced during mid-July in a 200-foot deep hole at the Uinta Basin Observatory near Vernal, Utah for evaluation over a similar period. A third unit was emplaced in a hole 169 feet deep at the south edge of Sandia Base, Albuquerque, during September. This installation will be used as a test facility for evaluating possible modification and improvements to the USO systems.

The prototype USO's were built for DOD's Advanced Research Projects Agency by Sandia to increase the U.S. capability to detect, identify, and locate underground nuclear explosions. They will operate unattended for up to 120 days with a 98 percent reliability and consist of three packages: (*a*) a down-hole unit consisting of three short-period seismometers and three long-period seismometers; (*b*) an electronic package including logics, tape recorder, timing system, etc.; and (*c*) a thermoelectric power supply.

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VELA SATELLITE PROGRAM

The AEC continued to participate in the joint DOD-AEC Vela Satellite Program. As a part of the program, a research and development effort is being conducted by Sandia and Los Alamos Scientific Laboratory to develop the means for detection of nuclear explosion phenomena in space through satellite-based instruments and detectors.

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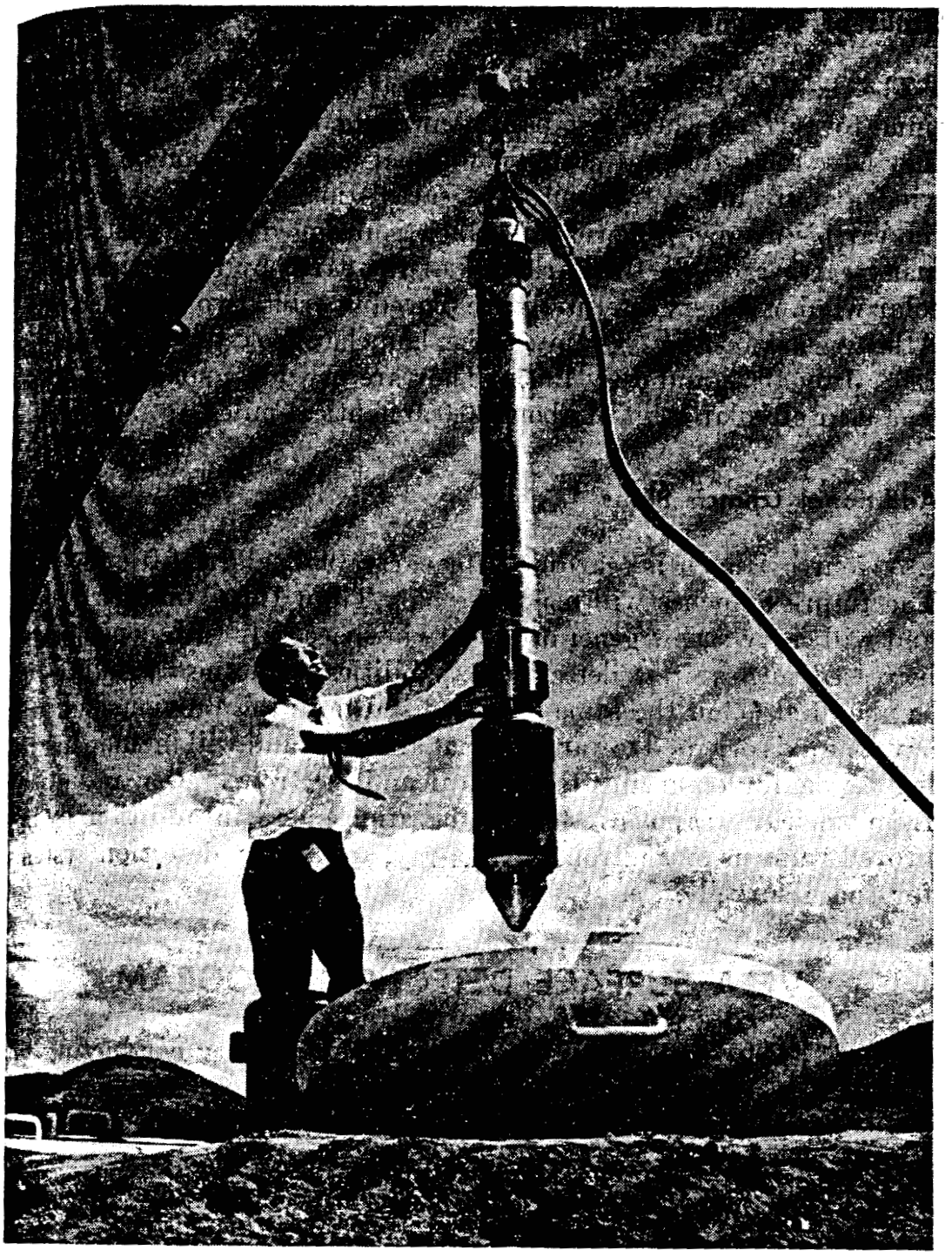

Unmanned Seismic Observatory. The borehole package for an unmanned seismic observatory (USO) was emplaced in a test hole at Sandia Base in April 1966. The location is near the U.S. Coast and Geodetic Survey's seismological laboratory south of Albuquerque. The unit was later emplaced in Alaska for testing in an Arctic environment. The USO, a prototype designed to operate unattended for 120 days with 98 percent reliability, was developed at Sandia Laboratory as part of the Vela Uniform Program for detecting, locating, and identifying underground nuclear detonations. The observatory's most significant feature is its ability to record reliable, precisely timed seismic data while operating unattended in a variety of environments.

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Status of Orbiting Satellites

The six AEC-instrumented Vela nuclear test detection satellites continue to perform their test ban monitoring functions. In addition, they have relayed back to earth new scientific information on the solar wind and its interaction with the earth's magnetosphere, including the earth's magnetospheric tail which is dragged out to distances of many earth radii on the dark side of the earth by the action of the solar wind. The six satellites were placed in orbit, two at a time using Atlas-Agena booster systems. The launches took place in October 1963, July 1964, and July 1965. They are in widely spaced positions on a near circular orbit of about 60,000 nautical miles.

Additional Launch Plans

A fourth launch is scheduled for early 1967, and a fifth for 1968. The future launches will make use of a Titan III C booster system, and will carry a new generation of twin spacecraft with considerably increased nuclear test detection capabilities. The new satellites, to be placed at about the same orbital distance as the previous six, will have one axis oriented toward earth at all times, and will include instrumentation for observing the optical and electromagnetic radiations from nuclear weapons tested in the atmosphere in addition to improved versions of neutron, gamma-ray, and X-ray detection systems for space surveillance.

VELA SURFACE DETECTION PROGRAM

The AEC, with Los Alamos Scientific Laboratory conducting the research and development, has continued to participate with the DOD in the joint program of ground-based detection of nuclear explosions in space. The program is directed primarily on the air fluorescence detection method which is based on the measurement of the fluorescent light produced in nitrogen when air at high altitude is bombarded by X-rays from a nuclear explosion.

Data analysis on the 1965 lightning summer study is proceeding well. This study was an experimental program at LASL to investigate background interference produced by lightning, particularly as it affects air fluorescence and electromagnetic pulse (EMP) detection systems. Joint AEC-DOD analysis of data to date has shown that there are certain relationships between the features of lightning-produced EMP and fluorescence signals which will be helpful in associating the fluorescence signals with lightning. Studies of the correlation between air fluorescence and EMP signals will continue.

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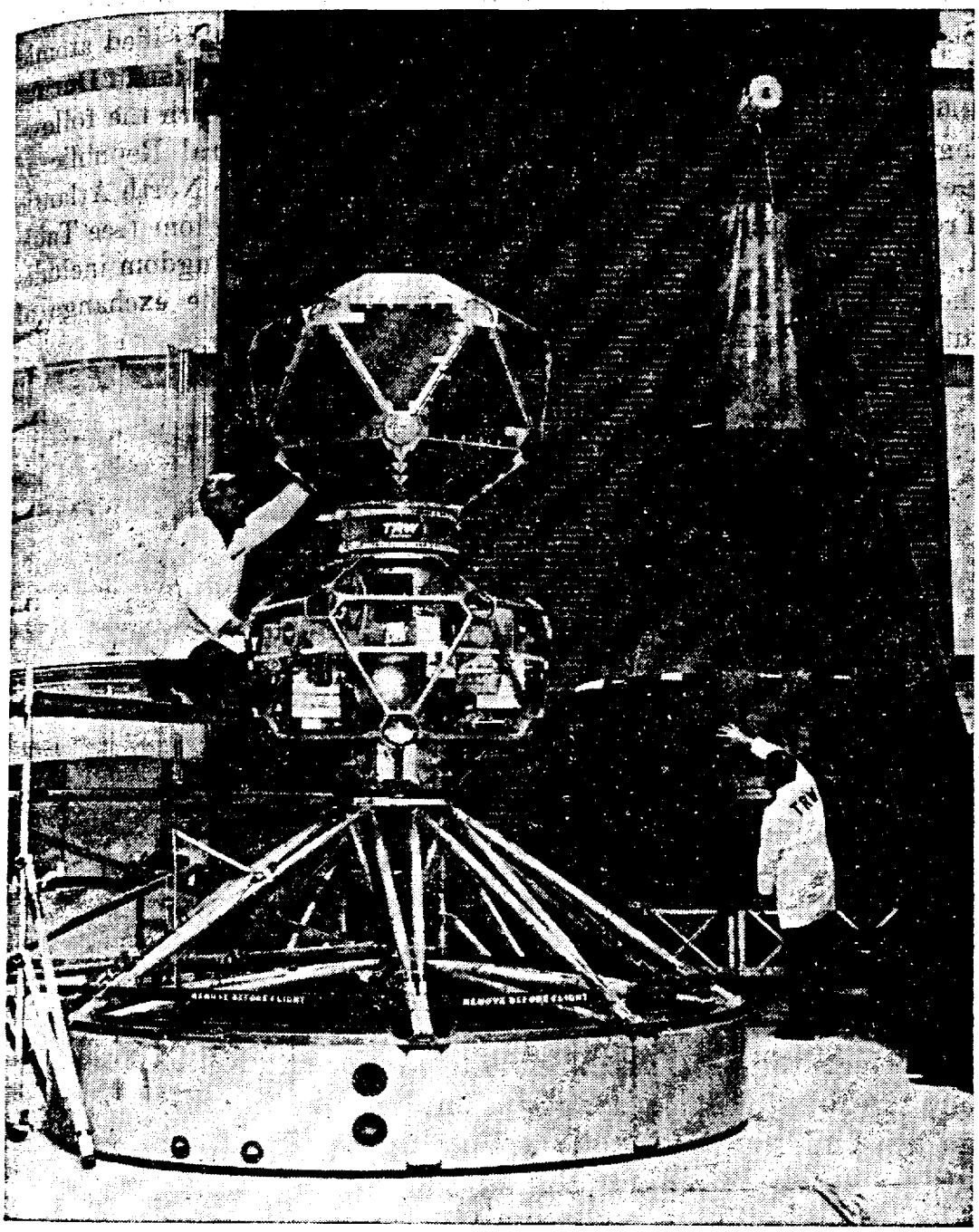
LASL is assembling an all-sky system using a 5-inch diameter lens (versus the 2-inch diameter lens in present systems) with improved optics in the hope of obtaining greater detection ranges under field conditions.



New Vela Satellite. A new version of the Vela Nuclear Detection Satellite (NDS), designed and built by TRW Systems at Redondo Beach, Calif., is one of two scheduled to be launched in tandem early in 1967. Unlike the six predecessors from three previous launches which are now orbiting the earth and returning valuable data on natural nuclear activity in space, the new NDS's will be larger and heavier. It will weigh 730 pounds *vs.* 420 for the previous satellites; the payload (produced by Los Alamos Scientific Laboratory and Sandia Corp.) will weigh 145 pounds *vs.* 90; it will have 26 sides rather than 20 and will be only a few inches larger in diameter (57 *vs.* 54 inches). Shown *above* is one of the NDS's undergoing preparations for a vibration test that simulates the effects of a Titan 3C missile launch.

MUTUAL DEFENSE AGREEMENTS

Under the provisions of the Atomic Energy Act of 1954, as amended, the President may authorize the United States to cooperate with another nation or a regional defense organization in which the United States is a participant and to communicate certain classified atomic data as is determined necessary for mutual defense purposes. During 1966, there were mutual defense agreements in effect with the following: Australia, Canada, Belgium, France, the Federal Republic of Germany, Greece, The Netherlands, Turkey, Italy, the North Atlantic Treaty Organization (NATO), and the United Kingdom (see Table 1, Appendix 7). The agreement with the United Kingdom includes the exchange of weapon design information and the exchange of nuclear materials.

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Chapter 6

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Chapter 6

NAVAL PROPULSION REACTORS

The joint U.S. Navy-AEC naval reactors program has as its objective the design and development of improved naval nuclear propulsion plants having high reliability, maximum simplicity, and maximum fuel life for installation in ships ranging in size from small submarines to large combatant surface ships.

NUCLEAR FLEET

To date, Congress has authorized 104 nuclear-powered submarines, including 41 of the Polaris missile-launching type, and one deep submergence research vehicle. Six nuclear-powered surface warships have been authorized including two aircraft carriers, one cruiser, and three frigates. In addition, Congress has authorized procurement of long-lead-time items for a fourth nuclear frigate.

Of the ships authorized, 66 submarines, including 40 Polaris missile-launching type, and 3 surface ships were operational as of December 31, 1966.

The advantages of nuclear power in a combat environment were dramatically demonstrated when the aircraft carrier *Enterprise* and the guided-missile frigate *Bainbridge* joined the Seventh Fleet off Vietnam and entered combat for the first time on December 2, 1965. On the second day of operations the *Enterprise* demonstrated her high state of readiness following her long transit from the East Coast by setting a new daily record for combat sorties by an aircraft carrier. The nuclear-powered guided-missile cruiser *Long Beach* completed her first refueling early in 1966, as scheduled, and was assigned to join the *Enterprise* and *Bainbridge* in the Pacific Fleet.

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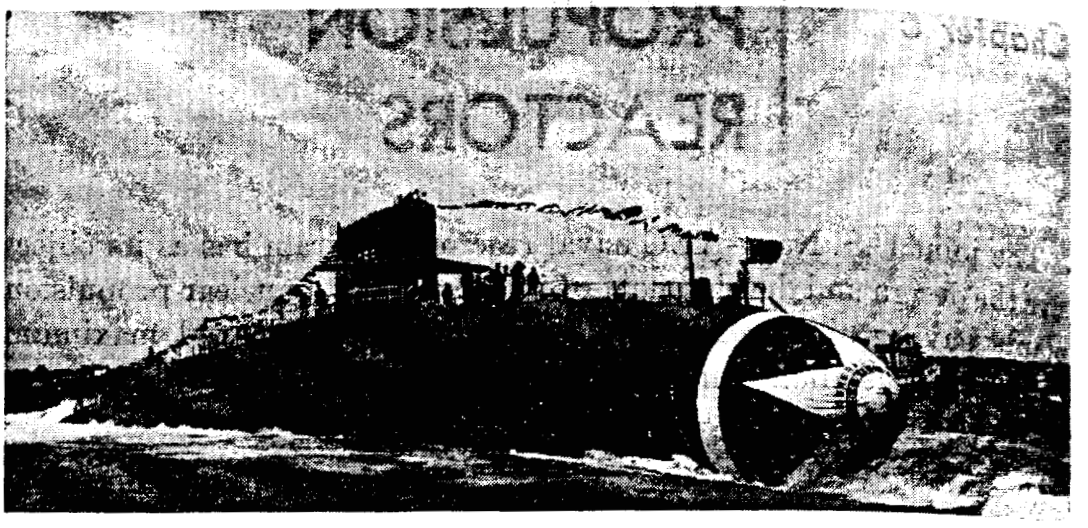
NUCLEAR PROPULSION PLANT DEVELOPMENT

Congress, during 1966, authorized the construction of a second nuclear-powered aircraft carrier. The new aircraft carrier will be powered by two reactors as compared to the eight reactors in the *Enterprise*. These new reactors are the highest-powered, longest-



Nuclear Navy. The *Will Rogers* (SSBN 659), *above*, the last of the presently planned fleet of 41 Polaris missile-launching type nuclear submarines, was launched on July 21, 1966 at the Electric Boat Division, General Dynamics Corp., Groton, Conn., under the sponsorship of Mrs. Hubert H. Humphrey. The nuclear-powered attack aircraft carrier *Enterprise* (*below*) continued to demonstrate the significant advantages of nuclear power for naval surface ships as she operated in the waters off Vietnam with the Seventh Fleet.

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core-life reactors under development in the naval reactors program; each will produce about as much power as four of the *Enterprise* reactors. Since the reactor cores will last for approximately 13 years of normal ship operation, the new carrier is expected to require refueling only once in a normal ship lifetime.

New Long-Life Cores

The initial operation of three improved longer-lived prototype cores for submarines and surface ships has been completed, and the application of these cores to the fleet has been initiated. The operation of the fourth prototype core is scheduled for early 1967. The development of these longer-life cores has a significant impact on the cost per mile steamed. The first core in the *Nautilus* cost over $4 million and steamed 62,000 miles. The next core cost $3 million and steamed over 91,000 miles. The new longer-life cores which will be installed in nuclear submarines cost about $3 million each and will propel the ship for approximately 400,000 miles. Development work is continuing on the technology required in physics, fuel elements, materials, and heat transfer to permit design of still longer lived cores. Development work is also underway on an improved core concept which shows promise of providing significantly more reliable plants. To date, no nuclear-powered ship has had to abort a mission due to failure of its nuclear propulsion plant.

Deep Submergence Research Vehicle

Development is underway on a nuclear-powered deep submergence research and ocean engineering vehicle, designated the NR–1. The NR–1 vehicle will be able to move submerged for periods of time limited only by its store of provisions. It will carry a crew of five plus two scientists and will provide the capability of exploring an area of the ocean bottom several times as great as that of the United States. The vehicle will be used to perform detailed studies and mapping of the ocean bottom, temperature, currents, and other oceanographic parameters for military, commercial, and scientific uses.

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Chapter 7

REACTOR DEVELOPMENT AND TECHNOLOGY

The objectives of the AEC's reactor development and technology programs are: (*a*) to develop a self-sufficient and competitive nuclear industry, and (*b*) to exploit nuclear fuel resources by the practical development of nuclear powerplants for use in central power stations, remote installations or under emergency conditions, and in merchant ships; process heat applications such as desalting and dual-purpose power-desalting; and a wide variety of special applications on the earth's surface and on, or under, the sea. As part of the overall program, the AEC conducts, on a continuing basis, a general nuclear safety research and development program to generate and apply information which will contribute to the safe development, design, construction, and operation of nuclear reactors and nuclear systems in all environments; and a reactor technology research and development program to provide information basic to the development and improvement of reactor systems of all types.

CIVILIAN NUCLEAR POWER

During the year, utility organizations announced plans to install 26 nuclear power reactors on their systems. These reactors, which have a combined generating capacity of 21,224 megawatts of electricity (Mwe), will bring to 56 the total number of central station-type nuclear reactors in operation, under construction, or planned in the United States as of December 31, 1966, and will increase the grand total of present and future installed U.S. nuclear plant capacity to about 31,500 Mwe. Pertinent information about these plants is shown in Appendix 4.

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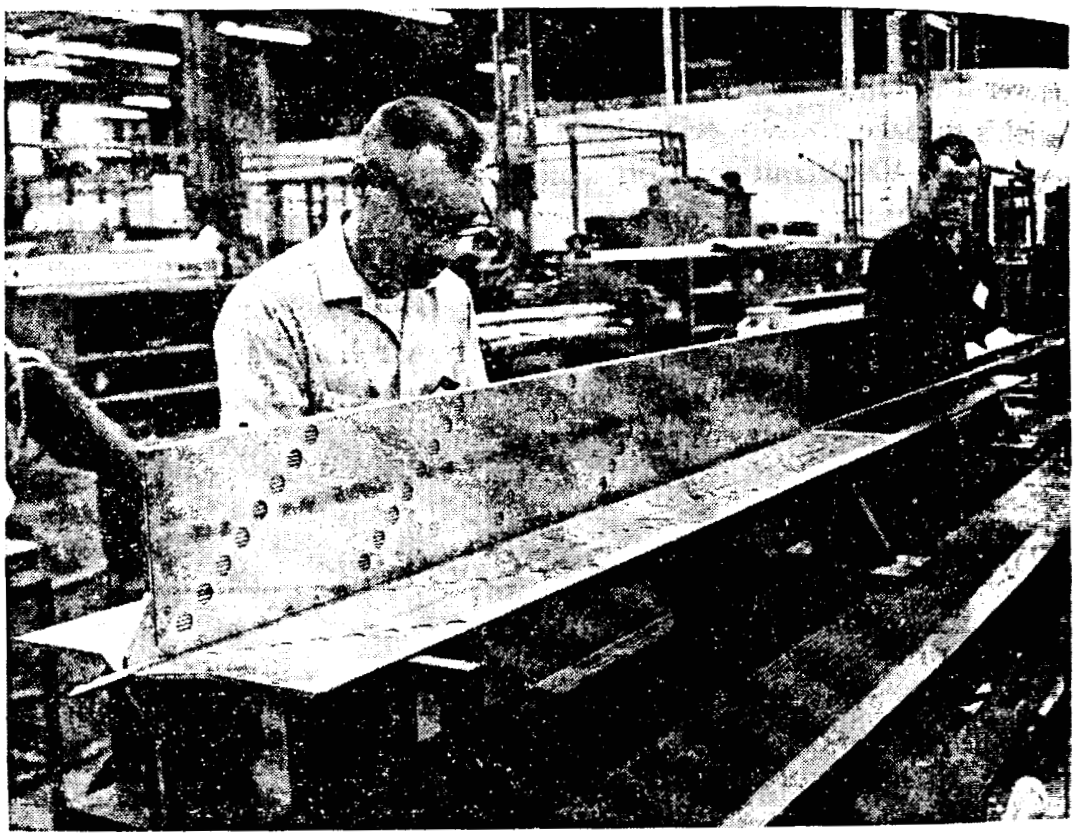
CENTRAL STATION POWERPLANTS

With the acceptance—as is evident from the unprecedented number of new plant announcements in 1966—by utilities of pressurized and boiling water reactor concepts (called "light water reactors" to differentiate them from reactors which use other materials as coolant or moderator), the AEC is now mainly concentrating its effort on the development and demonstration of power reactor systems more advanced than the light water reactors that can use the nuclear fuel resources more efficiently and produce energy more economically in central station powerplants.

FUTURE PROGRAMING

In authorizing appropriations for the AEC for fiscal year 1967, the Joint Committee on Atomic Energy requested that the AEC undertake a general updating of the program presented in the 1962 Report



New Control Rods. A completed control rod assembly for the AEC-Rural Cooperative Power Association Elk River (Minn.) reactor is shown being inspected prior to shipment from Atomics International at Canoga Park, Calif., where 14 Elk River control rod assemblies are being fabricated under an AEC contract. The control assembly consists of neutron absorbing boron carbide pellets encased in nickel-chromium (Inconel 600) alloy tubes. The tubes are spot welded between type 304 stainless steel sheaths to form a cruciform shaped assembly.

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to the President on Civilian Nuclear Power.[1] The report had been prepared by the AEC in response to President Kennedy's request for ". . . a new and hard look at the role of nuclear power in our economy. . . ." Since its issuance in November 1962, the report has served as the guideline for planning the AEC's program to develop civilian nuclear power reactors.

Two-Phase Project

A comprehensive review of the total civilian power reactor program, including the updating of the 1962 report, is being done in two phases: first, a supplement to the 1962 report is being prepared which will review the developments in the civilian nuclear power program since November 1962. The information in the 1962 report will be updated, but the scope of the report will not be extended. This phase of the updating is scheduled for completion early in 1967. The second phase will include comprehensive technical and economic analyses of reactor concepts and reactor systems. These analyses are scheduled for completion in late 1967. AEC national laboratories, utility organizations, and AEC contractors are participating in making the various studies and investigations. The direction and coordination to assure the timely completion of the studies, and the assessments essential to program planning, are being performed by the AEC.

Near-Term and Longer-Term Goals

The AEC's current near-term civilian nuclear power program is aimed at the development and demonstration of advanced converter-near breeder reactors.[2] Reactors of these types are considered to have a potential for: (*a*) achieving power costs below those of the light water reactor plants; (*b*) making major contributions to the conservation of fissile materials; (*c*) making fuller use of the energy potentially available in the reserves of nuclear materials; or (*d*) offering economic potential for applications additional to the generation of electricity (such as for the desalting of sea or brackish water).

For the longer-term, low- and high-grain breeder reactors are being developed which will produce or "breed" more fissionable material than they consume. These include the thermal- and the fast-breeder

[1] "Civilian Nuclear Power . . . a Report to the President—1962," available from the AEC's Division of Technical Information Extension, P.O. Box 62, Oak Ridge, Tenn. 37831, without charge.

[2] A "converter" reactor produces less fuel material than it consumes in its operation; an "advanced converter-near breeder" produces almost as much; a "low-gain breeder" produces slightly more; a "high-gain breeder" produces considerably more.

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reactor concepts.[3] Success of the AEC's breeder reactor program will establish the capability to better exploit the energy contained in nuclear fuel resources, and thus will guarantee the availability of a low-cost source of energy into the indefinite future.

NEAR-TERM PROGRAM

The AEC is taking a three-pronged approach in its program to develop advanced converter-near breeder reactor concepts: (*a*) it is continuing the development and advancement of the heavy water organic-cooled reactor (HWOCR) technology; (*b*) it is continuing the development and advancement of high-temperature gas-cooled reactor (HTGR) technology; and (*c*) it is continuing the development of technology to explore the feasibility of a subsequent demonstration of the breeding potential of the light water seed-blanket breeder concept in an operating reactor.

Heavy Water Organic-Cooled Reactor

One of the attractive features of the heavy water organic-cooled reactor (HWOCR) concept is its high efficiency in the use of neutrons. This characteristic enables the HWOCR to generate more power from each ton of ore mined, thus conserving the fissionable fuel resources. An Atomics International-Combustion Engineering (AI–CE) joint venture organization HWOCR Program Office at Canoga Park, Calif., serves as the AEC's prime contractor for the planning and execution of the HWOCR research and development program. Many AEC laboratories, contractor organizations, and facilities are also contributing to the HWOCR program in direct support of the AI–CE work.

1,000 Mwe-Plant Goal

The near-term HWOCR program objective is to develop the technology which would permit the eventual construction, preferably on a cooperative basis with industry, of a demonstration plant having engineering features which can later be applied to central station powerplants in sizes up to one million electrical kilowatts (1,000 Mwe).

To date, the HWOCR program resources have been concentrated on: (*a*) the development of a successful fuel, including the testing of

[3] In a "thermal" reactor, most of the fission neutrons are slowed down (moderated) before interacting with the nuclear materials; this is accomplished through many collisions with light nuclei such as hydrogen (in water or organic compounds), carbon (in graphite), or beryllium. In a "fast" reactor, little or no moderation is used, so that most of the neutrons retain the high energies and velocities with which they were emitted in the fission process.

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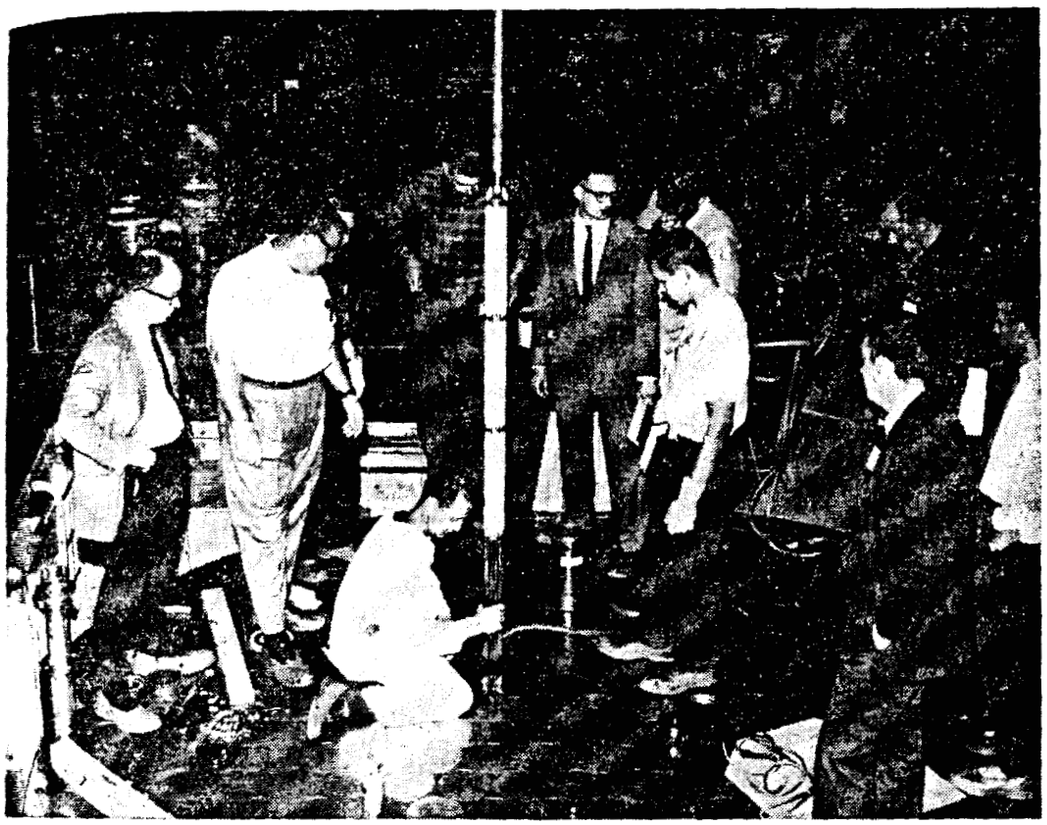
the fuel at design conditions; (*b*) the development and testing of structural components, including a mechanism—an on-line refueling machine—which will permit the reactor to be refueled without being shut down; and (*c*) the evaluation and performance testing of organic coolants.

Use of Canadian Facilities

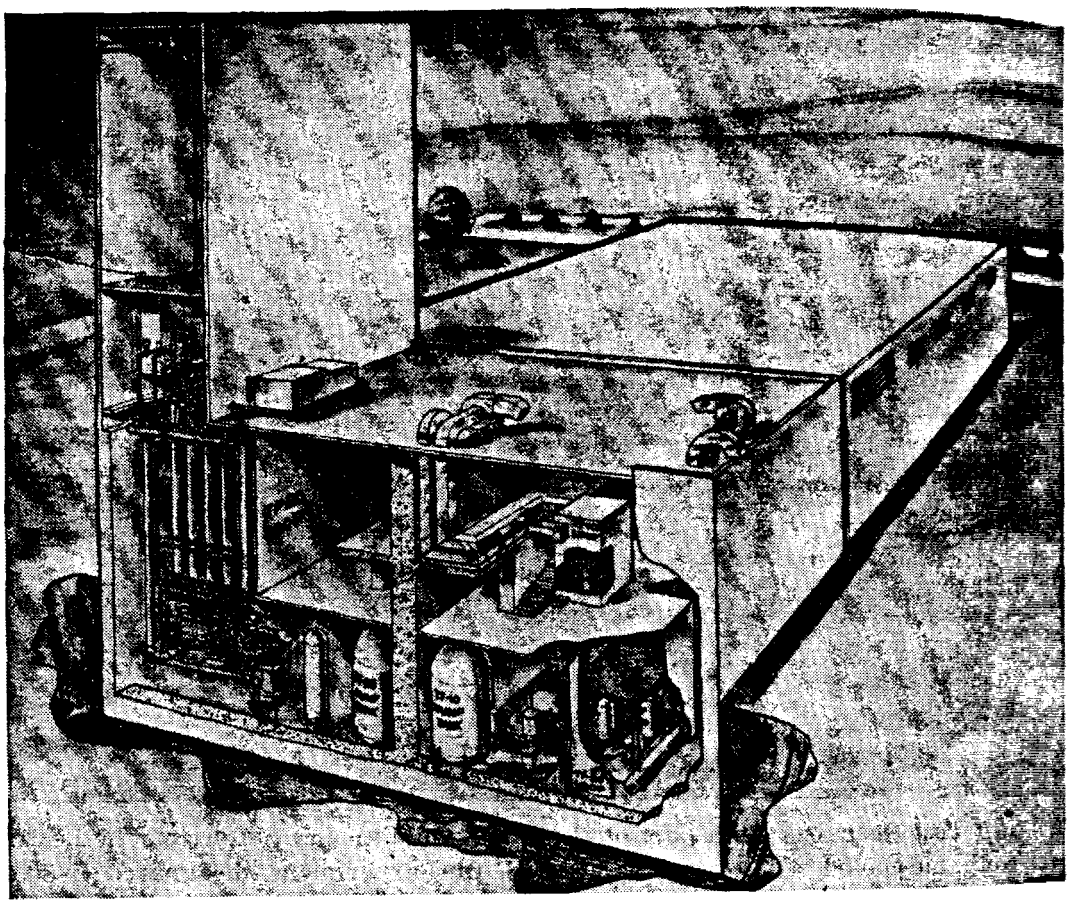
Under the terms of an agreement with Atomic Energy of Canada Limited (AECL), the AEC has access to one-half of the irradiation spaces in the Whiteshell Reactor-1 (WR-1) in Manitoba, and to the U-3 organic-cooled loop in the National Reactor Universal (NRU) test reactor at Chalk River, Ontario, for development of the HWOCR concept. Sintered aluminum powder-clad uranium carbide (SAP-UC) fuel assemblies, fabricated by AI-CE, are being irradiated in these Canadian facilities.



HWOCR Test Success. As a part of the U.S.-Canadian joint effort on the heavy water organic-cooled reactor concept, a U.S. fuel experiment, designated U-305, operated successfully for 10 months until April 1966 at Canada's NRU test reactor, Chalk River, Ontario. It had achieved its design burnup of 10,000 megawatt days per metric ton of uranium, and was removed to a Chalk River hot cell for initial examination. Some of the assemblies were subsequently taken to the Atomics International hot cell facilities at Canoga Park, Calif., for detailed examination. The original experiment, shown as it was being inserted into the NRU reactor during July 1965, consisted of three uranium carbide SAP (sintered aluminum powder) clad assemblies and two uranium oxide zirconium clad assemblies.

1966 Progress

During the year, one of the key components of the HWOCR—SAP pressure tubes 4 inches in diameter—were extruded in lengths up to 30 feet. These tubes are now being tested with organic coolant in Combustion Engineering's full-size pressure tube loop in Windsor, Conn. A loop in the Massachusetts Institute of Technology heavy water research reactor is being used to obtain experience of radiation and temperature effects on the organic coolant of interest in the HWOCR program. The on-line refueling machine work is also in progress at Windsor, Conn. Developmental work on, and fabrication of, carbide fuel is being conducted by Atomics International at Canoga Park. A fuel fabrication pilot line has been assembled and is being used for the development of fuel fabrication processes. It will be used to fabricate a second core for the Piqua Nuclear Power Facility at Piqua, Ohio.



HWOCR Organic Test Loops Facility. Cutaway view shows the three major organic test loops of the heavy water, organic-cooled reactor (HWOCR) test facility at Combustion Engineering, Inc. in Windsor, Conn. Two of the loops, TF–10 and TF–20, are used to test HWOCR pressure tube assemblies; and TF–50 is used to test smaller components under thermal cycle conditions. TF–20, which will start up early in 1967, will be able to test simultaneously five pressure tube assemblies in long-life tests.

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The potential of a HWOCR thorium-fueled system is being studied by Babcock & Wilcox (Lynchburg, Va.), and E. I. du Pont de Nemours Co. is heavily engaged in a HWOCR experimental physics effort at the AEC's Savannah River Laboratory.

Piqua Experience Useful

The design, operation, and maintenance experience derived from the AEC-owned organic cooled and moderated reactor, the Piqua Nuclear Power Facility (PNPF), will also contribute materially to the development of the HWOCR concept. The Piqua reactor was shut down in mid-January 1966 because of control rod and fuel element binding problems. A heavy buildup of carbonaceous material in the moderator region of the PNPF core resulted in deformation of the fuel elements which, in turn, caused the control rods to bind when attempts were made to move them up and down. As a consequence of this serious problem, all of the fuel elements were unloaded from the core, the carbonaceous deposits were removed, and the reactor vessel and systems were thoroughly cleaned. Corrective modifications are being made to the core hydraulics, and extensive analysis, testing, and monitoring will be carried out during the next operating period. These activities should minimize the formation of carbonaceous material as well as provide technology applicable to the HWOCR program. In addition, the replacement fuel assemblies for the PNPF are to be made of SAP-clad uranium carbide. Since this is the fuel which at the present time is the prime candidate for use in the HWOCR system, its fabrication and operation in the Piqua facility will provide direct technical information in support of the HWOCR program.

High-Temperature Gas-Cooled Reactors

The AEC's high-temperature gas-cooled reactor (HTGR) program is directed toward advancing the technology of gas-cooled reactors to provide high thermal efficiency, conserve fissile fuel resources, and to permit the development of commercially competitive HTGRs with outputs up to 1,000 Mwe.

General Atomic Principal HTGR Contractor

The General Atomic Division (GA) of the General Dynamics Corp. is the principal commercial contractor in the HTGR program. GA is the nuclear contractor for the 40 Mwe HTGR at Peach Bottom, Pa., which was built under the AEC's Power Reactor Demonstration Program with Philadelphia Electric Co. Operation of the

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Peach Bottom plant is expected to demonstrate the technical performance, reliability, and economics of several features of HTGRs, including helium containment in large dynamic systems, gas circulators and steam generators, and fuel composed of uranium and thorium carbide particles coated with pyrolitic carbon. GA is also the contractor for the Public Service Co. of Colorado (PSC) in the design, construction, and operation of a 330 Mwe HTGR prototype (the Fort St. Vrain Nuclear Generating Station) for the PSC system near Platteville.

Peach Bottom Achieves Criticality

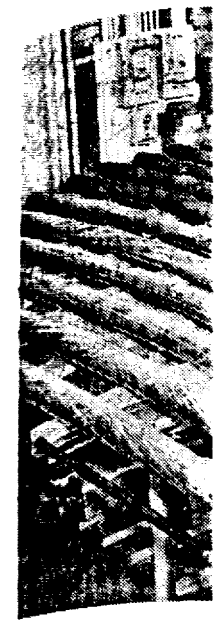
The protype HTGR at Peach Bottom, Pa., achieved initial criticality[4] on March 3. Following the completion of a series of low-power tests, the reactor was shut down in mid-May to analyze initial operations data, apply for a full-power license, repair the steam generators, and modify the fuel transfer machine. (Cracks, due to chemical corrosion, had been found in the steam generator's superheater tubes in December 1965; the superheaters were not necessary for use in low-power test operations but have been repaired so the reactor can be operated at full power.[5]) The Peach Bottom reactor is expected to begin power operations early in 1967. The early operational experience of this reactor will provide information applicable to the Fort St. Vrain project.

Fort St. Vrain Nuclear Generating Station

Work was completed on the preliminary design of the Fort St. Vrain reactor, and detailed design was initiated during the year. Certain features of the Fort St. Vrain plant will differ from those of Peach Bottom. For example, Peach Bottom uses a steel reactor pressure vessel, whereas the Colorado station plans call for a vessel of prestressed concrete; Peach Bottom uses electrically-driven circulators and PSC is to use steam-driven; Peach Bottom uses multi-pass steam generators and PSC will use once-thru-type.

Associated work. The AEC is sponsoring, and GA, along with Oak Ridge National Laboratory (ORNL), is carrying out, a base development program on these as well as other aspects of gas-cooled reactors. The results will be applicable not only to the PSC–HTGR project but also to the furtherance of the AEC's gas-cooled reactor program.

[4] Criticality—The state of a reactor when it can sustain a chain fissioning reaction.
[5] See p. 311, "Annual Report to Congress for 1965."



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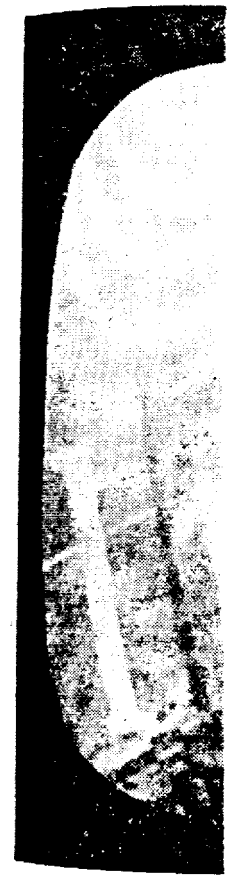
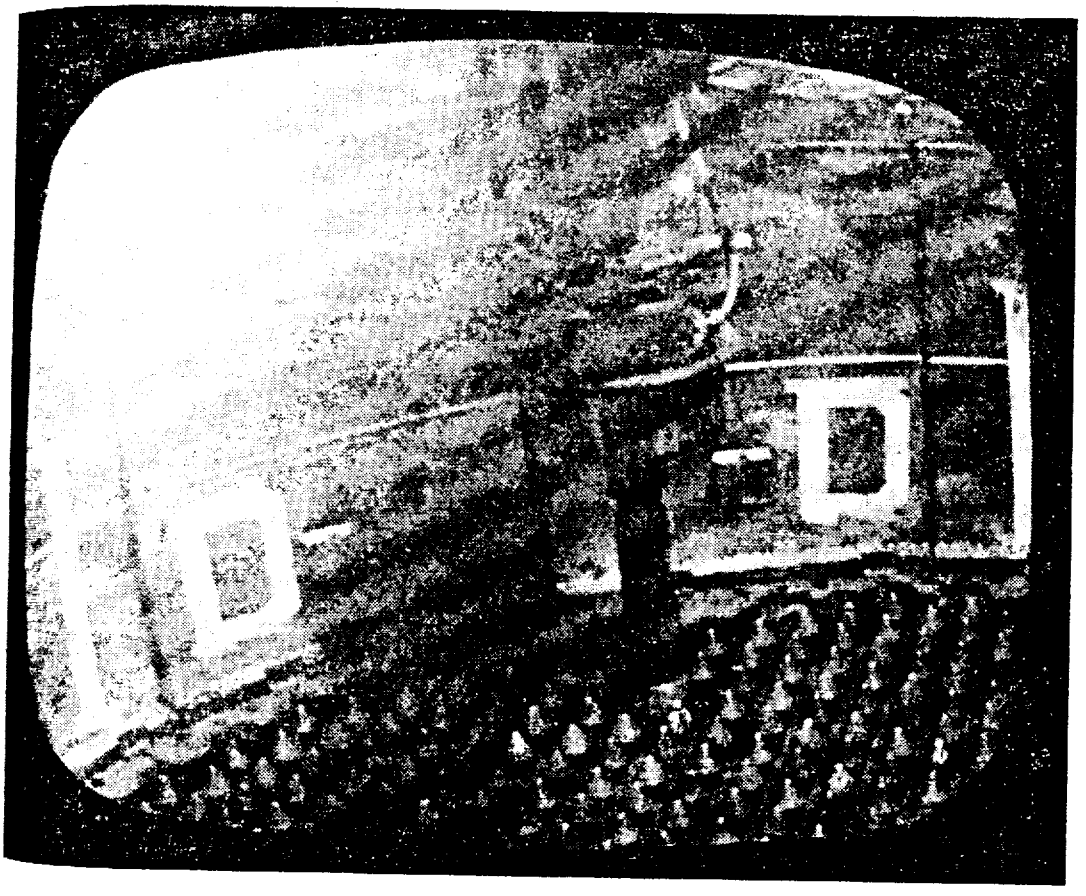


Peach Bottom Fuel Elements. Photo *above* shows some of the 825 graphite-clad fuel elements fabricated by General Atomic Division of General Dynamics in San Diego, Calif., for the Peach Bottom High Temperature Gas-cooled Reactor nuclear power station in Pennsylvania. The AEC has contributed to the research and development costs for the Peach Bottom plant. The 40 Mwe gas-cooled reactor achieved criticality (ability to sustain a chain reaction) on March 3 when 682 of the fuel elements had been inserted in the core. Photo *below* shows a section of the reactor core as seen through a core-viewing device during the fuel loading.



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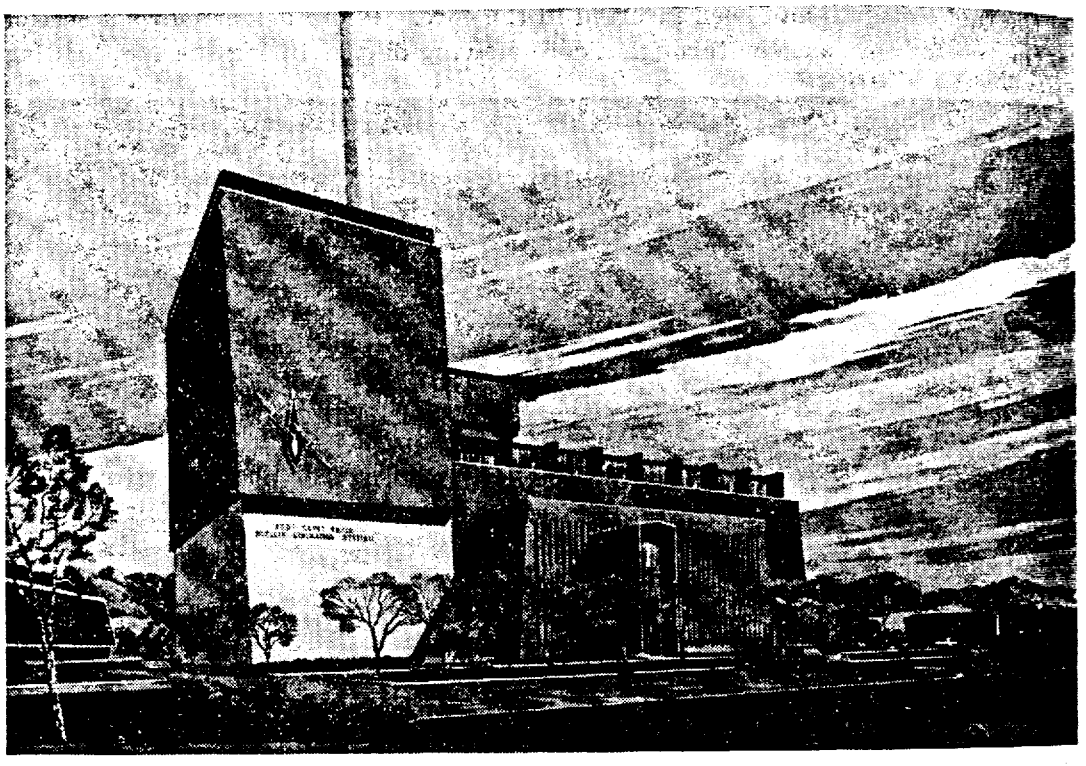
The basic development program encompasses the areas of fuel, physics, and component development. Fuel development work is currently being concentrated on fission product chemistry and graphite studies; on recycle fuel elements; and on the testing of advanced fuel particles, primarily in the Oak Ridge Research Reactor and the Engineering Test Reactor at the National Reactor Testing Station (NRTS), at temperatures up to 3,000° F. to determine their operating limits, the effects of high burnup, their fission product retentiveness, and fuel-coolant interactions. Current emphasis in the physics development area is on analyses and experiments pertinent to a 1,000 Mwe HTGR. In the component development area, emphasis is on establishing the characteristics of prestressed concrete reactor vessels (PCRV) under simulated operating and accident conditions. A PCRV model similar to the vessel to be used in the Fort St. Vrain plant has been built by GA and is currently undergoing mechanical testing. Another important component under development is the main helium circulator which will be driven by steam. The testing of a full-scale prototype circulator will begin early in 1967.



Fort St. Vrain. An artist's concept shows the 330 Mwe Fort St. Vrain nuclear generating station to be built by Public Service Co. of Colorado as part of the AEC's power reactor demonstration program. The high temperature gas-cooled reactor (HTGR) powerplant, to be constructed by General Atomic Division of General Dynamics, will operate at modern, high-efficiency steam conditions of about 2,400 psi pressure and temperature of 1,000° F.

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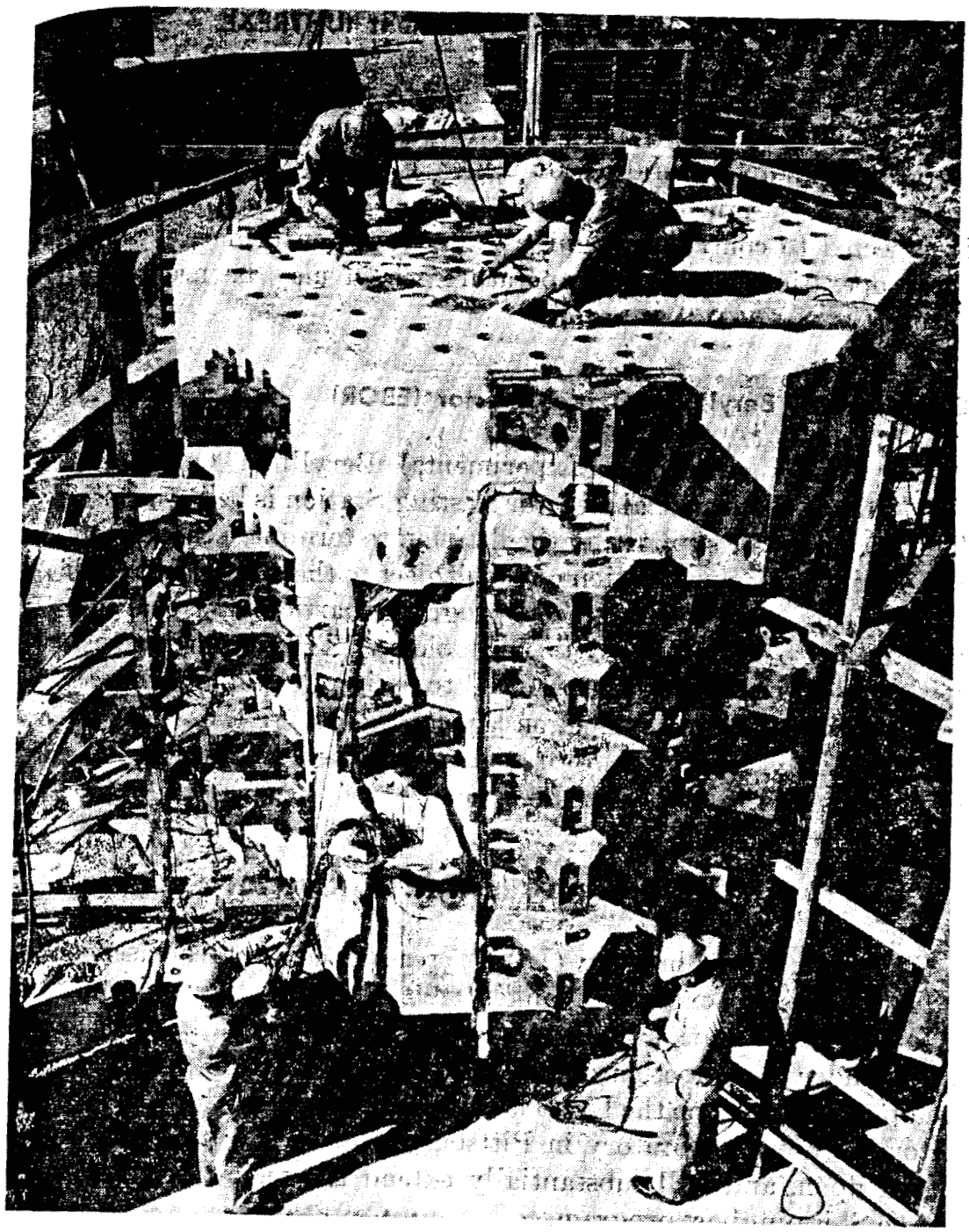

Concrete Pressure Vessel. Photo shows a scale model of a prestressed concrete reactor vessel (PCRV), built and tested for the AEC at General Atomic Division of General Dynamics, at San Diego, Calif. The model is undergoing mechanical testing under simulated operating and accident conditions to provide operating characteristics of PCRV's. Plans call for using a prestressed concrete reactor vessel in the Fort St. Vrain high-temperature gas-cooled reactor plant in Colorado.

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Ultra-High Temperature Reactor Experiment (UHTREX)

The UHTREX, which is scheduled to achieve criticality in the spring of 1967 at Los Alamos, N. Mex., is unique in that it is designed to operate at a temperature of 2,400° F. Since present gas-cooled reactors are designed to operate at about 1,400° F., the UHTREX is expected to contribute significant technical information about reactor operations at high temperature which may be needed in the future.

Experimental Beryllium Oxide Reactor (EBOR)

The AEC's gas-cooled Experimental Beryllium Oxide Reactor (EBOR) at the National Reactor Testing Station is being terminated. The major factor supporting the decision to terminate the EBOR was the diminishing contribution of the project to the AEC's current high-temperature gas-cooled reactor program, particularly that portion pertaining to beryllium oxide technology. The action is consistent with continuing efforts of the AEC to assign available resources, including funds and personnel, on a priority basis to those reactor concepts with the best promise of economic power production and more efficient use of nuclear materials.

Light Water Breeder Reactor

The light water breeder (LWB) reactor 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 LWB is being carried out at the AEC's Bettis Atomic Power Laboratory in Pittsburgh, Pa. The LWB concept is based upon, and will substantially extend the technology developed in the Shippingport program.

Based on the work done to date, there is continued indication that a successful light water breeder core design can be developed. The successful development of this reactor concept could ultimately make available for power production about 50 percent of the energy potentially available in this 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. 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 the 1–2 percent of the energy potentially obtainable from uranium or thorium ore resources using present types of light water reactors.

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LONGER-TERM PROGRAM

To paraphrase a statement which AEC Chairman Seaborg included in his letter to President Kennedy which transmitted "Civilian Nuclear Power—a Report to the President—1962": Only by the use of breeder reactors, which can make use of nearly all of our reserves of the nuclear fuels uranium and thorium, will we really solve the problem of adequate energy supply for future generations.

Although the 1962 Report to the President is being revised to be in accord with developments of recent years, the statement made by Chairman Seaborg is as true today as it was when written: the capability to more fully exploit the energy contained in our nuclear fuel resources—and thus guarantee the availability of a low-cost source of energy into the future—will require the development of breeder reactors and their successful introduction into commercial use. Breeder reactors have the advantage not only of making possible the use of the full potential energy available in nuclear fuels—perhaps 50 times more energy being available per pound of uranium than in the light water reactors of the type being sold commercially—but breeders also have the advantage of making higher-cost fuel economically feasible because of the efficient way in which a high proportion of the fuel is used. The net result is that with breeders the use of nuclear fuel will be effectively multiplied by a substantial factor.

Breeders Given Priority

The AEC's program to develop breeder reactors is giving the highest priority to development of the high-gain liquid metal (sodium)-cooled fast breeder reactor concept. Investigations are also being made to determine the advantages and disadvantages of: (*a*) other reactor concepts which appear to have potential for breeding—the low-gain light water breeder (LWB), previously discussed, and the molten salt low-gain thermal breeder reactor concept which would be based on an advancement of the technology developed by the Molten Salt Reactor Experiment—and; (*b*) on a limited basis, other coolants, such as gas and steam, for use in high-gain fast breeder reactor concepts. To date, research and development work on the low-gain thermal breeder reactor concepts is in its early stages and is concentrating on the fuel element, large plant core physics, safety, and components.

Molten Salt Reactor Experiment

In May, the Molten Salt Reactor Experiment (MSRE) at Oak Ridge National Laboratory reached its maximum power capability of 7.5 megawatts (thermal) (Mwt) at the normal reactor outlet tempera-

ture of 1,210° F. The design full-power of 10 Mwt was not achieved because of limitations in the heat rejection equipment.

Liquid Fuel Shows Stability

This reactor is unique in that it uses a molten salt solution of the fluorides of uranium, lithium, beryllium, and zirconium as a liquid circulating fuel. The reactor runs at low pressure and at high temperature. Samples of fuels were taken weekly from the reactor while it operated at maximum power, and samples of the reactor materials—Hastelloy N and graphite—were removed from the core after 1,000 hours of 7.5 Mwt operation. Examinations of the samples gave encouraging evidence that the fuel salt has been completely stable and that there has been no appreciable corrosion of the structural metal or graphite. The reactor has run well except for problems with auxiliary equipment, and operation is continuing into 1967. The goal is to provide some of the experience and data necessary to design and evaluate the potential of larger molten-salt power reactors.

Low-Gain Breeding Promise

A study was made of a molten-salt thermal breeder reactor powerplant of 1,000 Mwe capacity. The results indicated that such a plant offers promise for low-gain breeding on the thorium-uranium 233 fuel cycle while producing power at low cost. The low inventory of fissionable material in the plant compensates for the low-gain breeding. The study also served to point out many engineering and materials problems that must be solved before a large plant can be built. Those problems are being studied further along with gaining more experience with the MSRE.

Liquid Metal-Cooled Fast Breeder Reactors

The planning and execution of the research and development program required for mastering the technically difficult and complex liquid metal-cooled fast breeder reactor (LMFBR) concept in a timely manner is proceeding on a high priority basis. The Nation's extensive industrial capabilities and resources are being brought to bear heavily on the LMFBR development program. On January 24, the AEC established an LMFBR Program Office at the Argonne National Laboratory. This program office, which is functionally and administratively separate from the research and development activities of Argonne, is assisting the AEC Headquarters staff in the detailed plan-

ning and evaluation of the numerous technical activities of the LMFBR program which are and will be carried out by AEC laboratories and industrial contractors.

Technical Study Areas

Based on the results of an overall assessment of the status of the LMFBR program, formal reviews are continuously being made in each technical area of the LMFBR program to determine its major needs, its deficiencies, and the program required to eliminate these deficiencies. The eight LMFBR technical areas have been defined as: (*a*) fuels and materials, (*b*) reprocessing and recycling, (*c*) physics, (*d*) nuclear safety, (*e*) sodium technology, (*f*) component development, (*g*) instrumentation and control, and (*h*) plant design—and, in each case, their associated facilities.

Initial Planning Completed

The detailed program plans for each of these technical elements will be coordinated into an overall master LMFBR program plan which is scheduled for completion during the first half of 1967. The detailed plans will establish objectives, criteria, and standards for the LMFBR program elements; they will include consideration of the available national resources in terms of manpower and facilities; and they will establish priorities and schedules for the achievement of program objectives, making the best possible use of the national resources.

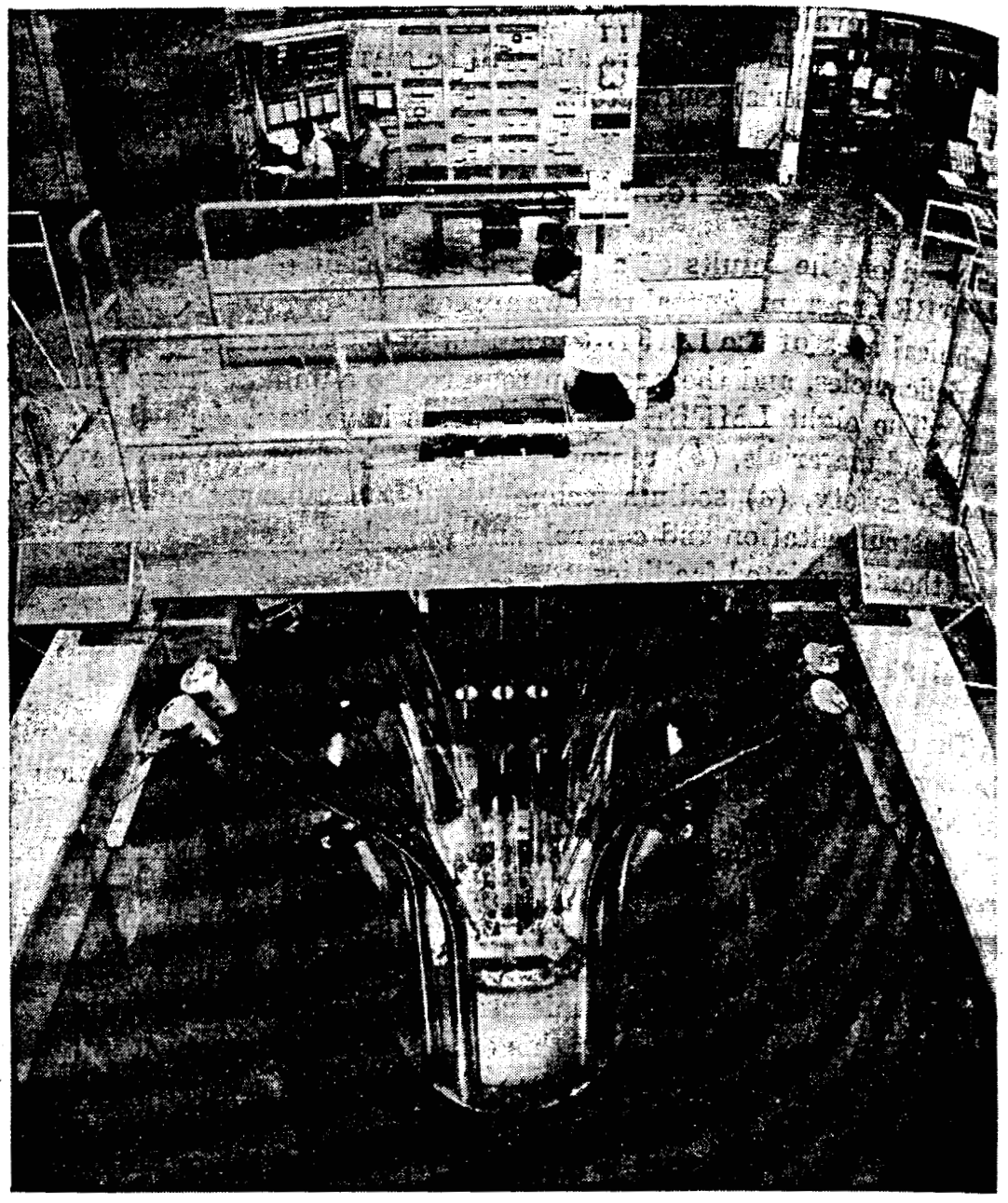
To date, the initial phase of this extensive planning effort has been completed on each of the program elements and is now undergoing refinement. Conclusions of the first phase reviews are that each of the program elements requires significant strengthening and augmentation. When the detailed program plans have been completed, they will be circulated to industry for comments. When these comments have been evaluated and the plans have been approved, they will be implemented.

Status of Current Work

The current status of and plans for implementing each of the LMFBR program elements are summarized below.

Fuels and Materials

The LMFBR fuels and materials program review has been completed and indicates the need for extensive research and development to develop satisfactory fuels and cladding materials for the fast re-



ATR Nearing Completion. The Advanced Test Reactor Critical (ATRC) at the Advanced Test Reactor (ATR) facility is shown under 24 feet of shielding water at the National Reactor Testing Station in Idaho. The ATRC is used to check the nuclear characteristics of the unique 4-lobed core designed for the parent 250-megawatt ATR which is expected to achieve initial low power operation in 1967. The ATR, which is adjacent to the Materials Testing Reactor (MTR) and the Engineering Test Reactor (ETR), will be used for irradiation testing of materials for advanced military and civilian reactors. It will provide nine 5-inch diameter regions four feet long. Unperturbed thermal fluxes in the range of up to 2.5×10^{15} neutrons per square centimeter per second will be achieved. The ATR, which will be operated for the AEC by the Idaho Nuclear Corp., is being equipped with a high temperature helium-cooled loop for irradiation-effect tests on materials.

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actor environment. The current program is aimed at developing a reliable, safe, low cost, high-burnup fuel which will have a 3-year average lifetime in the core. Plans were put into effect during the year, to devote primary attention to the two fuels which have the best potential to reach these objectives—the plutonium-uranium oxides and carbides. For the next few years these fuel types will be developed and irradiation-tested to determine which should be emphasized in the following years.

Since the reliable containment of fuels in an adequate cladding material in the LMFBR environment is a major requirement, several materials are being investigated as potential cladding candidates. These include stainless steels, nickel-base alloys, and refractory alloys. Investigations are in progress to determine the compatibility of these cladding materials with LMFBR fuel materials and with sodium, and their long-term mechanical properties.

FFTF studies. To a significant degree, the program on fuels and cladding materials will be paced by the availability of fast fuel test facilities. The United States presently has no test facility which parallels the fast reactor environment. Although the existing EBR–II fast reactor will be used to the maximum extent possible for irradiation experiments on the priority fast reactor fuels, much of the LMFBR fuel and cladding materials testing will have to await the availability of the Fast Flux Test Facility (FFTF) which is being designed at the Pacific Northwest Laboratory especially to meet LMFBR testing needs. During 1966, a review of the FFTF interim conceptual design [6] was completed by Atomics International, Idaho Nuclear, General Electric, and Westinghouse. The results of this review are being incorporated in modifications to the interim concept and alternate concept studies by Pacific Northwest Laboratory, General Electric, Idaho Nuclear, and Westinghouse. These studies are directed toward defining the facilities which best meet the test capabilities as economically as possible. At year's end, a site for the FFTF had not been selected.

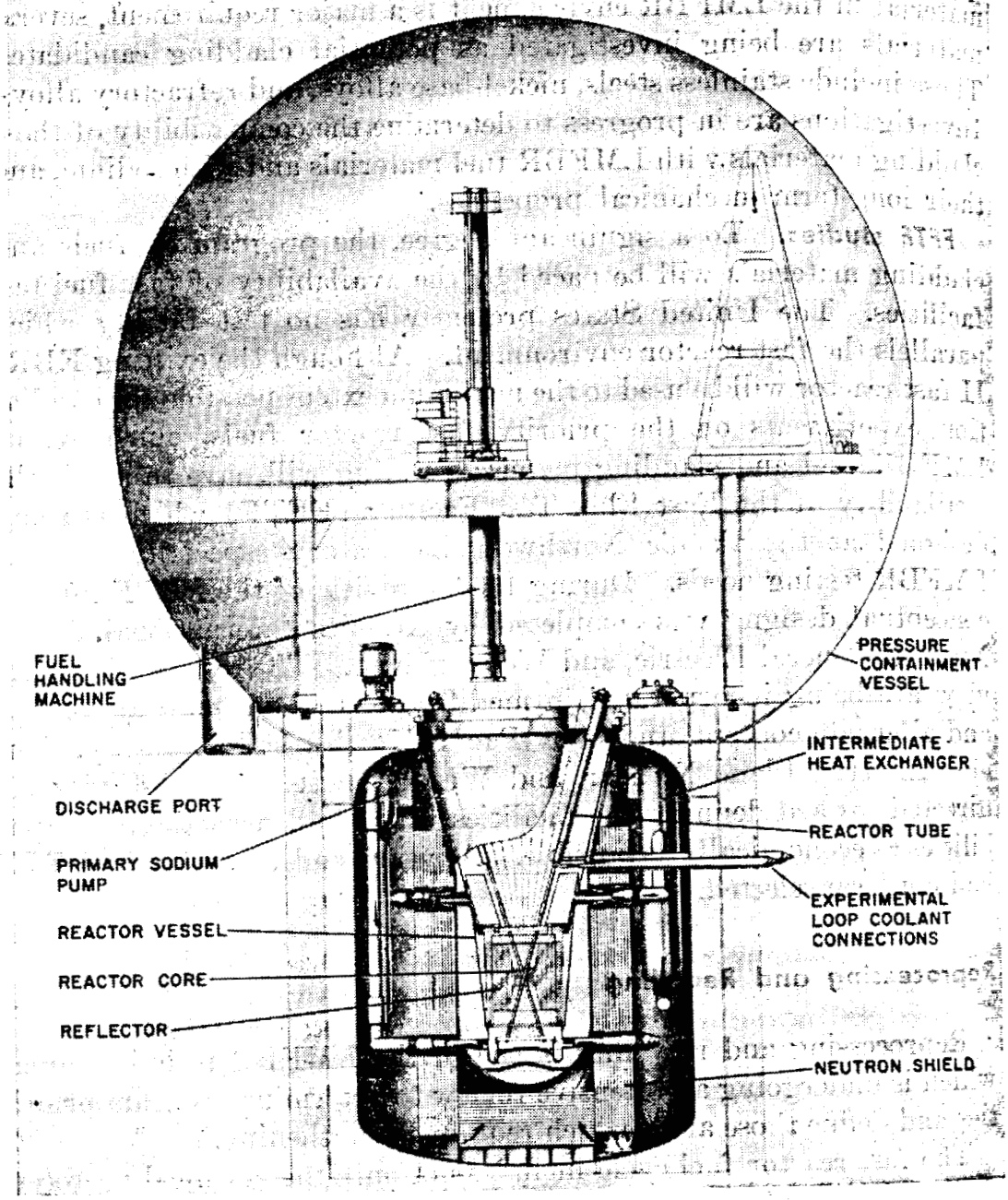
Reprocessing and Recycling

Reprocessing and recycling is one of the LMFBR technical areas which is undergoing an intensive review to determine program priorities and define those areas which require strengthening.

The fast reactor fuel cycle includes not only the chemical reprocessing of irradiated fuel, but also the conversion and refabrication of the recovered fuel for further irradiation. Although reprocessing techniques developed for thermal reactor fuels may find some application

[6] See p. 129, "Annual Report to Congress for 1965."

to fast breeder reactor fuels, the following areas will introduce new problems which require resolution: (*a*) the high fuel burnup in the fast reactor system; (*b*) the high fuel enrichment of fast reactors, and (*c*) the geometry of the fast reactor fuel rod. The research and development program will include the development of economic advanced reprocessing techniques and semi-remote and fully remote fabrication technology.



Fast Flux Test Facility. Drawing shows the major components of the Fast Flux Test Facility (FFTF) which is being designed by Pacific Northwest Laboratory especially to meet liquid metal-cooled fast breeder reactor (LMFBR) testing needs.

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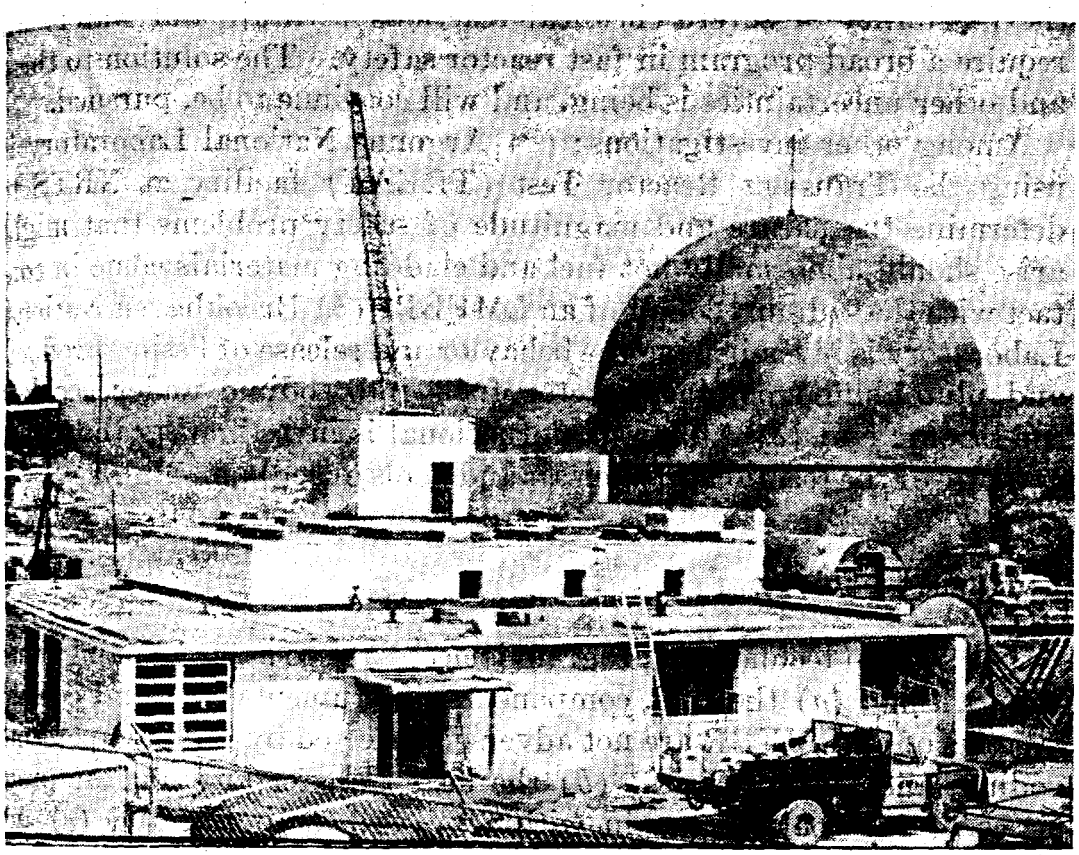
Physics Area

The review in the physics area of the LMFBR program has been completed and confirms the fact that significant gaps exist in the knowledge and understanding of the physics of fast breeder reactors. Some of these gaps will be partially filled in as information is derived from the research and development programs presently in progress in such facilities as the Zero Power Reactor (ZPR)–III in Idaho and ZPR–VI and ZPR–IX at Argonne. All of these zero-power critical facilities are being used by the Argonne National Laboratory to investigate the physics of large fast reactor cores. Additional physics data will result from operation of the Zero Power Plutonium Reactor (ZPPR) in Idaho and the Southwest Experimental Fast Oxide Reactor (SEFOR) in Arkansas, both of which are under construction



SEFOR Progressing. Construction of the Southwest Experimental Fast Oxide Reactor (SEFOR) near Fayetteville, Ark., is scheduled to be completed in 1968. When the General Electric-built facility becomes operational, it will be used to study the nuclear characteristics of a fast breeder reactor system which uses mixed plutonium oxide-uranium oxide as fuel and sodium as coolant. The SEFOR project, on which construction was started in 1965, is being jointly supported by the Southwest Atomic Energy Associates, a West German Corporation, the European Atomic Energy Community (Euratom), and the AEC.

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and are scheduled to be operational in 1968. These facilities will provide data on critical mass, sodium void effects, *Doppler* effects, and other information necessary for the detailed design of large fast breeders. They will also contribute data on the economics and safety aspects of large, fast, plutonium-uranium fueled breeder reactors.

Nuclear Safety

The AEC has always placed primary emphasis on nuclear safety with regard to the different reactor concepts. Further reviews are being made to identify and resolve the safety questions and unknowns associated with fast breeder reactors. The short neutron lifetimes for fast reactors, the use of plutonium with its resultant small delayed neutron fraction, the hypothetically possible critical reassembly of a large core after meltdown, and the use of sodium—which introduces the possibility of severe chemical reactions with air and water—all require a broad program in fast reactor safety. The solution to these and other uncertainties is being, and will continue to be, pursued.

Among other investigations: (*a*) Argonne National Laboratory is using the Transient Reactor Test (TREAT) facility at NRTS to determine the nature and magnitude of safety problems that might arise should abnormally hot fuel and cladding materials come in contact with the sodium coolant of an LMFBR; (*b*) Brookhaven National Laboratory is investigating the behavior and release of fission products and plutonium from fast reactor fuels into sodium under accident conditions; and (*c*) Atomics International is investigating the extent and rate of the reaction between air and pools of sodium.

Sodium Technology

The sodium technology program is necessary to assure, among other things, that: (*a*) the fuel, components, instrumentation, and coolant systems of an LMFBR are not adversely affected by high temperature sodium and its impurities; (*b*) the heat transfer and nuclear properties of the coolant remain within prescribed limits; and (*c*) any abnormal effects such as sodium-water and sodium-air reactions can be contained.

During the year, General Electric (San Jose, Calif.), Atomics International (Canoga Park, Calif.), the Mine Safety Appliances Research Corp. (Pittsburgh, Pa.), Babcock & Wilcox (Alliance, Ohio), and the Argonne and Brookhaven National Laboratories have all been conducting engineering-type studies to determine the corrosion resistance and the effects of sodium on the mechanical properties of various containment materials. The results of these corrosion and mechanical

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property studies will provide LMFBR designers with the data necessary for preparing sound engineering designs of primary and secondary sodium systems. Brookhaven and Atomics International are also studying the basic solubilities of pure metals in sodium as a function of impurity content. Further effort will be given to the development of this and other supporting sodium technology studies when the refinement of the sodium technology program plan, which is now underway, is completed.

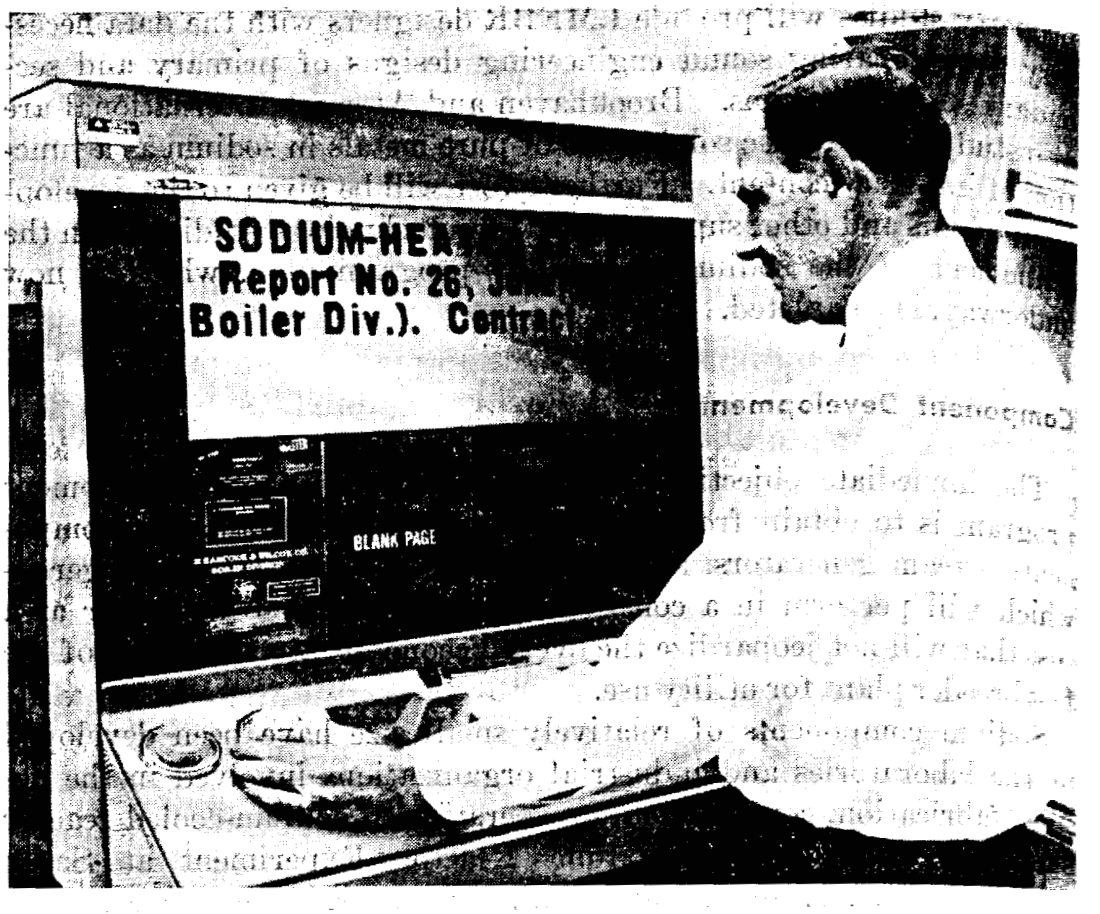
Component Development

The immediate objective of the sodium components development program is to obtain from industry the fast breeder reactor components—steam generators, large pumps and valves, heat exchangers—which will perform in a consistently safe and reliable manner at a cost that will not jeopardize the overall economic attractiveness of the fast breeder plant for utility use.

Sodium components of relatively small size have been developed by the laboratories and industrial organizations involved in the design, fabrication, construction, or operation of sodium-cooled reactor plants—EBR–II, SRE (Sodium Reactor Experiment at Santa Susana, Calif.), Hallam, and Fermi. However, the extremely large components which will be required in the LMFBR program differ considerably from these small components and will impose difficult tasks on the industrial designers and fabricators who will play key roles in the LMFBR component development program. The fabrication of these large sodium components must be to an exceptionally high standard, and their design must be positively verified through realistic proof-tests before they are installed in a costly plant. (The AEC announced early in December that the SRE was being deactivated. Following the 1965 termination of the sodium-graphite reactor program, the SRE was evaluated for possible use as a radiation test facility for the high-priority LMFBR program. The evaluation indicated that to perform satisfactorily as such a facility, the SRE would require extensive modificaton. A determination was made that the diversion of resources necessary to modify the facility could not be justified at this time.)

Late in October, the AEC awarded contracts to Byron Jackson Pump, Inc. (Los Angeles, Calif.) and Westinghouse Electric Corp. (Cheswick, Pa.) to develop pump designs to meet the requirements of future LMFBR systems.

To provide a focal point for much of this proof and model testing, the AEC has established a Liquid Metal Engineering Center at Santa Susana, Calif., with Atomics International as the contractor-operator.



Liquid Metals Information Center. Research and development in sodium and sodium-potassium technology will be under continuing evaluation, analysis, and indexing at the Liquid Metals Information Center (LMIC) established during the year at Canoga Park, Calif., by the AEC, with Atomics International as the contractor-operator. LMIC's major functions will be to maintain an up-to-date compilation of liquid metals data that can be made available to the AEC and private industry. In photo *above* a liquid metal technologist reviews a microfilm copy of a technical report to select retrieval terms and prepare an abstract for the LMIC file. In photo at *left* a computer is used during preliminary stage of transfer of bibliographic data, retrieval terms, and abstracts of current accessions of the LMIC, from punched cards to the magnetic tape file.

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Among the principal facilities in the center are the Sodium Components Test Installation, the Control Rod Test Tower, Large Component Test Loop, the recently authorized Sodium Pump Test Facility (SPTF), and a Liquid Metals Information Center. Use of these facilities by component vendors will be an important factor in developing a strong commercial base for fast breeder reactors.

Instrumentation and Control

From the liquid metal instrumentation and control program will come the technical base—including standards, fabrication and performance specifications, and demonstration by adequate proof-testing—upon which industry can supply adequate instruments and control equipment for the safe and economical operation of a LMFBR powerplant.

Analyses and studies performed in 1966 resulted in identifying the need for: (*a*) in-core measuring instruments capable of operation in the severe liquid metal high-temperature and fast neutron flux environment; (*b*) under-sodium scanning systems that can be used in-core for routine inspection, repair, and refueling; and (*c*) accurate, easy-to-use instruments to detect impurities of nitrogen, hydrogen, oxygen, and carbon in sodium at levels of a few parts per million.

Specific instruments and systems to meet these requirements are under development. These development programs will continue, and experience derived from existing instrumentation and control equipment in operating LMFBR program facilities will also be analyzed and used to formulate the overall LMFBR instrumentation and control program.

Plant Design

The purpose of the plant design program is to integrate the entire LMFBR powerplant system, from heat source (the reactor) to electric power generation. The interrelationships of all elements of the reactor plant are being examined, tradeoffs (comparison of the advantages and disadvantages of various plant concepts) are being studied, and individual design details are being adjusted to develop the best overall plant design which will achieve the fast breeder reactor program objectives.

To identify some of the problems in fast breeder reactor plant design, five conceptual design studies for a 1,000 Mwe LMFBR were performed by the industrial firms of Allis-Chalmers (Milwaukee, Wis.) with Babcock & Wilcox (Lynchburg, Va.), Combustion Engineering (Windsor, Conn.), General Electric (San Jose, Calif.), West-

inghouse (Pittsburgh, Pa.), and Atomics International (Canoga Park, Calif.). These studies examined problems associated with safety, fuel performance, fuel cycles, and breeding. All the firms except Allis-Chalmers, which withdrew from the nuclear energy field early in 1966, are continuing these studies in greater depth. The results of the studies will provide an engineering base for one or more conceptual designs of a 1,000 Mwe plant, which in turn will be useful in planning future LMFBR demonstration plants.

DESALTING AND DUAL-PURPOSE PLANTS

The AEC's nuclear desalting program, conducted in coordination with the Office of Saline Water of the U.S. Department of Interior, is directed toward analyzing, developing, and demonstrating nuclear reactor systems for desalting applications.

PROGRESS IN 1966

Substantial progress was made in 1966: (*a*) agreement in principle to proceed with a large nuclear desalting project was reached with the Metropolitan Water District of southern California (MWD), and the AEC obtained authorization to participate in this cooperative project; (*b*) the program of studies and evaluations initiated in 1965 at the Oak Ridge National Laboratory are continuing; (*c*) several cooperative studies for specific applications were completed; and (*d*) teams made inspection tours of foreign countries which have expressed interest in nuclear power-desalting technology.

Southern California Project

Agreement on a memorandum of understanding was reached between the MWD, the AEC, and Interior's Office of Saline Water on the general basis of arrangements for a cooperative project for the construction of a two-unit nuclear power-desalting plant. Current plans are for the plant to be located on a 40-acre man-made island about 3,000 feet offshore of Bolsa Chica State Beach between Huntington and Seal Beaches, Calif. On August 9, the MWD Board of Directors decided to proceed with the project on the basis of these arrangements with the Federal Government agencies and the continued willingness of the electric utilities in the area to participate in the project. Negotiations looking toward definitive agreements are presently underway.

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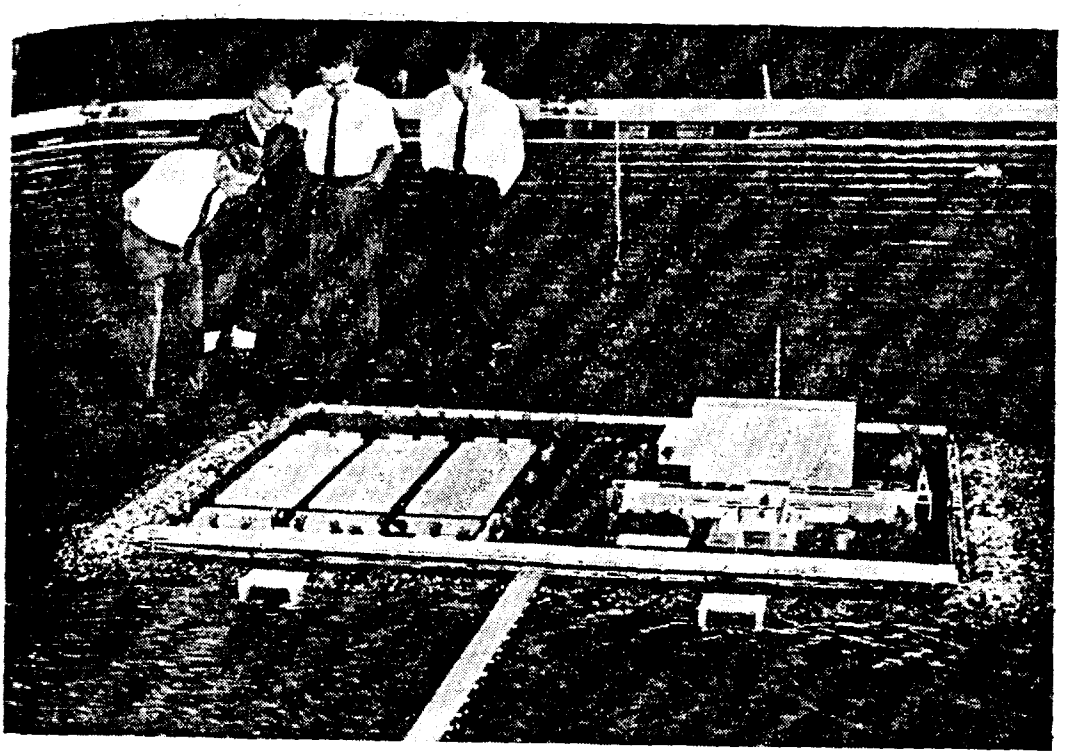
AEC assistance. Subsequent to hearings before the Joint Committee on Atomic Energy on September 14, Congress authorized the AEC to participate in the cooperative project and to provide $15 million of assistance to the MWD pertaining to the dual-purpose aspects of the project; the siting and related design of the complex; the coupling of the desalting plant with the back-pressure turbine and the nuclear power plants; and to other aspects of the project pertaining to the interrelationship of nuclear power and desalting. The President signed the authorizing legislation on October 13.

Expandable desalting capacity. The project contemplates two light water reactors with a combined net electrical generating capacity of about 1,600 Mwe and, initially, a desalting unit capable of producing 50 million gallons per day (mgd) of fresh water from the sea. If operation of the first desalting unit is satisfactory, MWD would then expect to add additional desalting capacity of 100 mgd. Two private utilities (the Southern California Edison Co. and the San



Wave Motion Studies. Preliminary work for the island siting in connection with world's first large-scale nuclear power and desalting plant has included studies of how Pacific Ocean waves will affect the proposed man-made island location off the Orange County, Calif., coast. An 8 by 10 foot model of the island was placed in a shallow 90 by 130 foot tank in the California Institute of Technology hydraulics and coastal engineering laboratory at Azusa. The ocean bottom, a 3-mile section of the coast line, and the 40-acre island were modeled at 1/150 of actual size. The water would actually be only 38 feet deep at high tide in front of the proposed island. The 4-month study provided a basis for the design of a safe and economical wave defense for the project so that the island will be able to withstand southern California's strongest wave actions.

Diego Gas & Electric Co.) and one public utility (the Los Angeles Department of Water and Power) will participate in the project. They will furnish, own, and operate two complete nuclear powerplants—the two utilities will jointly own one plant; the other will belong to the City of Los Angeles—which, in addition to supplying the power needs of the utilities, would have sufficient capacity to meet the energy demands of the desalting plant.

Joint board established. Negotiations of the definitive contracts between MWD and the Federal Government, and between MWD and the electric utilities, are underway. A project management board consisting of a representative of each of the participating organizations has been established to provide policy guidance and overall management of the technical aspects of the project. Additional investigations of the site and the plant design are proceeding.

Oak Ridge National Laboratory Analyses

The general technical analyses and evaluations of the application of nuclear energy to desalting and other process operations are continuing at Oak Ridge National Laboratory. Promising techniques for coupling nuclear powerplant systems with desalting plant systems are being investigated, and detailed design and economic data are being developed.

During 1966, computer codes for the design and optimization of large nuclear desalting plants were developed, several methods for providing flexibility in water and power production by dual-purpose plants were analyzed, studies of the practicability of reactor extrapolations to 10,000 thermal megawatt single-unit sizes were completed, and the siting problems of large reactor systems were investigated.

Specific Application Studies

New York–New Jersey. An interdepartmental Federal task force, appointed by the President to assess the potential use of large nuclear desalting facilities to help "drought proof" the northeast metropolitan area in the event of prolonged periods of below-average rainfall, issued a final report in June 1966. The report concluded that while large-scale nuclear desalting plants appeared to be technically feasible and have reasonable economics, use of Hudson River water, with proper treatment, appeared to be a more attractive immediate solution to augmenting the area's water supply. However, the report further concluded that in consideration of the potential advancements both in desalting and nuclear technology, large nuclear desalting plants might well be attractive alternatives during the next 10–20 years for this application.

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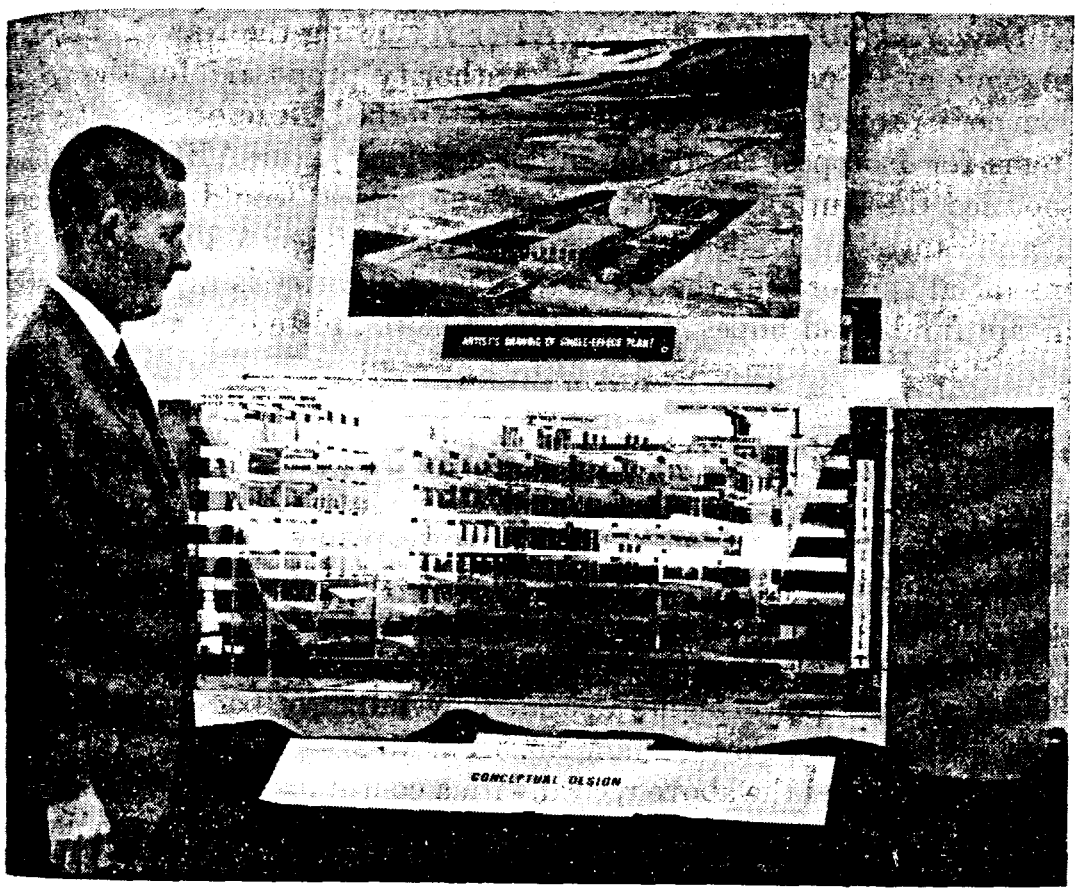
Israel. A detailed engineering study, undertaken by Kaiser Engineers in association with Catalytic Construction Co. under the auspices of the Governments of the United States and Israel, to investigate a dual-purpose plant to serve the water and power needs of Israel was completed and a final report issued in January 1966. The plant recommended by this study would use a light water reactor to produce 200,000 kilowatts of saleable electric power and 100 mgd of desalted water from the Mediterranean Sea. The total estimated capital cost of the dual-purpose plant would be about $200 million, and the cost of water at the plant boundary is 29, 43, and 67 cents per thousand gallons for fixed charge rates of 5, 7, and 10 percent, respectively. These costs are based on a fixed value of 5.3 mills per kilowatt-hour for the saleable electric power. (See Chapter 12—International Cooperation Activities for other details.)



Future Freshwater Source. Photo shows a scale model of a 250-million-gallon-per-day multi-stage flash distillation plant for converting seawater to freshwater as part of a nuclear-powered dual purpose plant which could also generate 675 megawatts of electricity. This conceptual design was prepared at the Oak Ridge Gaseous Diffusion Plant and Oak Ridge National Laboratory for the Department of Interior's Office of Saline Water (OSW). The AEC and OSW are conducting cooperative studies toward substantially reducing the cost of purifying water through the use of large-scale nuclear desalting plants.

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Mexico. Technical representatives from the United States and Mexico are presently studying the water and power needs of the Mexican states of Sonora and Baja California and the states of Arizona and California in the United States, and are assessing the feasibility of using large dual-purpose power-water plants to meet those needs. (See also Chapter 12—International Cooperation.)

Other foreign studies. During the year, the AEC: (*a*) held discussions with representatives of Tunisia, Italy, Lebanon, and other nations interested in nuclear desalting; (*b*) participated with representatives of the Government of Greece in making a preliminary study of the feasibility of desalting in combination with an electric powerplant as a means of providing needed additional supplies of freshwater for the Athens area; (*c*) demonstrated a continued willingness to share its technology for desalting application with its friends abroad; and (*d*) continued to implement its exchange agreement with the Soviet Union regarding the exchange of nuclear desalting technology.

New York SURFSIDE project. After reviewing the New York State Atomic and Space Development Authority proposal [7] for the triple-purpose project SURFSIDE (Small Unified Reactor Facility Systems for Isotopes, Desalting, and Electricity), the AEC in January notified the Authority that, because the project would not contribute significantly to the desalting program, it had decided not to provide financial support for the project. The Authority is proceeding with State funds, and hopes to have the plant completed by mid-1969.

MILITARY POWERPLANTS

Four military land-based nuclear powerplants continued in operation throughout the year: (*a*) the Portable Medium Power Plant No. 1 at Sundance, Wyo., which on August 8, 1966, recorded 3,355.5 hours (amost 140 days) of continuous power operation—a new high for land-based nuclear powerplants operated by military personnel; (*b*) the Portable Medium Power Plant No. 3A at McMurdo Sound, Antarctica, which surpassed the above record with a continuous power run of 3,390 hours and 24 minutes ending on October 8; (*c*) the Stationary Medium Power Plant No. 1 at Fort Belvoir, Va., which continued to be operated primarily for the training of military personnel who are to operate nuclear reactors, but, as an adjunct to its training mission, also supplied the Fort Belvoir military installation with electricity for use in normal post operations; and (*d*) the Stationary Medium Power Plant No. 1A—patterned after the prototype plant at Fort Belvoir—which supplied electrical power as well as steam for space heat to the Army's Arctic Test Center at Fort Greely, Alaska.

[7] See pp. 132–133, "Annual Report to Congress for 1965."

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Research and Development

Nil-ductility (embrittlement) tests. The Idaho Nuclear Corp., which took over certain NRTS operations, continued the series of tests (begun by Phillips Petroleum Co., in 1965) on the irradiated Portable Medium Power Plant No. 2A (PM–2A) reactor pressure vessel to determine the extent of radiation-induced embrittlement which an actual reactor vessel has undergone. (The PM–2A supplied power to the Camp Century, Greenland, research center for almost three years before being dismantled in 1963 when the center was closed.) In the tests, a defect of varying depth and length is intentionally machined into a section of the pressure vessel. The vessel is then subjected to a variety of progressively more severe internal pressure and temperature conditions to observe the exact temperature-pressure combination at which, and the exact manner in which, the vessel will fail. Data obtained from these tests will be useful in establishing operating limits to prevent brittle fractures of pressure vessels. During the year, a defect 1¾ inches deep and 11 inches long was tested at 5,250 pounds per square inch and -20° F. without vessel failure. Eventually, however, the vessel failed on November 18 at 4,475 pounds per square inch and –20° F. The failure came after an acid bath formed very sharp cracks at the base of the 1¾-inch deep notch.

Plant Improvement Program

The testing and operating experience of the portable medium (PM) powerplants have indicated that certain of the systems and components of these plants need to be improved to increase their reliability, maintainability, and lifetime. Consequently, the AEC is designing, procuring, and testing new and improved components for these plants. The status of the various areas looked at to date is as follows:

Actuator improvement program. Upon completion of an investigation conducted by Westinghouse (Pittsburgh, Pa.), the Navy and Air Force determined that a new actuator design at that time was unwarranted since modifications made by the Department of Defense (DOD) to its respective plants were resulting in improved operation. The area of primary concern to the Navy and Air Force was that of the actuator power supplies and control equipment. A request for proposals involving the design, fabrication, installation at the PM–1, and test of an actuator control console was sent to 19 industrial firms on October 14. Bids submitted are currently being reviewed.

Improvement of reactor instrumentation. Based upon the results of its studies in the area of reactor instrumentation—especially on those areas concerned with safety—the Bailey Meter Corp., Wickliffe, Ohio,

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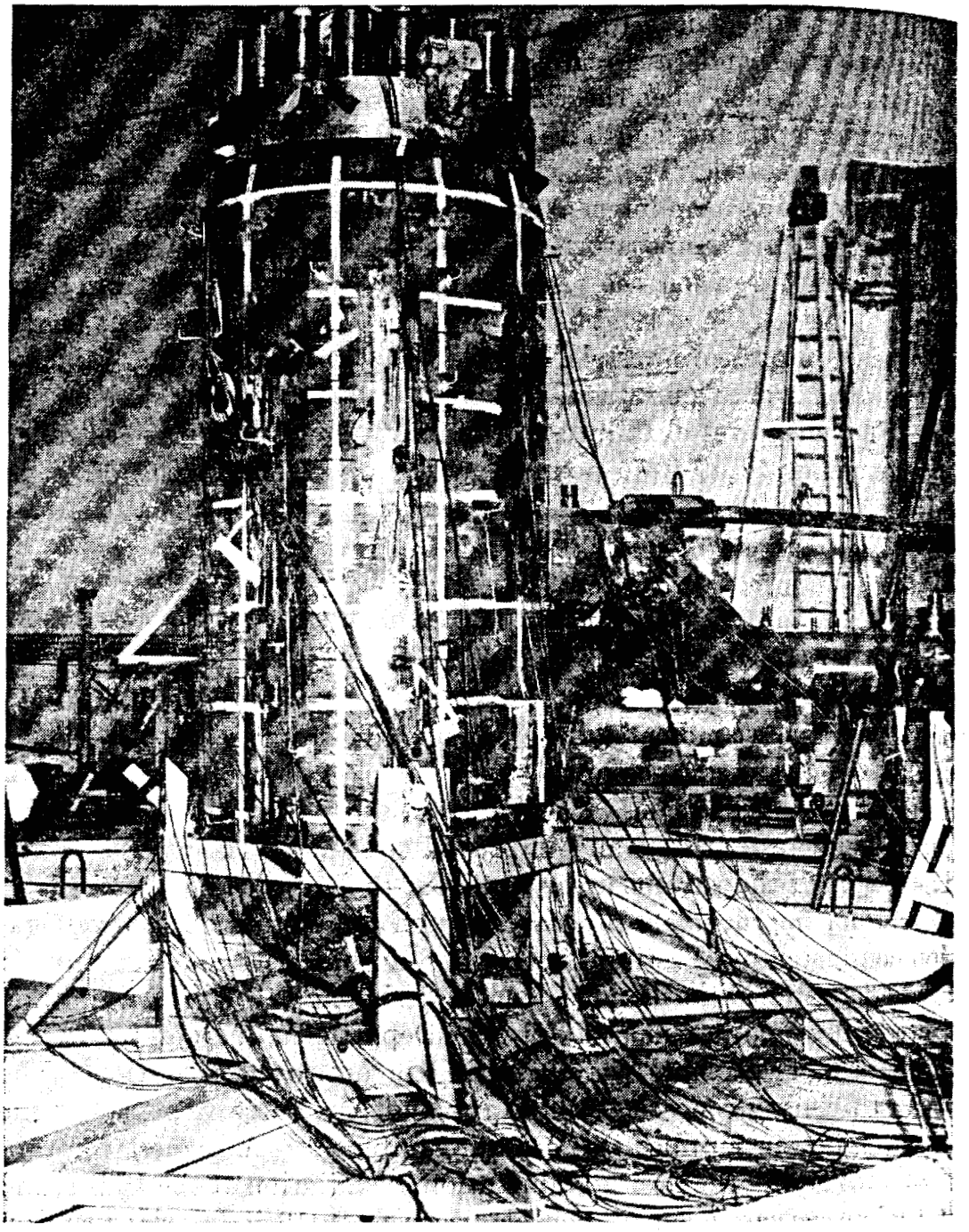
recommended improvements which should be accomplished in the PM–1 and the PM–3. To implement these recommendations, the AEC has made funds available to the Navy, to which the Navy plans to add funds of its own, to procure a completely new instrumentation system for the PM–3A. The AEC funds will be used for design, development, and testing of this system. It is also anticipated that the AEC



Embrittlement Tests. Photo shows the Portable Medium Power Plant PM–2A pressure vessel, instrumented for embrittlement testing, at the National Reactor Testing Station. The Idaho Nuclear Corp. conducted a series of tests for the AEC to determine the extent of radiation-induced embrittlement which an actual reactor vessel has undergone. The PM–2A served as the power supply for almost three years at Camp Century, Greenland, before being dismantled in 1963.

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will contract for an updating of the PM–1 system in those areas affecting safety and reliability.

Hydrogen generation reduction. As a consequence of studies carried out by Nuclear Utility Services, Washington, D.C., modifications were made to the PM–3A which were effective in eliminating the problem of hydrogen generation in the plant. These modifications can be incorporated into any military plants procured in the future.

Radioactive waste disposal system. The Atomics Division of American Machine and Foundry (York, Pa.) has fabricated and installed a new radioactive waste disposal system at the PM–1. Acceptance testing of the unit, delayed by the need to replace an annunciator panel which failed, is now in progress.

Tritium evaluation. A report prepared by Battelle Memorial Institute, Columbus, Ohio, recommending means of processing the tritiated water experienced at the PM–1 and the PM–3A was finalized late in the year. The report concluded that the tritium is produced by ternary fission with subsequent diffusion through the fuel element cladding. Recommended methods of handling the tritium, which are being evaluated, include: (*a*) dilution of primary waste with on-site disposal; (*b*) collection of primary leakage with off-site disposal; (*c*) return of primary leakage to system with annual coolant drain and disposal off-site; and (*d*) isotopic concentration of primary leakage with off-site disposal of concentrate and return to system of effluent.

Design of low-enriched replacement core. Procurement specifications and final design reports for a low-enriched PM replacement core have been submitted to the Government by Hittman Associates of Baltimore, Md. Proposals were requested in November from industry to fabricate this core. The award of a contract for the fabrication of the core will be contingent upon the review and acceptance of the design by the Government. The AEC is attempting to meet a December 1967 delivery of the first core to the PM–3A at McMurdo Sound.

Advanced technology studies. The Army has undertaken a series of studies of advanced technology and advanced plant concepts leading to nuclear power units inexpensive to build and requiring few or no operators. If the concepts appear to be worth developing, the DOD would be expected to recommend that the AEC undertake their development. Contracts have been awarded to Battelle Memorial Institute for studying the performance of thermoelectric elements of very high power densities; Hittman Associates for the design of an irradiation test of a heat pipe-thermionic converter combination; Martin Co. (Baltimore, Md.) for a rodless uranium zirconium hydride core and a thermoelectric power conversion system; Nuclear Utility Services for a rodless load-following boiling water reactor; and General Electric (Schenectady, N.Y.) for a study of thermionic reactor concepts. Contracts for other studies are being negotiated.

Testing of Mobile High-Power Plant

Early in April, a floating nuclear barge, the *Lt. General Samuel D. Sturgis*, which will contain a 10 Mwe (net) nuclear powerplant—the MH-1A (Mobile High Powerplant No. 1A)—was towed from the Alabama Shipbuilding and Drydock Company's Mobile, Ala., shipyard to a testing site in the Potomac River at Fort Belvoir, Va. This barge, which has no propulsion system, is capable of supplying a community of from 10,000 to 20,000 persons with electrical power should a disaster knock out ground stations. After a period of operational testing and inspection at Fort Belvoir, the *Sturgis* will be turned over to the Army, ready to be towed on short notice to any offshore anchorage where emergency power is needed. Transfer of the MH-1A to the Army is scheduled for the early part of 1967.

SPECIALIZED APPLICATIONS

The operation of the N.S. *Savannah* has demonstrated the practicality of nuclear-propelled merchant ships, although there are no current plans to build more nuclear vessels. During the year, the AEC took steps toward developing low-power reactors—of less than 2,000 kilowatts capacity—for specialized applications. The phase-out of the plutonium utilization program has begun as industry has shown an interest in carrying on the effort to develop the technology for safe and economical recycling of plutonium in thermal reactors.

MARITIME PROPULSION PLANTS

At present, the AEC's civilian maritime reactors program is planned to encompass basic studies for improved merchant ship reactor plants. Although the AEC is confident that nuclear propulsion could play a future role in propelling the Nation's merchant marine, it must first determine, in coordination with the Department of Commerce's Maritime Administration and in cooperation with interested segments of industry, overall future maritime needs. To this end, the AEC is participating in studies to determine the scope and direction of a program leading toward the development of economic nuclear propulsion plants for civilian maritime applications.

The world's first nuclear-powered cargo ship, the N.S. *Savannah*, completed her first year of commercial operation in the service of First Atomic Ship Transport, Inc. on June 30, 1966.

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LOW-POWER SYSTEMS

For several years, the AEC has been actively engaged in developing, demonstrating, and promoting the use of nuclear systems to provide low-level electrical power for use in a variety of specialized outer space, earth-surface, sea-surface, and undersea applications. Some of these systems, several of which are already in operation, use as their energy source the heat generated when radioisotopes decay, while others, under development, will use the heat produced by atomic fissioning in a small nuclear reactor. The reactor units for space applications are discussed in Chapter 8—Space Nuclear Systems. Isotopic systems for space, terrestrial, oceanographic, and other specialized applications are summarized in Chapter 9—Isotopic Heat and Power Applications.

Terrestrial Low-Power Reactors

Low-power nuclear reactors—initially covering the 100 to 2,000 electrical kilowatt range—are envisioned as being capable of providing power needed for a variety of remote terrestrial, marine surface, and deepsea applications. The initial step in the terrestrial low-power reactor (TLPR) program was taken late in 1966 with the establishment, at the Oak Ridge National Laboratory, of a TLPR program office. This office will assist AEC Headquarters staff in the detailed planning, coordination, and evaluation of the activities of the TLPR program to be carried out by the AEC's laboratories and industrial contractors.

The initial phase of the TLPR program, now in progress, is devoted to application studies to determine the characteristics required of nuclear reactor powerplants in terrestrial, marine surface, and deepsea applications—the specific power level required, size and weight requirements, special design features needed to withstand their potential operating environments—and to determine the additional technology that must be developed to bring such systems into being.

PLUTONIUM UTILIZATION

The objective of the plutonium utilization program has been to develop the technology required for the safe, economical recycling of plutonium in thermal reactors. Although much has been accomplished under this broadly-based technology program, a great deal remains to be accomplished before the objectives are completely met. A major effort is required to translate the information presently at hand and still being developed to practical application in operating power reactors.

Phase-Out Started

In view of the present commercial status of light water reactors and the need for the AEC to focus its available resources on the development of more advanced reactor concepts, the phase-out of the AEC-sponsored plutonium utilization program has begun. This phase-out is to be completed in the next several years. It is expected that the nuclear industry will assume an ever-increasing responsibility for the necessary continuation and completion of the work needed to make commercial plutonium recycling a reality. The AEC expects to work closely with industry during the period of transfer of the effort from the laboratory and test reactor environment to the commercial reactor environment to insure that the most essential work is accomplished and that a smooth transition is made.

1966 Progress

High-power-density core. The Plutonium Recycle Test Reactor (PRTR) at the Pacific Northwest Laboratory was shut down during most of 1966 to permit recovery from the failure of an in-reactor fuel testing loop which occurred in September 1965, and to prepare for a high-power-density core experiment. Critical experiments with the new core in the PRTR began in September 1966; power operation is scheduled to begin early in 1967. The objective of the experiment, which will continue for two to three years, is to develop physics and material performance information to determine if any limitations peculiar to mixed plutonium-uranium oxide fuels might exist.

Fuel lattices. A significant effort continued on the generation of basic and engineering physics data required to develop and substantiate calculation techniques. Measurements were made on subcritical and critical fuel lattice assemblies moderated with both heavy and light water. This work was performed at the Pacific Northwest Laboratory, as well as at Westinghouse and General Electric facilities, using AEC-owned fuel rods.

EBWR experiments. The work with the Experimental Boiling Water Reactor (EBWR) at Argonne National Laboratory continued through the year using a partial core loading of plutonium-enriched fuel. The critical experiments which began in the EBWR in September 1965 were completed, and power operation began during October 1966. At the end of the year, the EBWR was operating at a nominal 40 Mwt power level.

AEC-Euratom project. The Saxton reactor plutonium recycle program, an AEC-Euratom sponsored effort being carried out by Westinghouse in the Saxton Nuclear Experimental Corp.'s reactor in Saxton, Pa., continued throughout the year. Following criticality in

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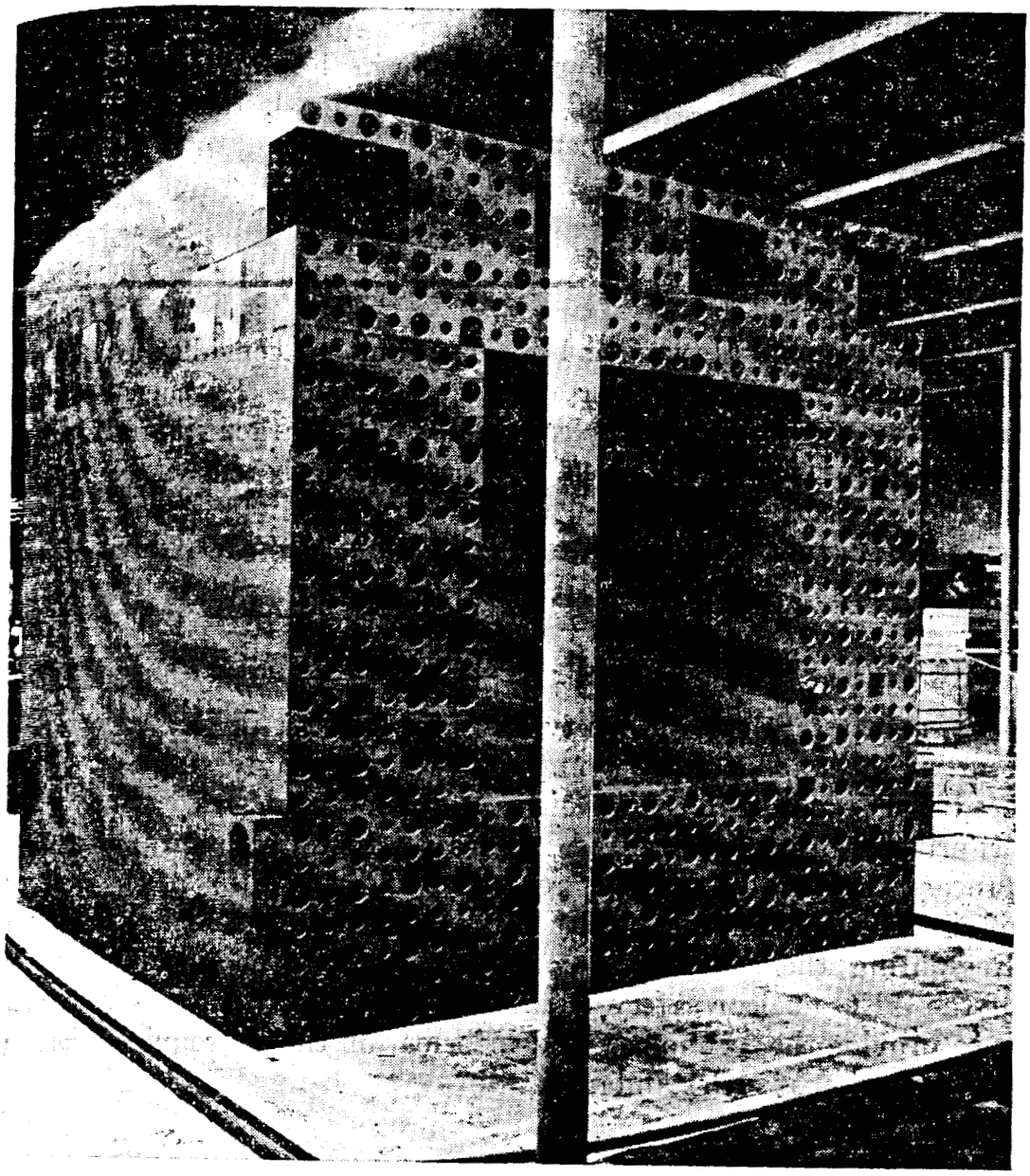
December 1965, the Saxton reactor reached full power (23.5 Mwt) in January 1966. Operation at this power level during several operating periods through the year resulted in the plutonium-enriched portion of the core reaching a peak exposure of 19,500 megawatt-days per ton (MWD/T); the average exposure was 10,500 MWD/T.



High Temperature Lattice Test Reactor. Photo shows the graphite moderator for the High Temperature Lattice Test Reactor (HTLTR) assembled in mockup form just prior to installation in the HTLTR building at Pacific Northwest Laboratory The graphite is expected to be in place and fuel loading started in early 1967. The HTLTR will provide a critical facility to obtain nuclear data for high temperature reactor systems. This research will contribute fundamental data for high temperature reactor physics studies and nuclear engineering data to the support of design and safety analysis of high temperature power reactors. The design and construction of advanced reactor facilities for research and irradiation testing is carried on under the AEC's general reactor technology research and development program.

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Industry interest. Concrete evidence of industry interest and determination to participate more actively in the development of plutonium recycle technology developed during 1966. Prime examples are the efforts being jointly sponsored by the Edison Electric Institute with Westinghouse and General Electric. These programs are intended to develop the specific information required to permit the use of plutonium-enriched fuel in commercial pressurized and boiling light water reactors. Direct AEC participation in these efforts is expected to be minimal; it will probably be limited to the lease or loan of plutonium for specific experiments.

NUCLEAR SAFETY

Safety is, and always has been, a paramount consideration in the development and exploitation of nuclear energy. Furthermore, the increasing growth of the nuclear industry, the larger sizes of central station plants being designed and built, and the incentive for industry to locate these plants closer to metropolitan areas have all served to sharpen the focus of attention on nuclear safety during 1966.

PROGRAM DEVELOPMENTS

It is clear that reactor safety has its roots in a properly designed, constructed, and operated plant. This has strongly emphasized the need for establishing and enforcing consistent and appropriate criteria, guides, standards, and codes for materials, equipment, and processes associated with a reactor plant (see also "Development of Safety Standards for Reactors" in Chapter 1—Licensing and Regulating the Atom). Accordingly, one of the basic objectives of the AEC nuclear safety research, development, and test program is to provide the technology and information that is required for the promulgation of such standards.

New Offices Established

To assist in planning for a nuclear safety research and development program, *i.e.*, identifying the needs for research and development and establishing the objectives to be achieved in meeting these needs, and further to develop the experiments and tests that must be carried out to accomplish these objectives, safety program offices for the liquid metal-cooled fast breeder (LMFBR), water, and gas-cooled reactor systems have been established. For the LMFBR system the safety section is an integral part of the LMFBR Program Office operating

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under the Argonne National Laboratory. The water reactor safety program has been established under the Phillips Petroleum Co. operating through the AEC's Idaho Operations Office, while the gas-cooled safety program planning is being carried out by a group at the Oak Ridge National Laboratory. These groups, which assist the AEC Headquarters staff in the detailed planning and coordination required for maximum program effectiveness, are not associated with direct research and development program operations. Initial efforts of these 3 groups are well underway, but it should be noted that their detailed activities vary, not only because of differences in cycles, but also because of differences in status of technology associated with these systems.

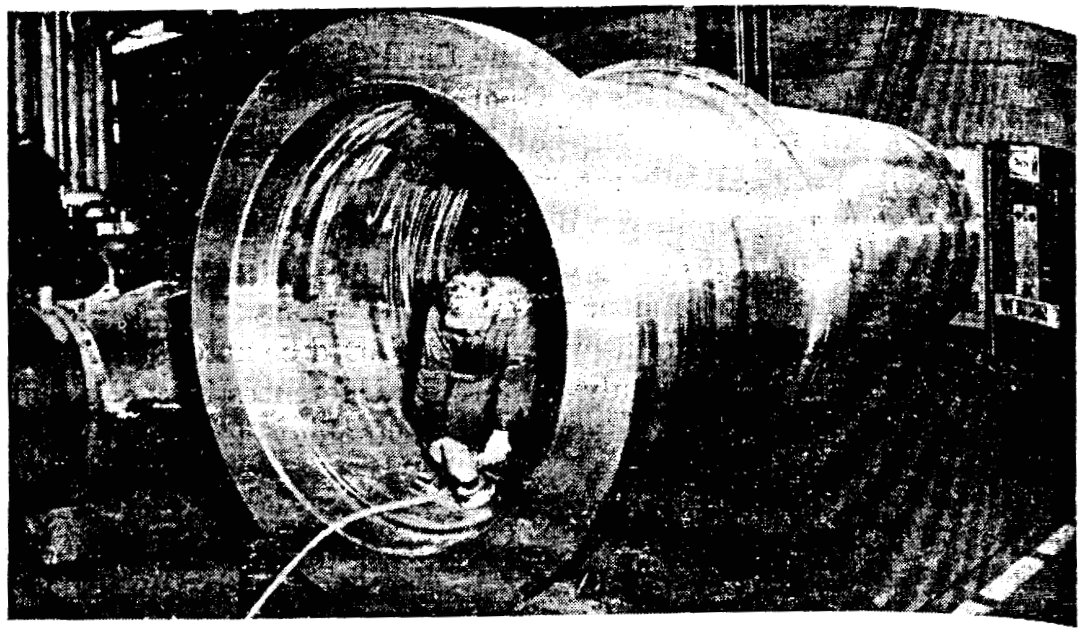
Work Being Augmented

The technological developments noted previously in this chapter are reflected in the dynamic nature of the planning effort for the safety research and development program and have resulted in a significant augmentation and reorientation of the existing program. Examples of this have been the increased emphasis on the performance and reliability of engineered safeguards systems, the initiation of research and development in such areas as aseismic design, and the exploration of in-plant tests of safety systems to provide quantitative engineering information on their performance and reliability. In the latter regard, it is recognized that important high-risk tests cannot be carried out in existing operating central station nuclear plants, and highlights the importance of such new facilities as LOFT (Loss of Fluid Test), PBF (Power Burst Facility), and CSE (Containment Systems Experiment) for such tests.

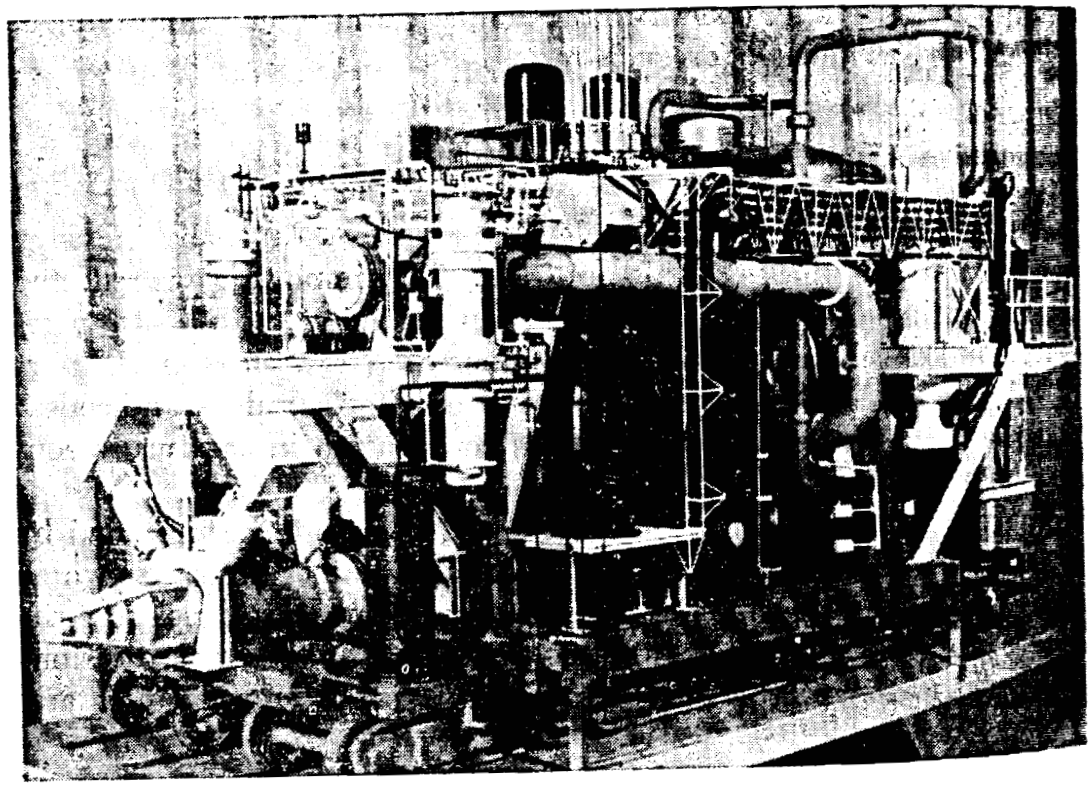
Cooperative Efforts

Also important is the vital role that must be played by industry in essentially all phases of this program. This importance is reflected in the continued industrial participation in major nuclear safety research and development projects; the increased awareness on the part of industry of the necessity for appropriate criteria, guides, and codes; and the need for expanded industrial cooperation in the future conduct of the program.

The program has also profited through the guidance provided by the in-house Steering Committee on Reactor Safety Research which was established in 1965 and is comprised of representatives from the AEC's regulatory staff as well as from the operational divisions concerned with reactor development and technology, biology and



LOFT Vessel. The 80-ton, 22 foot 7 inch-high, forged steel pressure vessel for the Loss of Fluid Test (LOFT) facility is shown *above* during fabrication by P. F. Avery Co., Billerica, Mass. The scale model *below* shows how the LOFT reactor safety test equipment will be mounted on a double-width flatcar, or dolly, which can be pulled by a shielded locomotive over quadruple rails to an existing hot shop nearby for post-test analysis at the National Reactor Testing Station (NRTS). The large plug at the front of the model represents a pipe rupture device for deliberately initiating the maximum credible (though highly improbable) accident postulated for a pressurized water reactor, namely, rupturing of a major coolant line. Top center are the reactor control rod drive mechanisms. A principal reason for building and operating LOFT is to evaluate the safety of water cooled power reactors by deliberately subjecting it to the damage caused by rupture of a major coolant pipe. LOFT is part of the safety test engineering program conducted for the AEC by the Phillips Petroleum Co.



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medicine, and operational safety. The committee has been active in assisting in planning and coordination activities, encouraging better dissemination and exchange of reactor safety information, and in reviewing plans and programs for specific proposed projects to augment the existing program and for the development of safety criteria, standards, and codes.

Supplemental Report

The details of the nuclear safety research and development program, as well as work in progress under the AEC's general reactor technology research and development program—which has the continuing long-range goal of generating data and technology basic to the development of advanced reactor concepts and systems, and to the improvement of existing reactor concepts, processes, and systems—are described more fully in the supplemental report, "Fundamental Nuclear Energy Research—1966."[8]

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

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Chapter 8

SPACE NUCLEAR SYSTEMS

All AEC space-related nuclear research and development activities are conducted in close collaboration with the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD).

SPACE NUCLEAR ROCKET PROPULSION

The nuclear-rocket program is a joint AEC/NASA endeavor aimed at providing the technology and systems for conducting heavy payload, high-energy missions in space. Analyses have indicated that a wide variety of such missions can be accomplished with the advanced propulsion efficiency provided by nuclear rockets.

An important result of program mission studies has been the definition of a single NERVA (Nuclear Engine for Rocket Vehicle Application) engine that could be utilized to perform all of the major missions for which nuclear rockets would offer significant advantages over chemical rockets. Mission analyses indicate that this engine could be incorporated into a versatile nuclear rocket propulsion module which could be used for all of the major nuclear rocket missions. The module, with a diameter of 33 feet, could be installed as a third stage on the Saturn V Apollo booster rocket to improve its performance capabilities for lunar and deep-space missions. Furthermore, depending on the thrust level required for the mission, the module could be used singly or in clusters in a variety of space missions, including manned missions to Mars and Venus.

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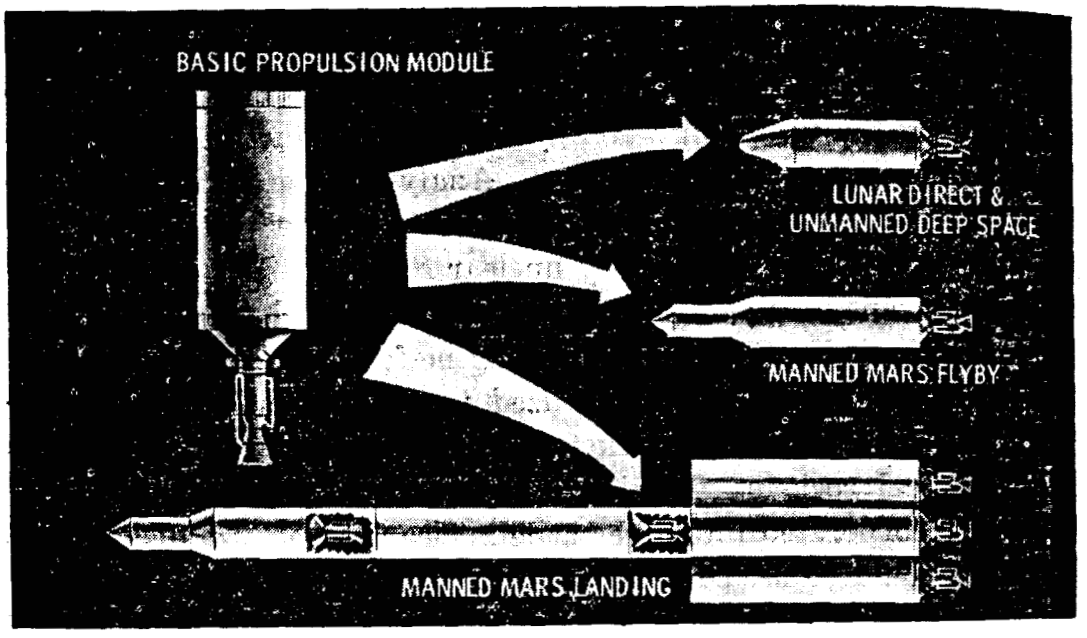
GRAPHITE REACTORS AND ENGINE SYSTEMS

The primary emphasis in the nuclear rocket program has been, and will continue to be in the foreseeable future, on graphite reactors and engine systems. Graphite is the fuel element structural material selected because of its excellent structural properties at high temperature and excellent nuclear characteristics. During 1966, emphasis was directed toward: (*a*) continued establishment of graphite reactor technology to a capability of operating at full design conditions for about 60 minutes, using a 1,100 megawatt thermal reactor; (*b*) the establishment of engine system technology based on the 1,100 megawatt reactor technology; and (*c*) the advancement of graphite reactor technology to provide the basis for the extension of reactor performance beyond near-term goals.

The 1,100 megawatt reactor and engine system technology work is being performed under the NERVA project heading and is an outgrowth of the Kiwi reactor technology developed previously (1959–1964) by the Los Alamos Scientific Laboratory (LASL). The establishment of advanced graphite reactor technology is being carried out at LASL under the Phoebus project. This work has the objective of



Nuclear Rocket Propulsion Module. The concept for the nuclear rocket propulsion system is that liquid hydrogen will be passed through a compact engine where it will be heated by the fission energy in a nuclear reactor and then expelled through the engine jet nozzle to provide the thrust for propulsion of space vehicles. The drawings show the versatility of the basic nuclear rocket propulsion module (at *top left*)—a 33-foot diameter hydrogen storage tank and the NERVA engine. The various applications shown use the same basic propulsion module, either as a single unit or in clusters, and would require only one basic set of hardware.

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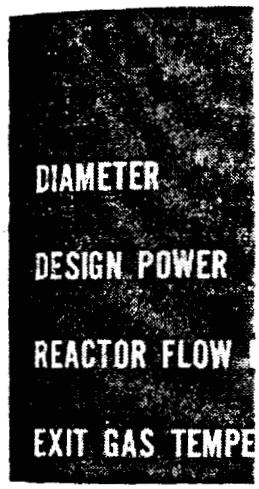

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providing a reactor of approximately 5,000 megawatts, called Phoebus-2, capable of operating at higher exit gas temperature (which provides higher specific impulse) and greater power density.[1] The technology stemming from the investigation of the Phoebus-2 reactor will be applied directly to the development of a flight-type reactor of similar size for the large NERVA engine with a thrust rating between 200 and 250 thousand pounds. At present, Kiwi-sized reactors, called Phoebus-1, incorporating a variety of experiments are being tested to explore some of the operating characteristics and design features planned for the larger Phoebus-2.

NERVA Reactors and Engine Systems

Significant advancements were made toward achieving the objective of developing a reactor capable of operating at a nominal power of 1,100 megawatts for 60 minutes. These advancements were demonstrated in tests of the nation's first nuclear rocket engine—a "breadboard" engine—and tests of the NRX–A5 reactor. Called the NRX/EST (NERVA Reactor Experiment/Engine System Test), the "breadboard" engine system included all principal components and essentially the same system characteristics as would be found in a flight engine, but they were not arranged in an actual flight engine configuration.

	KIWI/NRX	PHOEBUS-1	PHOEBUS-2
DIAMETER	35"	35"	55"
DESIGN POWER	1120 MW	1100-1500 MW	5000 MW
REACTOR FLOW RATE	70 LB/SEC	70-94 LB/SEC	285 LB/SEC
EXIT GAS TEMPERATURE	4100°R	4100-4500°R	4500-5000°R

Kiwi-Phoebus Comparison. The chart compares the nominal design values of the Kiwi/NRX, Phoebus-1, and Phoebus-2 reactors in the space nuclear rocket propulsion program. Five Kiwi-B and four NERVA–NRX-A reactors with the noted characteristics have been tested at power since the first Kiwi-B test in 1961. Three low-power (100 Mw) Kiwi-A reactors were tested in 1959 and 1960. The initial Phoebus-1 reactor test occurred in 1965 and the first Phoebus-2 reactor will be ready for testing late in 1967. (To convert temperature from degrees Rankine (°R) to degrees Fahrenheit, subtract 460.)

[1] Specific impulse is the amount of thrust produced when propellant is consumed at the rate of one pound per second; power density is the rate of fission heat generation per unit volume of the reactor core.

NRX/EST Tests

The NRX/EST consisted of a reactor (designated the NRX–A4) installed in an up-firing position on a modified reactor test car; a regeneratively-cooled, hot-bleed port nozzle; a close-coupled turbopump; and associated lines and valves. The turbopump (for pumping liquid hydrogen through the nuclear reactor) was driven by hot hydrogen bled from the regeneratively-cooled jet nozzle through the nozzle hot-bleed port. The objectives of the NRX/EST program were to: (*a*) demonstrate the feasibility of the hot-bleed cycle engine; (*b*) demonstrate "bootstrap" startups of the engine into the power region; and (*c*) secure data on engine operations, component interactions, and various control modes.

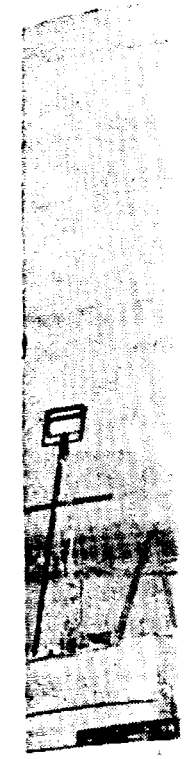
A summary of the experiments performed on the NRX/EST is given in Table 1. In the five days of power testing the NRX/EST accumulated a total of 110 minutes of power operation, including about 29 minutes at full power. These tests were conducted over a period of seven weeks during February and March at the Nuclear Rocket Development Station (NRDS) in Nevada.

Although the detailed analyses of test data from the engine experiments are still in progress, it has been established that: (*a*) the hot-bleed cycle of the engine system is stable and flexible over a wide range of operating conditions and can be throttled at full specific impulse; (*b*) several start techniques are feasible and a number of alternate control modes are available; and (*c*) multiple starts and many tests can be conducted on a single engine assembly.

An assessment of the behavior of the major engine components is given in Table 2. As the table indicates, difficulties were encountered with only one component—the turbine power control valve actuator, which exhibited excessive wear after the first and second tests and had to be replaced in both instances to permit the experiments to continue. The second replacement was an improved model which functioned well for the remainder of the test program.

NRX–A5 Reactor Tests

The NERVA NRX–A5 reactor was successfully operated at full power for 15½ minutes on June 8, and was then restarted and operated for an additional 14½ minutes on June 23. The tests were conducted under tightly controlled conditions to gain further understanding of reactor operation and life. The test data indicated that both experiments were conducted essentially as planned, and the objectives of the test series were met.



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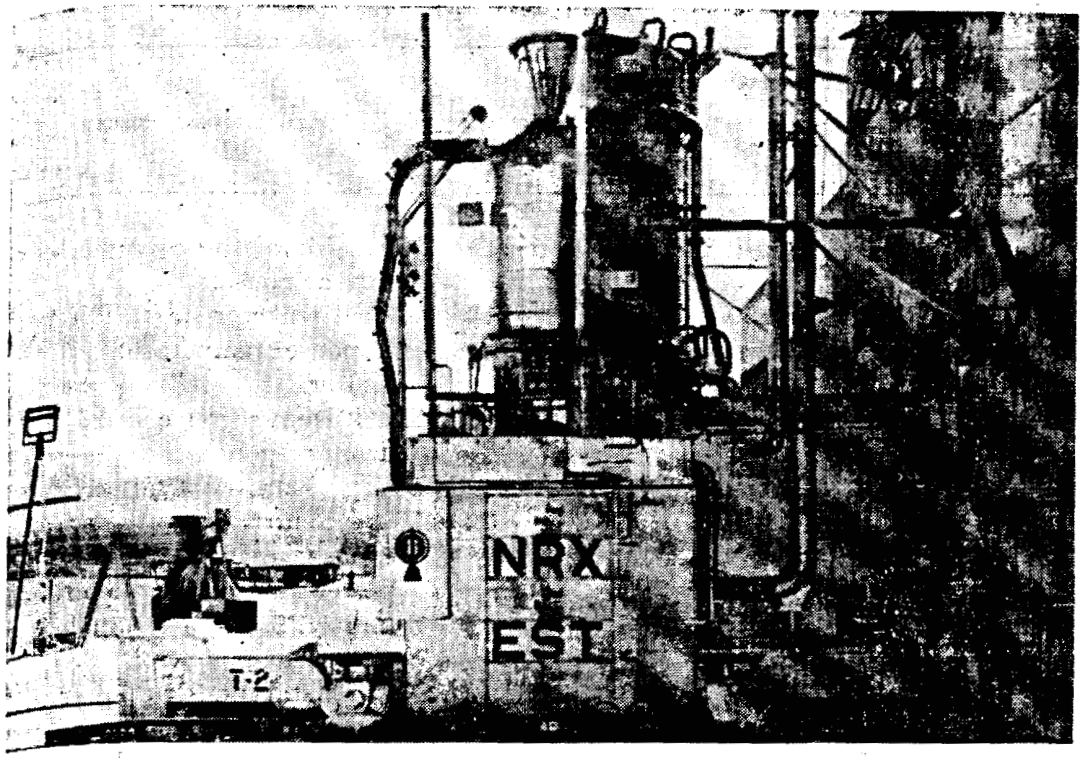

Engine System. Operation of the NRX/EST (NERVA Reactor Experiment/Engine System Test) through 10 startups during February and March advanced the development of a nuclear propulsion rocket engine considerably. The series of tests was the first to include all the major components and system characteristics of a flight-type engine although they were not in the ultimate configuration. Photo *above* shows the engine mounted on a modified test car with its jet nozzle pointing skyward. Drawing *below* compares the size of the nozzle of the 1,100 Mw NRX/EST with that planned for the 5,000 Mw Phoebus-2 reactor.

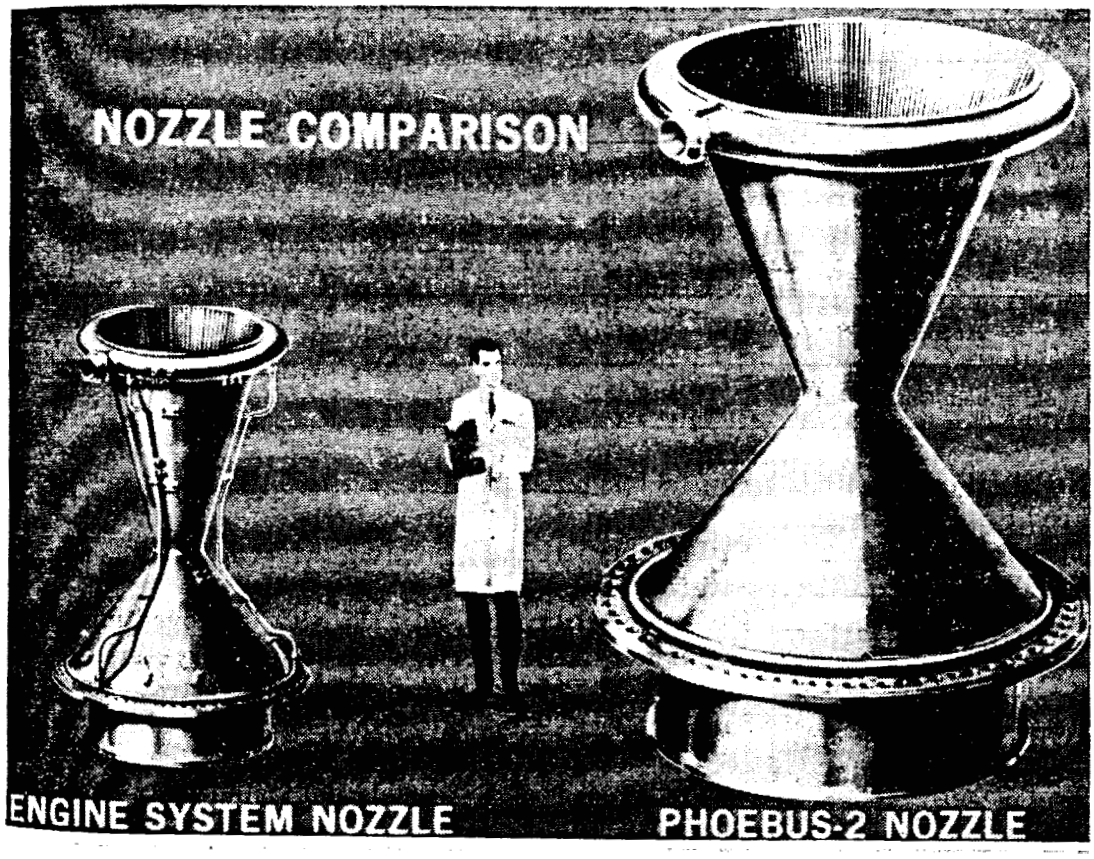

TABLE 1.—ENGINE SYSTEM TEST SUMMARY OF POWER TESTS

Date	Start	Maximum power (in megawatts)	Maximum temperature (in degrees Rankine)*	Duration (minutes)	Partial list of experiments
2/ 3/66	1	440	2, 550	11	Normal bootstrap; temperature response.
	2	250	2, 050	13	Chilled reflector start; TPCV** response; temperature limiter.
2/11/66	3	230	2, 000	9	Fixed drum start: control drum response.
	4	160	1, 450	--------	Low pressure start (abort).
	5	350	2, 590	22	Normal start; pressure response; temperature and power limiter; cross-loop limiter; 2,500° R. mapping; no-flux-loop control.
3/ 3/66	6	1, 090	4, 100	6	Normal start; design power and temperature.
	7	1, 040	3, 690	15	Normal start; 3,400° R. mapping; on-off controller.
3/16/66	8	170	1, 500	--------	Control positioning error led to automatic flow shutdown.
	9	1, 090	4, 090	18	Low pressure start; design point system response; 4,000° R. mapping.
3/25/66	10	1, 130	4, 175	16	Duration capability; design point system response.
Total--	------	--------	--------	110	(29 minutes at nominal full power)

*To convert to degrees Fahrenheit, subtract 460.
**Turbine Power Control Valve.

TABLE 2.—ENGINE SYSTEM TEST

ASSESSMENT OF BEHAVIOR OF MAJOR ENGINE COMPONENTS

Subsystem/Component	Behavior	Remarks
Nozzle/Bleed Port----	Satisfactory-------	
Feed System---------		
Turbopump----------	Satisfactory-------	
TPCV*----------	Satisfactory-------	
TPCV Actuator------	Excessive Wear---	Replaced with improved model.
Reactor----------	Satisfactory-------	Structure satisfactory—significant corrosion as expected.
Reactor Control Drum Actuator.	Satisfactory-------	Sluggish operation of one actuator due to hydraulic line freeze; insulation installed.

*Turbine Power Control Valve.

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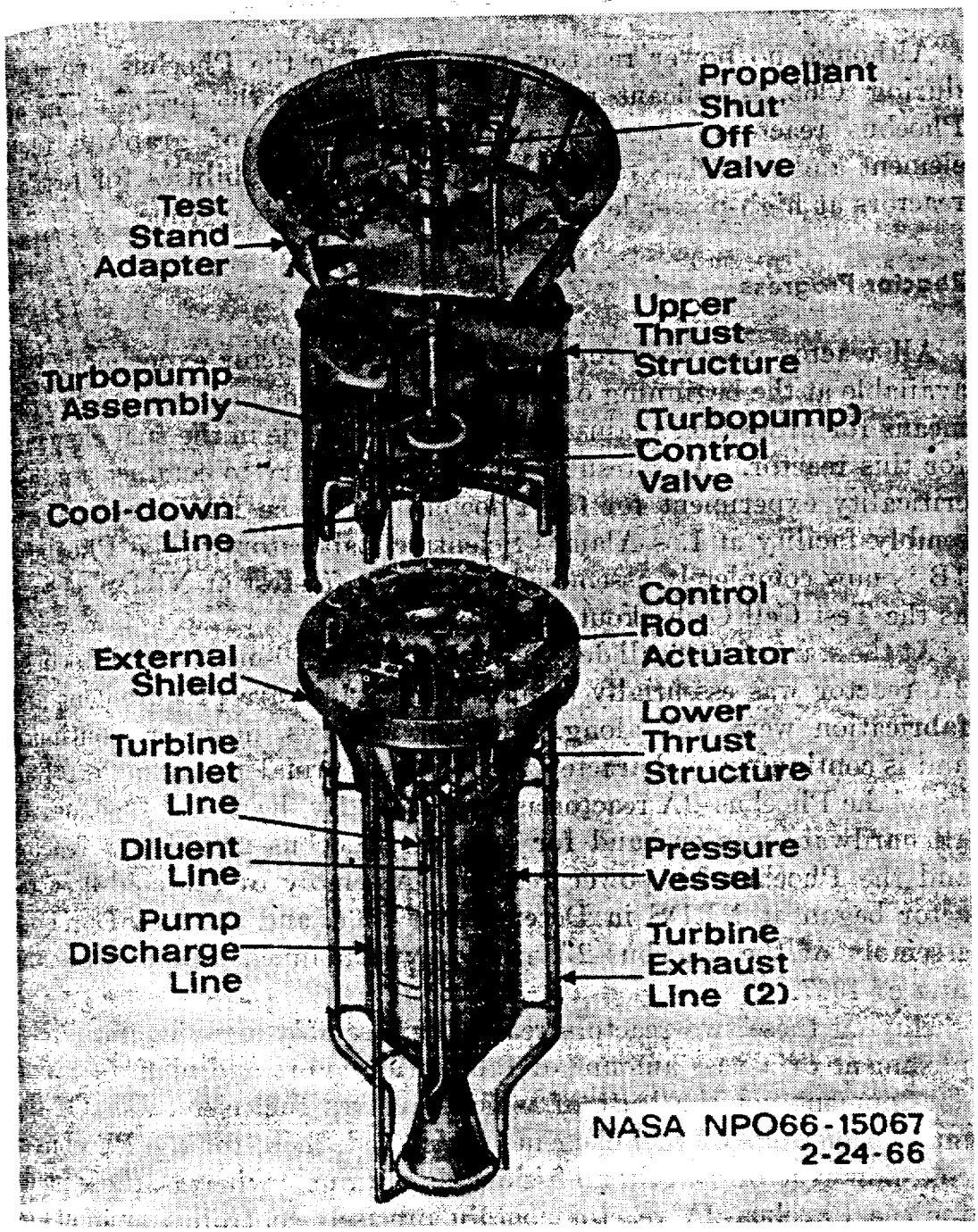
Experimental Engine Work

In addition to the testing of the NRX/EST "breadboard" engine and NRX–A5 power reactor, work was also continued during the year to provide the components and facilities to accomplish the next phase of the engine system technology program—building and testing ground experimental engines (XE's). These engines will closely resemble actual flight engines and will be tested in a down-firing test stand with



Ground Experimental Engine (XE). The exploded drawing shows the major components of the ground experimental engine (XE) which will be tested during the coming year under conditions simulating space flight. The engine can be divided into two modules or sections to facilitate maintenance should a malfunction occur.

the exhaust going into a partial vacuum, thus simulating operation in space. The primary objectives of the XE program will be to explore further the phenomena associated with engine startup, and to acquire additional data on system interactions and control. An additional and very important aspect of the XE program will be to gain experience with the complex engine-facility system.

Phoebus Reactor Technology

Although no power reactors were tested in the Phoebus program during 1966, significant progress was made in the preparation of Phoebus reactors for test, in the advancement of graphite fuel-element and materials technology, and in the capabilities for testing reactors at high-power levels and for long periods of time.

Reactor Progress

All reactor hardware for the Phoebus–1B reactor experiment was available at the beginning of 1966; however, some modifications to the means for protection against corrosion were made in the fuel elements for this reactor. As a result, it became necessary to conduct another criticality experiment for the Phoebus–1B in the KIVA critical assembly facility at Los Alamos Scientific Laboratory. The Phoebus–1B is now completely assembled and ready for test at NRDS as soon as the Test Cell C checkout is completed.

At the start of 1966, all design work on the 5,000-megawatt Phoebus–2A reactor was essentially complete and hardware procurement and fabrication were well along. Reactor analysis, however, continued and is continuing to characterize fully the thermal and structural limits of the Phoebus–2A reactor as designed. By the end of 1966, nearly all hardware was on-hand for both the Phoebus–2 cold-flow reactor and the Phoebus–2A power reactor. Assembly of the cold-flow reactor began at NRDS in December of 1966, and the LASL–KIVA assembly of the Phoebus–2A reactor was planned to commence the first of 1967.

Having these two reactors ready for assembly signifies the accomplishment of a vast amount of fabrication effort and manufacturing development not the least of which involves fuel elements. Of the many thousands of fuel elements fabricated, those for the Phoebus–2 cold-flow reactor contain no fissionable uranium; whereas, those made for the Phoebus–2A reactor contain precisely-controlled amounts of uranium according to their intended location in the reactor. (Three-fourths of the fuel elements were made at LASL; one-fourth of the total came from the Y–12 Plant at the Oak Ridge production complex.)

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The prescription for the quantities of uranium to be loaded in the fuel elements resulted from a long series of analytical studies and critical experiments aimed at solving the nuclear design problem of the Phoebus–2 reactor. During 1966, LASL assembled a realistic nuclear mockup of the Phoebus–2A reactor to measure, in detail, the radial dependence of the fission power and the perturbations caused by control drums, thermocouples, and experimental, nonstandard fuel elements.

A significant development in high-temperature materials technology occurred during 1966. LASL scientists in association with others have produced composite materials consisting of mixtures of graphite with metal carbides which are machineable and which have a high degree of corrosion resistance and sufficient high-temperature strength to serve as structural materials in a reactor core.

Instrumentation development often paces the advancement in technology particularly in an activity such as the nuclear rocket program which strives to reach the highest temperatures possible. Therefore, significant developments in high-temperature thermocouples for placement in the reactors were made during 1966. Several new types of exit-gas temperature sensors and new core-material thermocouples will be used in the Phoebus–1B. If these work well, the reactor developers will have an improved means to monitor the temperatures within the core during test operations.

Major effort at LASL was on extensive design and analytical work to support the modification of Test Cell C (discussed later) and to establish the techniques to assure survival of the reactor in case anything fails in the facility. Main emphasis has been on saving the reactor in the event of a cessation of hydrogen flow regardless of the cause. During December of 1966, final facility checkout tests showed that the modified Test Cell C has the required capability to meet emergency cool-down needs for the Phoebus–1 and Phoebus–2 reactors, and future NERVA reactors.

Reactor Test Support Components

Aerojet-General Corp., Sacramento, Calif., is developing the exhaust nozzle for the Phoebus-2. The Phoebus-2 nozzle design is similar to the U-tube nozzle used for NRX reactor testing, except that Hastelloy-X material is being used instead of stainless steel to accommodate the higher Phoebus-2 temperatures and heat fluxes.

Fabrication of the basic nozzle hardware and activation and demonstration of the nozzle test stand (using an uncooled nozzle) were completed during the year. The first cooled nozzle also was moved into the final stages of fabrication, and is nearing completion.

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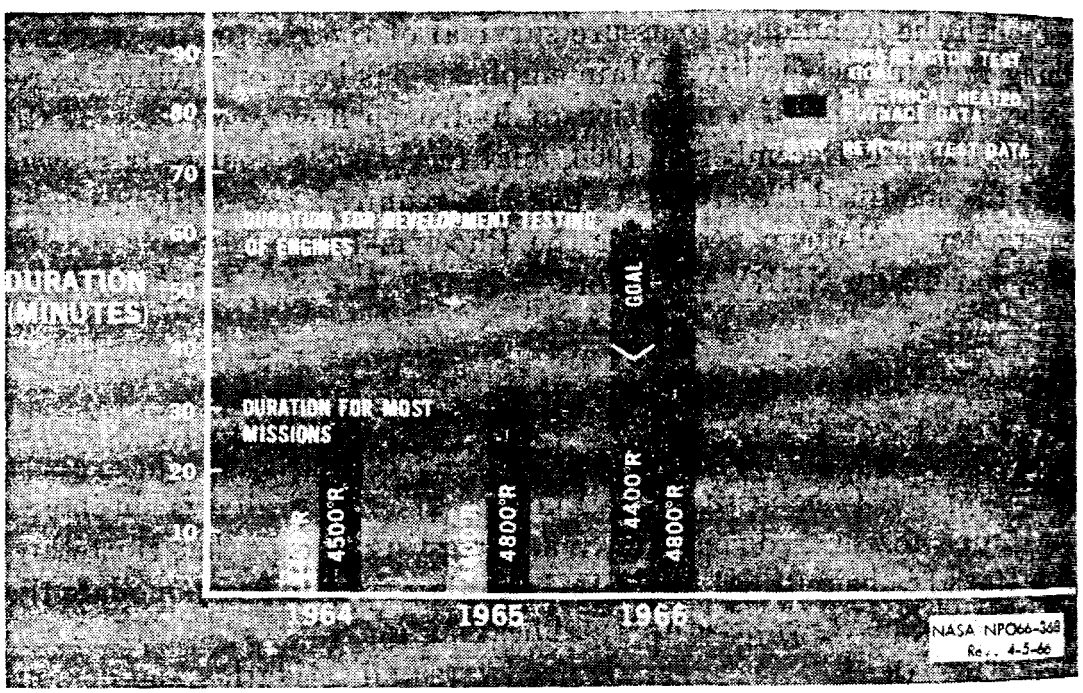
Development of the liquid hydrogen feed system for the Phoebus-2 reactor has been underway for the past four years at the Rocketdyne Division of North American Aviation, Inc., Canoga Park, Calif. Basically, the Rocketdyne system is an outgrowth of the pump-turbine system developed for reactor testing in the Los Alamos Kiwi program at NRDS. In the feed system (known as the NFS–3B) which will be used for Phoebus-2 power testing, two of the pump-turbine units are being combined in a parallel arrangement to provide the required Phoebus-2 flow rates. In addition, the pumps deliver hydrogen at pressures and flow rates higher than were required for the Kiwi tests. A single pump-turbine unit of this system will be used for the Phoebus-1B test and future NERVA NRX reactor tests.

Graphite Reactor Fuel Element Technology

Fuel element technology development is continuing at Los Alamos, Westinghouse (Pittsburgh, Pa.), and the Y–12 plant at the Oak Ridge production complex, and is aimed at increasing the corrosion lifetime of graphite reactors. An example of the progress being made is shown in the illustration. Sixty-minute tests of fuel elements in hot hydrogen corrosion test furnaces were freqeuntly conducted in 1966. The data from these tests are continually being compared with the data from full-scale reactor tests to improve the current fabrication technology and the reliability and quality of laboratory test techniques.



Fuel Element Performance. The chart graphically shows the advancements made in the development of graphite fuel element technology. Laboratory work with fuel elements in hot hydrogen corrosion test furnaces during 1966 showed a dramatic gain in operating duration over results achieved during 1965.

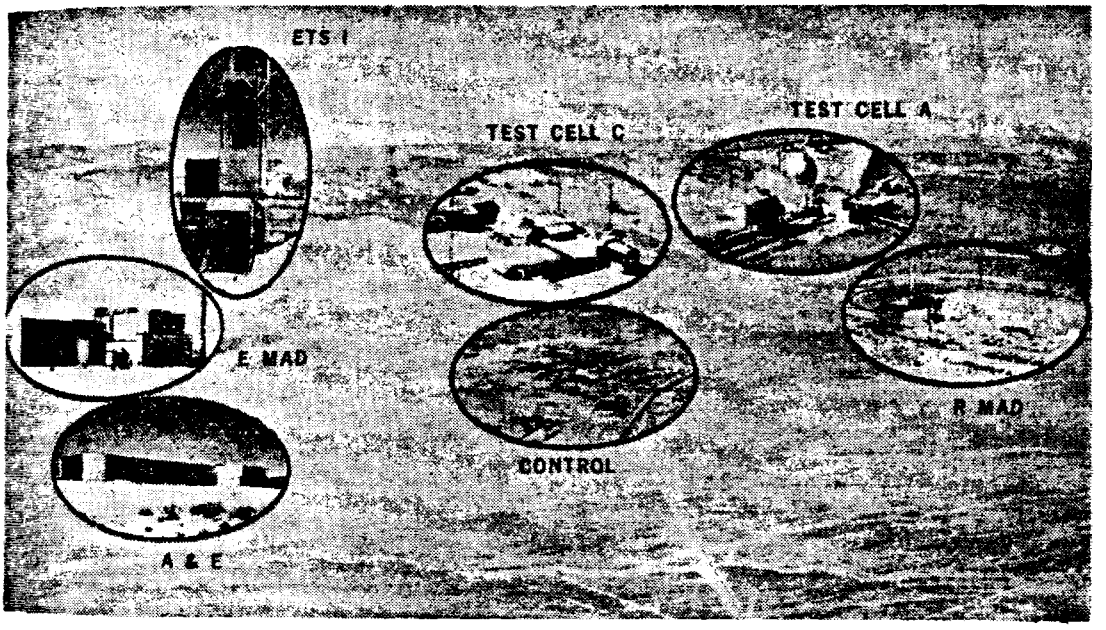
TUNGSTEN REACTOR TECHNOLOGY

Research on tungsten systems has shown that although tungsten reactors are feasible and can operate for long durations, their performance in terms of specific impulse approximates that of the graphite system. Inasmuch as the missions currently envisioned for nuclear-rockets do not require operating durations longer (30 to 60 minutes) than those that appear to be attainable with graphite, all work on tungsten systems was discontinued as of June 30.

The NASA Lewis Research Center (Cleveland, Ohio) and Argonne National Laboratory were the principal contributors to the tungsten effort. Argonne examined a fast reactor concept and Lewis, a thermal water-moderated reactor concept. The major problems investigated were related to the fabrication of suitable tungsten-uranium-dioxide fuel elements and the compatibility of tungsten-uranium dioxide fuel material in a hydrogen environment when subjected to various steady-state and cyclic temperature conditions. In addition, analyses were conducted on the design, neutronics, and control characteristics of a reactor based on the use of these materials. Both ANL and Lewis, along with their contractors, contributed significantly to the advancement of technology in the very difficult field of refractory materials.

NEW TEST FACILITIES

New test facilities for the development testing of nuclear-rocket reactors and engine systems are being added to the NRDS complex.

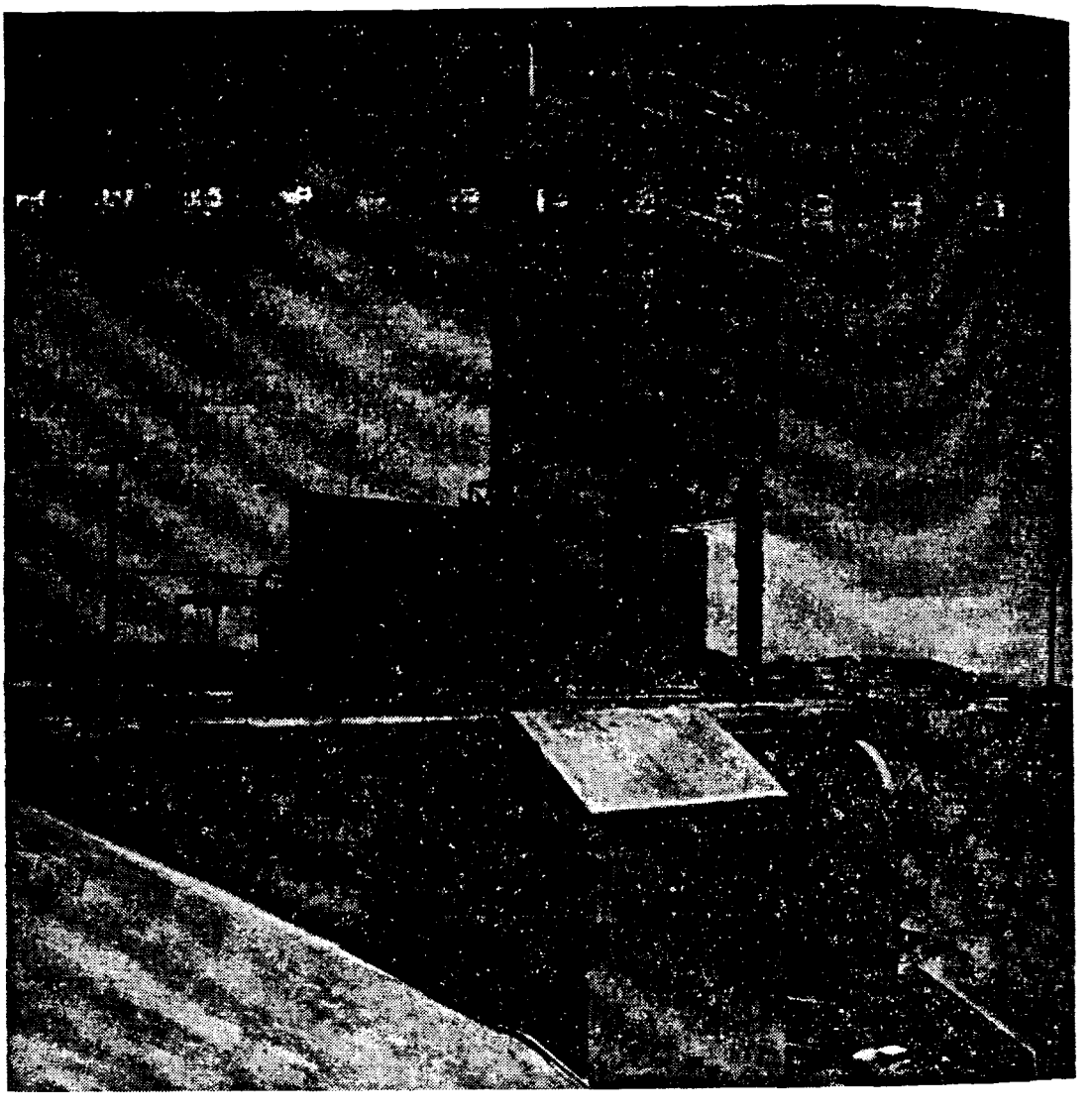


NRDS Complex. Superimposed on an aerial photo of the Nuclear Rocket Development Station (NRDS) in Nevada are the major facilities used for the AEC–NASA developmental work. Two new facilities—ETS-1 (Engine Test Stand No. 1) and the E-MAD (Engine Maintenance, Assembly, and Disassembly building)—are nearly completed and will be used to support the XE engine tests.

Engine Test Stand No. 1 (ETS–1), and the Engine Maintenance, Assembly, and Disassembly (E–MAD) building are in the final stages of completion and will be used in the servicing and testing of experimental engines (XE's) in the NERVA engine technology program.

Engine Test Stand

Experimental engines will be tested in ETS–1 in the normal "down firing" position; in all tests conducted to date, the jet nozzle was pointed skyward. A large cooled duct will deflect the highly inflammable hydrogen exhaust gases from the engine nozzle away from the stand. The duct, in conjunction with other ancillary equipment, also will be used to simulate space environment conditions. The fabri-



Engine Test Stand No. 1. Experimental engines (XE) to be tested at the Nuclear Rocket Development Station will be operated under conditions simulating actual space flight. The hot hydrogen gas exhaust from the downward-firing experimental engine will exit into a partial vacuum. This is facilitated through an exhaust duct located in the lower portion of the stand.

cation of the exhaust duct, the culmination of a difficult technology effort, was completed in 1966 by Air Preheater Co., Division of Combustion Engineering, Inc., Wellsville, N.Y. Installation of the duct in ETS–1 also was completed in 1966. The duct resembles an "L" shaped, double-walled tube, approximately 53 feet high and 56 feet long. Altitude conditions will be simulated by feeding superheated steam into the duct at very high velocity in the direction of the engine exhaust stream.

E–MAD Building

Construction of the E–MAD building has been completed for several months, and activation of the building is in progress. The facility will be used to assemble, disassemble, and service engines for testing and evaluation. Radioactive ("hot") components will be handled by using specially designed remote manipulators.

Cell Modification

Test Cell "C" has been modified to accommodate the testing of the high-powered Phoebus-1 and Phoebus-2 series of reactors. The major improvements made to the facility include the addition of two 500,000 gallon liquid hydrogen storage dewars,[2] an emergency pressurized liquid hydrogen storage dewar for supplying hydrogen coolant to a reactor in the event of a feed system failure, and a high-capacity liquid hydrogen feed system—the NFS–3B, described in the "Phoebus Reactor Technology" section.

SPACE ELECTRIC POWER

The nuclear systems being developed for generating electric power in space include radioisotopic heat sources and small nuclear reactors. The radioisotope power systems appear to be attractive for power levels up to about 10 kilowatts for very long durations and are described in Chapter 9—Isotopic Heat and Power Applications. The nuclear reactor power systems are being developed for higher power levels than those attainable with radioisotopes.

[2] A double-walled container for holding liquid and gas supplies.

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REACTOR POWER SYSTEMS

The AEC is developing two classes of reactors for space power application: the zirconium hydride SNAP-type reactors which are expected to satisfy potential space power needs of the mid-to-late 1970's, ranging up to about 100 electrical kilowatts; and the advanced space power reactors which are intended to satisfy later higher-power needs. The current scope of the space power reactor program is shown in Table 3.

TABLE 3.—SPACE POWER REACTOR PROGRAM

Type of reactor	Program designation	Electrical power range	Potential applications
Zirconium-hydride thermal reactors.	SNAP-10A	0.5 kw	Space stations; lunar bases; and communications satellites.
	SNAP-8	10–35 kw	Meteorological, reconnaissance, communications satellites; lunar bases; large manned space stations and laboratories; and direct broadcast TV satellites.
Advanced, high temperature fast reactors.	Liquid metal-cooled reactor.	300 kw–10 Mw.	Unmanned interplanetary probes; manned interplanetary missions; manned space stations and laboratories; and large lunar bases.
	Thermionic reactor.	300 kw–10 Mw.	
	Gas cooled reactor (710).	About 200 kw.	
	Boiling potassium reactor (MPRE).*	About 100 kw.	Developmental work on this concept was terminated in 1966 to concentrate resources on the above three higher-priority advanced concepts.

*Medium Power Reactor Experiment.

Zirconium-Hydride (SNAP-type) Reactors

SNAP–10A. The first reactor power system to be operated in space was the SNAP–10A which was launched into orbit on April 3, 1965, and operated successfully for 43 days before the reactor was shut down by a faulty command within the spacecraft. The endurance capability of this system was subsequently demonstrated when an identical

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SNAP–10A flight-type system (designated the FS–3) operated on the ground continuously and virtually unattended in a simulated space environment for more than 10,000 hours (about 417 days). The FS–3 is now undergoing detailed examination at Atomics International's Santa Susana test range to determine the state of the reactor following its successful operation. To date, the examination has revealed no problems or unexpected conditions in the system. The SNAP–10A system, which consists of a 40 thermal kilowatt sodium-potassium (NaK)-cooled zirconium-hydride reactor coupled with thermoelectric conversion, has a nominal electrical power output of 500 watts after one year of operation.

SNAP–8. SNAP–8 is a 600 kwt NaK-cooled zirconium-hydride reactor designed to develop 35 kilowatts of electrical power when used in conjunction with mercury Rankine cycle[3] power conversion. An experimental SNAP–8 reactor (S8ER) was operated at Atomics International, Canoga Park, Calif. The test included a year of operation at thermal powers of 400 to 600 kilowatts with a coolant outlet temperature of 1,300° F. Upon completion of the test, the reactor was disassembled and it was found that most of the fuel elements had cladding cracks. This problem, which is attributed to the combined effect of fuel swelling and cladding embrittlement, has been under intensive investigation throughout the year. Fabrication of the second generation SNAP–8 Development Reactor (S8DR) is being delayed pending the results of fuel clad tests which are now underway. Assuming that the test results continue to verify the improved fuel element design, the fuel elements for the S8DR will be fabricated in fiscal year 1968 and power testing of the S8DR will begin in fiscal year 1969.

Development of the companion mercury Rankine cycle power conversion system (PCS) for the SNAP–8 reactor is underway at NASA.

Advanced Space Reactor Concepts

Activities in the advanced reactors area are directed toward meeting future space power needs for very long-lived systems having electrical outputs in the hundreds and even thousands of kilowatts. Long-range technology programs are currently underway which support three basic advanced reactor concepts: (*a*) the liquid-metal-cooled reactor; (*b*) the in-core thermionic reactor; and (*c*) the gas-cooled

[3] Rankine cycle power conversion—A method of converting thermal energy-to-mechanical energy-to-electrical energy using a closed liquid-metal (mercury or potassium) vapor cycle. The reactor coolant takes fission heat from the reactor core and conveys it to a heat-exchange boiler where the liquid-metal working fluid in the Rankine loop is converted to vapor. The vapor turns a turbine, which is linked to an electric generator, and then passes through a radiator-cooled condenser where it is condensed back to a liquid which, in turn, is pumped back into the boiler.

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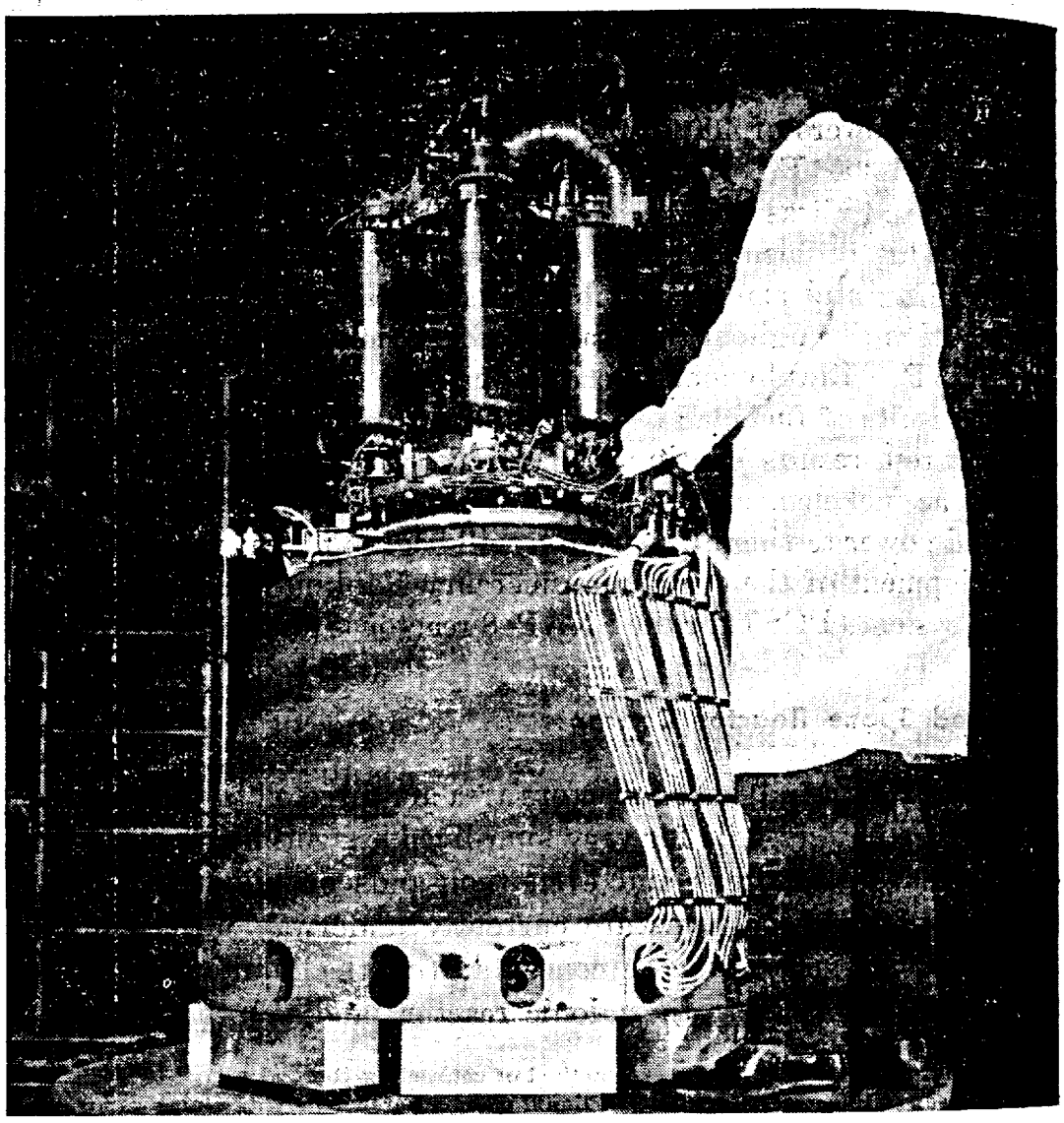
reactor (710). All of these are in the high temperature, fast spectrum reactor category. A fourth concept, the boiling potassium reactor (Medium Power Reactor Experiment, MPRE) at Oak Ridge National Laboratory was eliminated from the program during 1966 in order to concentrate effort and resources on the other concepts.

Liquid-metal-cooled reactor. The liquid-metal-cooled reactor concept is attractive for space power applications because of its inherent versatility and relatively predictable performance characteristics over a wide range of operating conditions. Emphasis is on reactors for space power systems having outputs in the multi-megawatt range for electric propulsion applications, but reactors for secondary power applications of several hundred kilowatts are also being considered.



SNAP–8. The photo *above* shows a prototype SNAP–8 reactor being prepared for shock and vibration testing. When fully developed, the SNAP–8 reactor will provide 10 to 20 kilowatts (kw) of electricity with thermoelectric power conversion, or 35 kw with the SNAP–8 mercury turbogenerator system.

The technology program supporting this reactor concept is being conducted by the Lawrence Radiation Laboratory, Livermore, Calif. During 1966, major attention was given to defining the reactor requirements for the liquid metal Rankine cycle power system, and a continued concentration of effort in this direction is expected. By the end of the year, the experiemental portion of the program was evolving from exploratory materials investigations into a basic technology effort supporting the reference reactor designs.

In-core thermionic reactor. The thermionic reactor offers long-range promise for both high reliability through redundancy of static conversion units and small radiator area due to high operating temperature. Programs conducted by General Atomic at La Jolla, Calif., and General Electric at Vallecitos, Calif., have been directed primarily toward developing long-endurance thermionic fuel elements, which must operate at temperatures above 3,000° F. During 1966, encouraging results were obtained from in-core tests of fueled thermionic diodes, and the scope of the thermionic effort is now being broadened to investigate overall reactor problems such as stability, control, and reliability.

Gas-cooled reactor (710). High-temperature gas-cooled reactor technology is being developed for application to noncondensing working fluid Brayton cycle space power systems. This effort is being conducted by General Electric at Evendale, Ohio, in what the company designates as the 710 program. The 710 concept, which uses an inert gas for cooling the reactor and driving the power-conversion equipment, provides an important potential alternative to the liquid-metal cycles for space-power generation. During 1966, emphasis was placed on the reactor design and fuel system development.

Space Reactor Shielding

The reactor shield accounts for a large fraction of the weight of a nuclear-powered space system. Shield weights vary from a few hundred pounds for instrument shields—such as the one used for SNAP-10A—to thousands or tens of thousands of pounds for manned flights.

The purpose of the space reactor shielding program is to develop analytical methods to accurately calculate the effectiveness of different shields for various applications. Equally important is the development of methods for fabricating shields that will meet structural and heat-removal requirements.

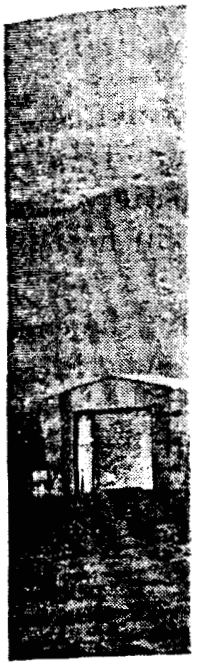
Advanced analytical methods are being developed at Oak Ridge National Laboratory which use neutron transport theory and Monte Carlo techniques.[4] In conjunction with the analytical program, a

[4] Monte Carlo techniques—A method of solving physical problems by means of a series of statistical experiments which are performed by applying mathematical operations to random numbers.

shielding experiment is planned where a modified SNAP-10A reactor will be used as a gamma and neutron source at the Oak Ridge Tower Shielding Facility. Comparisons will be made between the calculated and measured performance of a typical space shield. Shield material and fabrication techniques are under investigation at Atomics International where 11 neutron shields of lithium hydride, ranging from 200 to 700 pounds in weight, have been produced for a variety of tests in previous and current programs.

Dynamic Power Conversion Technology

To supplement space nuclear power development, the AEC is pursuing several research and development efforts to demonstrate the capabilities of both the mercury Rankine cycle, and at lower temperatures, the organic Rankine cycle to meet long-term requirements for future space applications.

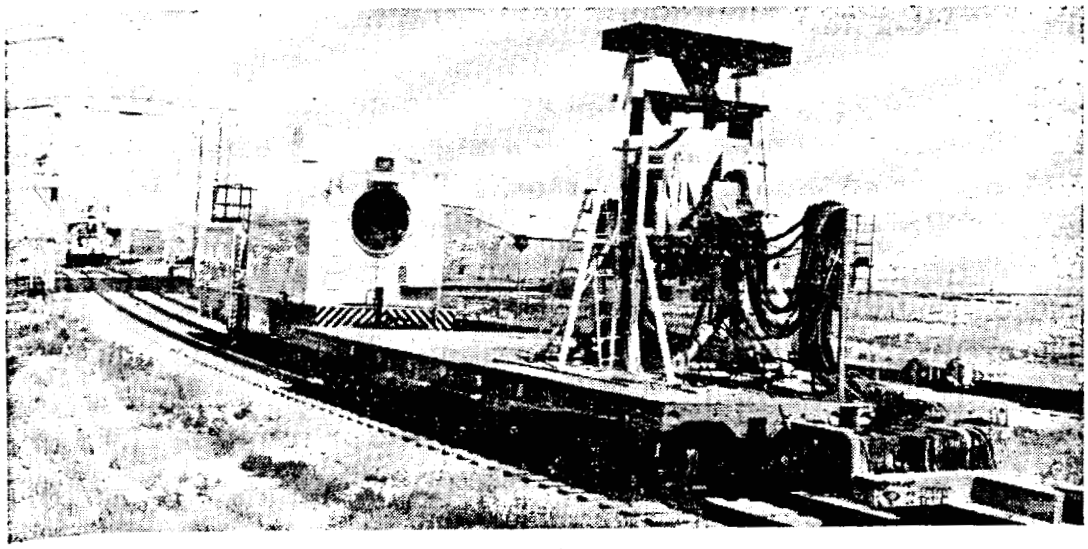


Mercury Rankine cycle. The mercury Rankine cycle turboelectric technology is being developed by Thompson-Ramo-Wooldridge (Cleveland, Ohio). Tests of the 3.5 kilowatt Combined Rotating Unit (CRU) were continued during the year. The CRU is an integrated package containing the mercury turbine, alternator, and mercury pump—all mounted on a single rotating shaft. An endurance test of greater than 4,000 continuous hours was completed on a unit of this type in August. The final configuration of the CRU has now been selected and 10,000-hour endurance tests have been initiated.

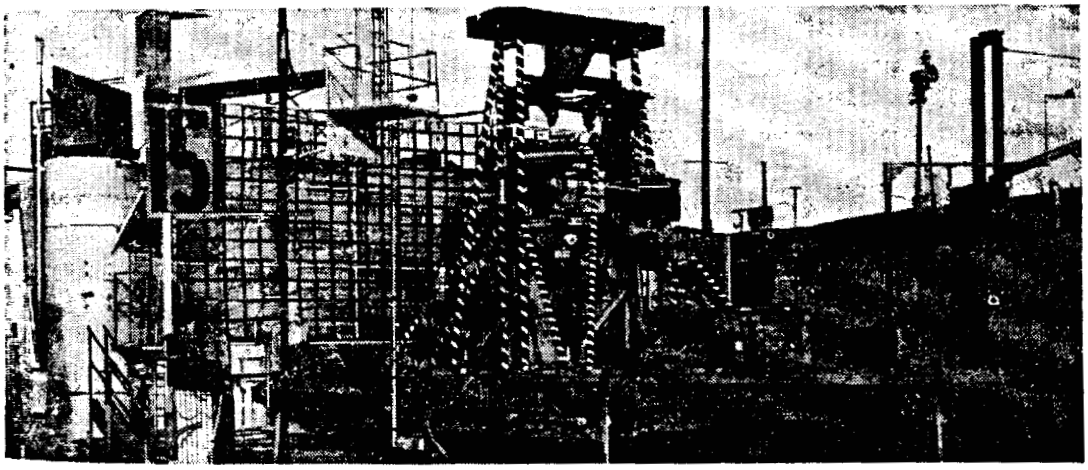
Organic Rankine cycle. The organic cycle is being investigated for use with an isotopic or indirect reactor heat source in the low power regime (several kilowatts). The advantage of the cycle for this application is that with relatively low cycle temperatures of only 600–700° F., net cycle efficiencies of about twice that of the higher-temperature mercury Rankine cycle appear to be possible. The feasibility of the cycle hinges on the long-term behavior of the organic working fluid under expected operating conditions. Candidate fluids (biphenyl, Dowtherm A, and monoisopropylbiphenyl) are being investigated for the AEC by the Philco Corp. (Newport Beach, Calif.), the Sundstrand Corp. (Rockford, Ill.), and the National Bureau of Standards.

SPACE REACTOR SAFETY

As a part of its nuclear safety effort, the AEC conducts tests in which space reactors are subjected to abnormal conditions to determine the consequences. In two such tests, the reactors have been deliberately destroyed.



SNAPTRAN–2 Test. On January 11, 1966, a SNAP–10A type reactor was deliberately destroyed at the National Reactor Testing Station in Idaho to provide kinetic data which would enhance the capability to predict the consequences of an accidental nuclear excursion of a SNAP reactor. Photo *above* shows the test rig being pushed by a shielded locomotive into position for the test (the reactor is covered). Photo at *left* shows the destructive excursion; the flash measured about 30 feet high and 50 feet wide. Photo *below* shows the test stand, which was still substantially intact although the small 8½″ in diameter, 12″ long keg-shaped reactor had disintegrated. The arrow points to place where reactor had been.



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SNAPTRAN–2 Test

The year's principal safety test activity conducted under the SNAP reactor safety program was the deliberate destructive test of a SNAP-10A reactor on January 11 at the NRTS, Idaho. This test, called SNAPTRAN–2, was a nuclear excursion conducted for the purpose of verifying the ability to predict, on a theoretical basis, the consequences that would follow the accidental excursion of a SNAP reactor. The excursion was caused by the insertion of the maximum amount of reactivity available in as short a time as could be mechanically contrived. As expected, destruction of the reactor resulted. In a 1964 SNAPTRAN test,[5] a SNAP–10A reactor blew itself apart in 0.0027 of a second after a sudden water immersion.

Core Geometries Study

While the SNAPTRAN test series has helped improve the predictive capability regarding the effects of an accidental excursion and water immersion of a SNAP reactor system, the SNAP reactor safety program is pursuing another effort at Atomics International which could eliminate the problem entirely. To date, this effort has consisted of studying various reactor core geometries which, by varying the core length, radius, and/or axial reflector dimensions, would be subcritical when immersed in water. Some success has already been achieved, and further refinement of this technique is in progress. Study is also underway to predict the behavior of SNAP reactor systems in the atmospheric re-entry heating regime by means of computer codes.

[5] See pp. 147–149, "Annual Report to Congress for 1964."

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Chapter 9

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Chapter 9

ISOTOPIC HEAT AND POWER APPLICATIONS

Radioisotopes produce heat by absorbing the kinetic energy of the radiation given off by the decay process. The direct use of this thermal energy, especially by thermoelectric conversion, into steady and long-lasting power sources is being developed for a number of applications in space, marine, and terrestrial environments. These applications are paced by the development of safe and satisfactory isotopic fuel forms and/or containment materials for the intended environment. (Chapter 10—Isotopic Radiation Applications, summarizes some of the work being done to put the radiation from radioisotopes to useful purposes.) A major advantage of most isotopic power systems is that since they have no moving parts they can operate unattended for long periods of time.

SPACE RADIOISOTOPE POWER SYSTEMS

The production of isotopes, the characterization and fabrication of isotopic fuel forms, and the research and development leading to practical thermoelectric generator applications involves a number of AEC laboratories and production facilities as well as industrial contractors. Since February 1966, Sandia Laboratory has been providing the technical direction for the rapidly expanding space radioisotope power program. This arrangement was deemed necessary to obtain adequate personnel strength with access to appropriate equipment and facilities so as to increase the effectiveness of efforts to attain program objectives. This includes guidance of the activities of AEC contractors engaged in the development of space isotope power systems, including independent systems and components testing as required; conduct of some in-house technology work; and performance of technical evaluation studies related to immediate or potential future isotope space systems requirements.

GENERATOR DEVELOPMENT

Radioisotope-powered systems are small in size, low in weight, and operate independently of the space mission's sun and shade cycle. Thus, they can serve as essential space power sources, replacing solar cells—the other main long-life space power technology—in those missions for which solar cells are not as well suited. Table 1 summarizes the status of most generator development programs undertaken to date.

TABLE 1.—SNAP ISOTOPIC POWER SYSTEMS FOR SPACE

Designation (SNAP No.)	Prime contractor	Electric power (watts)	Application	Fuel	Unit design life	Status
3	Martin Co.	2.7	Navigational satellites (DOD).	Pu^{238}	5 years	Unit launched June 1961 is still operating in orbit, but quantitative performance data not available.
9A	Martin 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.
11	Martin Co.	25	Moon probe (NASA).	Cm^{242}	90 days	First fueling of a generator with curium 242 accomplished in July. In Oct., fueled unit completed 90-day test under simulated lunar conditions. Testing of two electrically heated generators will complete planned SNAP-11 work.
19	Martin Co.	30	Nimbus-B weather satellite (NASA) (Launch scheduled for late 1967. Two SNAP-19 power units will be used in a mission.)	Pu^{238}	3 years	Electrically heated system undergoing compatibility testing with Nimbus-B spacecraft. Two prototype fueled generators tested to flight system qualification levels.
27	General Electric.	50	Apollo Lunar Surface Experiment Package (ALSEP) (NASA) (SNAP-27 will provide power for experiments placed on the moon by early Apollo astronauts.)	Pu^{238}	1 year	Electrically heated engineering generators placed on test. Electrically heated prototype system undergoing compatibility testing with ALSEP hardware.
29	Martin Co.	500	Possible manned and unmanned space applications (DOD and NASA).	Po^{210}	144 days	Detailed design and subcomponents development initiated.

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SNAP Devices in Orbit

Radioisotope-powered thermoelectric generators (RTG) have been in operation in orbit since the launch of the SNAP–3 (Systems for Nuclear Auxiliary Power) in June of 1961. The SNAP–3 unit, a 2.7-watt RTG, which was first demonstrated in 1959 using polonium 210 fuel, was modified to operate on plutonium 238 for use on two prototype Navy navigational satellites which were launched in June and November 1961. The generator on the satellite launched in June (1961) continues to provide power intermittently to the satellite after five years in orbit. Qualitative performance of the unit is still being monitored by the tracking stations. However, a failure in the satellite's telemetry system makes acquisition of quantitative data on the

SNAP–19. Radioisotopic generators such as the SNAP–19, shown being discussed by Sandia Corp. Vice-President G. A. Fowler, *left*, and AEC Chairman Glenn T. Seaborg, will provide electrical power for a variety of space vehicles, including lunar missions, space probes, communications and meteorological satellites, manned spacecraft, and other space systems. The plutonium-fueled SNAP–19 is designed to provide electrical power to the experiments on board the Nimbus-B weather satellite scheduled to be launched in late 1967.

performance of the generator unavailable. (The satellite launched in November (1961) operated only until June 1962, when it stopped transmitting, apparently as a result of a capacitor shorting-out.[1])

These successful flight tests of experimental RTG's led to the initiation of the SNAP-9A program to develop a 25-watt RTG for the Navy's prototype operational navigation satellites. SNAP-9A was the first isotopic power system developed for a specific space application. The first SNAP-9A was successfully launched in September 1963, and a second was placed in orbit in December 1963. These still-operational power systems provided all the power required by the satellites for the functional life of the satellite components. In April 1964, a third launch with a SNAP-9A unit aboard failed to achieve orbit because of a launch error.

Isotope Space Systems Development

SNAP-11. The SNAP-11 program is being brought to a close. It was initiated in 1962 to produce an RTG and associated power conditioning equipment for NASA's soft lunar landing mission spacecraft. The SNAP-11 was to supplement the prime power source (solar cells) during the lunar night when solar energy is unavailable. Under these conditions, the system could have produced 20 watts(e). However, because of a re-direction of the NASA program, SNAP-11 is no longer required and has been placed on tests aimed at gathering data to evaluate performance under simulated lunar operational conditions.

A SNAP-11 thermoelectric generator was delivered to the Oak Ridge National Laboratory (ORNL) in June 1966 for electrical system tests and subsequent use in a curium 242 fueling demonstration. After this electrically heated generator had successfully passed environmental testing under simulated lunar day and lunar night conditions, its fueling with the largest amount of the radioisotope curium 242 ever assembled was accomplished in July. A 90-day test of this fueled unit under simulated lunar conditions was successfully completed in October. Two more electrically heated SNAP-11 generators have been assembled and plans call for delivering them to the Jet Propulsion Laboratory (Pasadena, Calif.) and NASA-Manned Spacecraft Center, Houston, Tex. The electrical testing of these generators will complete the planned SNAP-11 work.

SNAP-19. SNAP-19, the next isotope power system scheduled to be flown—in late 1967—is designed to provide approximately 50 watts of electrical power to the experiments on board the Nimbus-B weather satellite, while about 200 watts will be provided by the satellite's large

[1] See pp. 2, 65–66, "Annual Report to Congress for 1961" and pp. 9, 178–180, "Annual Report to Congress for 1962."

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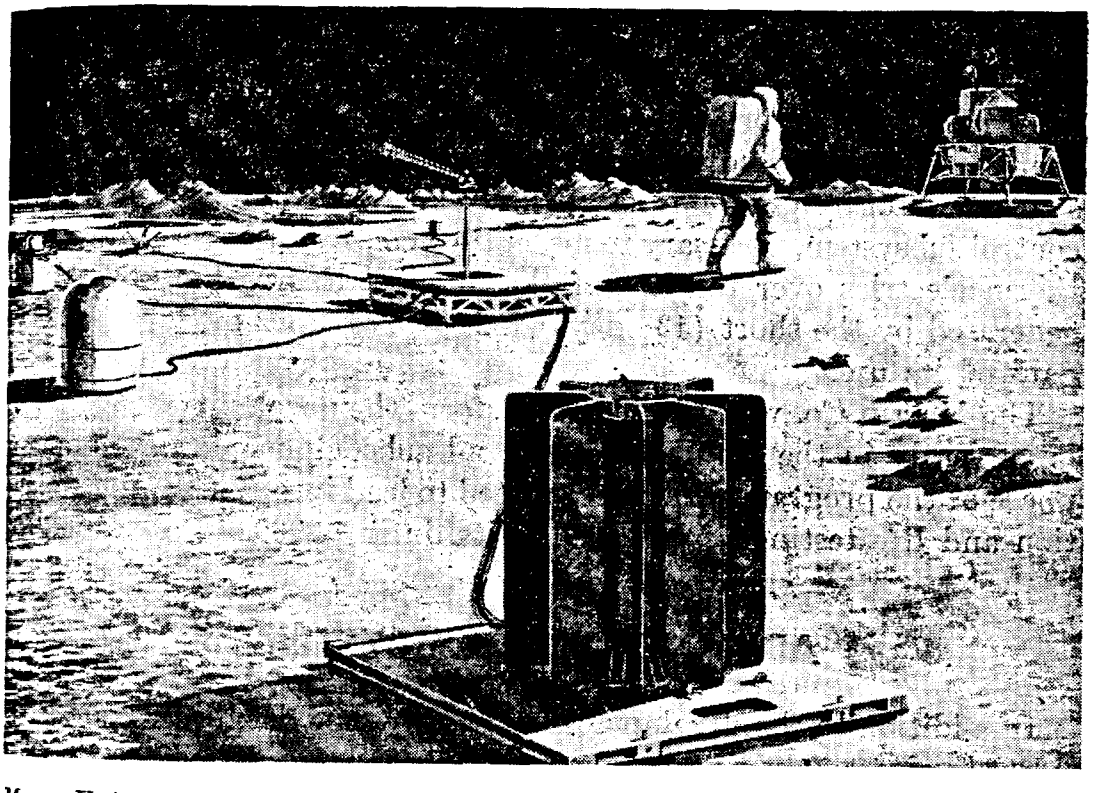
solar cell paddles. Two prototype SNAP–19 generators were thermally tested aboard a Nimbus-B weather satellite mockup in June. This work is being performed by the Martin Co., Baltimore, Md. Preliminary system marriage tests were also conducted at General Electric's Missile and Space Division, Valley Forge, Pa., using the ground support test console, DC to DC converters, telemetry conditioning unit, and two SNAP–19 generators each producing approximately 30 watts(e). The plutonium 238-fueled ground prototype system has successfully completed flight qualification testing.

SNAP–27. It is planned that a plutonium-fueled SNAP–27 radioisotope thermoelectric generator will be placed on the moon by U.S. astronauts during an early Apollo mission to provide 50 watts(e) of power to an Apollo Lunar Surface Experiment Package (ALSEP) for up to one year after the astronauts' departure. There are several unique features about the SNAP–27/ALSEP program. There is no other type power supply planned as a backup to the isotope generator. The generator is designed so that the fuel capsule can be inserted after it is placed on the moon. The planned use of a beryllium housing would provide an increased electrical power-to-generator weight ratio over previous generators.



Moon Unit. The SNAP–27/ALSEP (Apollo Lunar Surface Experiment Package) application is shown in the above drawing. It is planned that the SNAP–27 (*in foreground*) will be placed on the moon by astronauts during an early Apollo mission to provide power to the experiment package for up to one year after the men return to earth. General Electric Co. (prime), with Minnesota Mining and Manufacturing Co., and the Solar Division of International Harvester Co. form the major contractor team for the SNAP–27 system development.

The Missile and Space Division, General Electric Co., Valley Forge, Pa., is the project contractor, with the Minnesota Mining and Manufacturing Co. (3M), St. Paul, Minn., and the Solar Division of International Harvester Co., San Diego, Calif., the major subcontractors for the SNAP-27 system.

Final design of the engineering generators was completed during the year, and hardware procurement and manufacturing was initiated. Models of the complete SNAP-27 system—which included the generator, fuel capsule, lunar excursion module shipping cask, and power conditioning unit—were delivered to NASA in January for system compatibility studies. In October, the first electrically heated engineering generators were placed on test and are performing satisfactorily. Thermal test generator system mockups were delivered in November, and a prototype electrically heated system will be delivered in early 1967, to NASA's Manned Spacecraft Center in Houston for system compatibility testing with the ALSEP hardware.

SNAP-29. SNAP-29 is a radioisotope thermoelectric generator designed to provide a nominal power output of 500 watts(e) for 144 days with a total system weight of about 500 pounds. Heat is generated in the fuel source by the radioactive decay of polonium 210 (Po^{210}) which is contained in about 30 fuel capsules. These capsules are installed in a flat plate fuel block which allows a large surface to be used to radiate the isotopic-produced heat to a bank of thermoelectric elements which, in turn, convert a portion of the heat to electrical power. The waste heat at the cold side of the thermoelectric modules is delivered to a space radiator by a sodium-potassium (NaK) coolant loop. A thermal control subsystem, necessary to maintain a constant temperature on the thermoelectrics over the life of the mission, dumps the excess heat generated by the short (138 days) half-life of Po^{210} during the early part of its use.

The Martin Co. was selected to perform the development work and is currently in the detailed design and subcomponents development phase of the program which is expected to lead into generator fabrication and life testing of qualified units during 1969.

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ADVANCED SPACE SYSTEMS

In addition to the development of the systems listed in Table 1, the AEC is also conducting a number of studies on the use of isotopic power systems for both manned and unmanned space missions.

250-Watt Generator Studies

Advanced studies have been started to determine the feasibility of designing long-lived 250-watt(e) radioisotope thermoelectric gen-

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erators—fueled with either plutonium 238 or strontium 90—which would be capable of controlled re-entry into the earth's atmosphere from orbit in an intact condition. The re-entry of such intact generators would be carefully controlled: they would be made to impact safely in deep ocean water or, possibly, to impact in a pre-selected landing region so that their isotopic fuel material could be recovered and either be disposed of or salvaged for re-use. The Missile and Space Division, General Electric (Valley Forge, Pa.), Lockheed Missiles and Space (Sunnyvale, Calif.), and Martin companies have completed parallel 6-month studies of such a system. These design studies will be used as a basis for possible follow-on work in the event that DOD satellites require long-lived radioisotope-powered generators for practical operation in the few hundred watt power range. Liaison is also being maintained with NASA for possible application of this type of generator (using Pu^{238}) aboard the unmanned Voyager interplanetary probe spacecraft, as well as orbital missions.

Isotope Thermionic Module Development.

The isotope thermionic [2] module development program was initiated in June 1966 for the development of a 100-watt(e) module which, singly or in multiples, may be used to meet potential space applications. The first phase of the program, being conducted by the General Electric Co.'s Missile and Space Division (Valley Forge, Pa.), includes a detailed module design and safety study based on the use of both curium 244 and polonium 210 isotope fuels. The program schedule will be paced by heat source technology which will allow long-term operation at thermionic emission temperatures (up to 2,000° C.). Current thermionic converter technology indicates lighter weight and more efficient isotope power systems should be attainable.

Thermal insulation projects. Three projects were initiated in 1966 to improve thermal insulation in radioisotope generators. The three contractors, each working in a different specialized area, are: Johns-Manville (Manville, N.J.), working on fibrous insulations to be used at temperatures up to 1,800° F.; Linde Div. of Union Carbide Corp. (Tonawanda, N.Y.), working on evacuated foil insulations for the same temperature range; and Thermo-Electron Engineering Corp. (Waltham, Mass.), working on the development of evacuated foil insulations for temperatures of 1,800 to 3,000° F., primarily for thermionic applications.

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

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STATIC POWER CONVERSION TECHNOLOGY

To supplement prototype generator developments and studies, the AEC is conducting several research and development efforts to provide higher temperature, more efficient, and/or lighter weight thermoelectric systems, to meet requirements for future space applications.

Thermoelectric Technology Development

Compact thermoelectric module development. Westinghouse Electric Corp.'s Astronuclear Laboratory (Pittsburgh, Pa.) and the Radio Corporation of America (Harrison, N.J.) are working on solutions to thermoelectric materials and module fabrication problems under the compact thermoelectric module development program. Each company is developing a converter which is based on a different modular concept. The Westinghouse concept is a void-free tubular structure containing lead telluride thermocouples, while the RCA concept uses silicon-germanium thermocouples. During 1966, technical problems were studied through tests of thermoelectric elements in their potential operating environment. Both converters will be designed for space applications, with either radioisotopes or reactors as the heat source, to produce 1 to 20 electrical kilowatts.

ISOTEC. The ISOTEC (Isotope Thermoelectric Converter) project at the General Atomic Division of General Dynamics Corp. (San Diego, Calif.) employs thermal radiation coupling between an isotope heat source and lightweight, flat-plate thermoelectric panels that surround the heat source. Life testing of 2-couple modules has successfully passed 10,000 hours and 18-couple panels have gone beyond 1,500 hours. System calculations based on heat sources developed under SNAP programs promise power-to-weight ratios of greater than two watts per pound within present heat source temperature capabilities.

Direct radiating thermoelectric work. The objective of the direct radiating thermoelectric program, being conducted at Atomics International (Canoga Park, Calif.) with Radio Corp. of America as principal subcontractor, is to upgrade the thermoelectric technology used in the SNAP–10A space reactor so that higher efficiencies can be achieved with the SNAP–8 space reactor or with radioisotopes. The program to date has been emphasizing metallurgy and bond development and stack and structural development. Life tests of two-couple and eight-couple modules have been initiated.

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ISOTOPIC THRUSTER PROPULSION

Isotopic thrusters use the thermal energy produced by the decay of an encapsulated radioisotope to heat a propellant, which is exhausted through a rocket nozzle to produce thrust. These thrusters can provide relatively low thrust (one-millionth to one-tenth of a pound) at high specific impulse (200–800 seconds depending on propellant and radioisotope-fueled-capsule temperature capability.

Two Thruster Classes Studied

Two classes of radioisotope-heated thrusters were under investigation in 1966.

High-thrust type. One class is a relatively high-thrust, high-performance, short-lived thruster suitable for primary stage propulsion applications. Such a thruster requires the use of hydrogen as a propellant, capsule temperatures greater than 2,000° C. (3,632° F.), radioisotope thermal power in the range of 15 kilowatts, and thrust level of about one-fourth pound. Subsequent to the cooperative Air Force-AEC's limited ground test of this class of thruster in February 1965, the AEC has continued programs aimed primarily at establishing the radioisotope fuel form and capsule technology necessary for this high temperature service.

Lower-thrust type. The second class being studied is a lower-thrust, moderate-performance, long-lived thruster suitable for spacecraft attitude control functions. These thrusters, using ammonia as a propellant and near-at-hand 1,100° C. (2,012° F.) capsule technology, can provide specific impulses in the range of 250 seconds with thrust levels of 10 to 100 millipounds for thruster weights on the order of three pounds. Furthermore, these thrusters are simple, low-pressure, monopropellant systems and require no external power or thermal controls. While no specific system requirements have yet been identified, both the NASA's Goddard Space Flight Center (Greenbelt, Md.) and the Air Force's Rocket Propulsion Laboratory (Edwards Air Force Base, Calif.) have established cooperative programs with the AEC which include ground tests of radioisotope-fueled thrusters. Goddard's promethium-fueled thruster completed a one month test program at the AEC's thruster test facility at Mound Laboratory in early December 1966, and the Air Force's plutonium-fueled thruster is scheduled for testing in January 1967.

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SPACE ISOTOPE SYSTEMS SAFETY

The major flight safety research and development effort during 1966 was given to defining the response of radioisotope fuel to re-entry and other environments, such as vibration, impact, and geochemical environments.

Fundamental safety studies were conducted by the Sandia Corp. on radioisotope fuel capsule impact and burial phenomena, system responses to propellant fires and explosions, re-entry phenomena, atmospheric dispersion of particles, and terrestrial contamination problems associated with radioisotope fuels.

The U.S. Naval Radiological Defense Laboratory, San Diego, Calif., under AEC sponsorship, initiated a program to test radioisotope fuels, capsule materials, and capsule configurations in the ocean in order to obtain data on the response of fuels and materials in the marine environment.

TERRESTRIAL AND MARINE SYSTEMS

During the past five years, radioisotope-fueled thermoelectric power systems have demonstrated their capability to operate unattended in remote locations for long periods. Their success has led to development effort on an advanced series of units for a variety of other applications.

POWER SYSTEMS

A series of first-generation isotope power systems using strontium 90 fuel have been developed under the AEC's SNAP–7 program and tested in a variety of terrestrial and marine environments. These prototype systems have clearly demonstrated the feasibility of developing long-lived energy sources capable of unattended operation in remote areas of the world.

Advanced Systems

Using the basic technology developed under this program, the AEC is developing an advanced series of economically competitive isotope power systems for a variety of deepsea (SNAP–21) and terrestrial (SNAP–23) uses. In addition, milliwatt (a thousandth of a watt) power systems using plutonium 238 as the heat source are being de-

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veloped under the SNAP–15 program for specialized communications and electronic control applications.

Other applications are being found with increasing frequency for these versatile low-power isotope-fueled devices—to light airport runways, to detect earth movements, to power ocean-bottom instruments, just to name a few. The AEC is working closely with potential users (oceanographers, instrument makers, the oil industry, etc.) to determine the specific areas of their interest and to develop the technology that will be responsive to their needs. One such development effort planned for early initiation is to meet potential user requirements for deepsea and land-based isotope power systems in the 1 to 10 electrical kilowatt range.

In addition to the developmental isotope-fueled generators for terrestrial and oceanographic applications shown in Table 2, the AEC is also developing an isotope-fueled device designed for a unique application, such as the nuclear cardiac "pacemaker."

Nuclear Cardiac "Pacemaker"

Studies sponsored by the National Heart Institute, Bethesda, Md., and Newark Beth Israel Hospital, Newark, N.J., indicated the potential usefulness of radioisotopes as an energy source for a cardiac "pacemaker," a device which would be used to stimulate the pulsing action of a malfunctioning heart. Although the medical profession is currently implanting battery-powered "pacemakers" in certain heart patients, these devices require frequent replacement because their batteries are short-lived.

The completely self-contained radioisotope-powered heart pacer, which the Nuclear Materials and Equipment Corp. (NUMEC) of Apollo, Pa., is developing under contract to the AEC, is to have a minimum life span of 10 years, thus requiring less frequent surgery for the patient. It is to have a power level in the 30 to 100 microwatt range and will use plutonium 238 as the heat source. About 21 months (May 1966–Feb. 1968) will be required to develop such a device, after which it will be exhaustively tested for performance and endurance in animals. The first device is not expected to be available for surgical implantment in humans for about three to five years. Cooperating with the AEC in the technical management of this program, and in subsequent testing programs, are the National Institutes of Health and the National Heart Institute, Bethesda, Md., and the Newark Beth Israel Hospital.

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TABLE 2.—TERRESTRIAL AND MARINE ISOTOPE-FUELED GENERATORS

Designation	Prime Contractor	Use and User	Power (Watts)	Design Life (Years)	Remarks
Undesignated (SENTRY).	Martin Co.	Remote weather station (Weather Bureau).	5	2	Installed Aug. 1961 on uninhabited Axel Heiberg Island, Canada. Removed Oct. 1965 because of problems with non-nuclear equipment. Now in storage pending determination as to future use.
SNAP-7A	Martin Co.	Light buoy (Coast Guard).	10	2–5	Under test at Curtis Bay, Md., facility until August 1966 when it was removed for examination.
SNAP-7B	Martin Co.	Land light (Coast Guard).	60	2–5	Provided completely reliable power to beacon in Baltimore harbor lighthouse from May 1964 to April 1966. Installed August 1966 on offshore oil rig in Gulf of Mexico to replace defective SNAP-7F generator.
SNAP-7C	Martin Co.	Automatic weather station (Navy).	10	2–5	Installed February 1962 near McMurdo Sound, Antarctica. Still operating.
SNAP-7D	Martin Co.	Floating weather station (Navy).	60	2–5	Installed January 1964 in NOMAD weather station moored in Gulf of Mexico. Has operated without difficulty or maintenance through major hurricanes, and continues to function exceptionally well.
SNAP-7E	Martin Co.	Undersea acoustic beacon (Navy).	8	2	Installed July 1964 under 15,800 feet of Atlantic Ocean water off Bermuda where it is successfully powering a Navy acoustic beacon.
SNAP-7F	Martin Co.	Offshore oil rig (Phillips Petroleum Co.)	60	2–5	Installed June 1965 on offshore oil rig in Gulf of Mexico. Removed October 1965 due to swelling of shield container which caused a short in thermoelectric system. Extensive tests underway to determine cause of swelling. Preliminary evaluation indicates a uranium-hydride reaction, resulting from the presence of water adjacent to the shield, to have caused this swelling.
SNAP-15	General Atomic.	Small electronic apparatus (Developmental).	0.001	5	Fabrication and testing of developmental systems in progress. Delivery of first prototype system scheduled for early 1967.
SNAP-21	Minnesota Mining & Mfg.	Advanced deep-sea (General purpose Oceanographic Navy Application).	10–60	5	Four 10-watt and two 20-watt models under development. All units to be delivered to AEC for environmental testing by June 30, 1969.
SNAP-23	Under Selection.	Advanced terrestrial (Developmental).	25–100	10	Development of high performance thermoelectric modules initiated in FY 1966; complete system development scheduled for initiation in FY 1967.

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HEAT APPLICATIONS

The thermal energy generated as radioisotopes decay varies from isotope to isotope as do the hazardous neutron, gamma, and beta radiations. Thus, the use of this heat energy is, to a large extent, limited by the amount and weight of shielding needed to reduce the radiation, especially the highly penetrating gamma rays, to below-hazardous levels.

Swimsuit Heater

Further progress has been made at Mound Laboratory toward designing and fabricating a 400-watt plutonium 238 swimsuit heater in cooperation with the Navy. Its function is to keep swimmers warm by restoring body heat lost to the water in underwater operations. Loss of body heat is one of the principal dangers to swimmers exposed for periods greater than one hour. The unit heats a fluid which in turn is pumped through vein-like tubes in the swimmer's suit. Such a unit will permit longer work time underwater, thus increasing man's usefulness in undersea operations.

The unit is to be completed in 1967 for a manned test operation.

Battery Heaters

Progress has been made in the study of radioisotope heaters for maintaining the operating temperature of electric storage batteries. The radioisotopic heat source will be capable of supplying about 10 watts of thermal energy to a battery. The AEC is providing consultation and assistance to the U.S. Army's Picatinny Arsenal, Dover, N.J., for this project.

ISOTOPIC FUELS

The stringent operational and safety requirements imposed on isotope-fueled devices used for power conversion and heat utilization necessitate vigorous development and test efforts to establish the characteristics and behavior of the isotopic fuel forms in the intended environment.

FUEL FORMS DEVELOPMENT

Activities associated with the development of isotopic power fuels include: (*a*) selection and determination of chemical and physical properties (characterization), of specific fuel forms and capsule ma-

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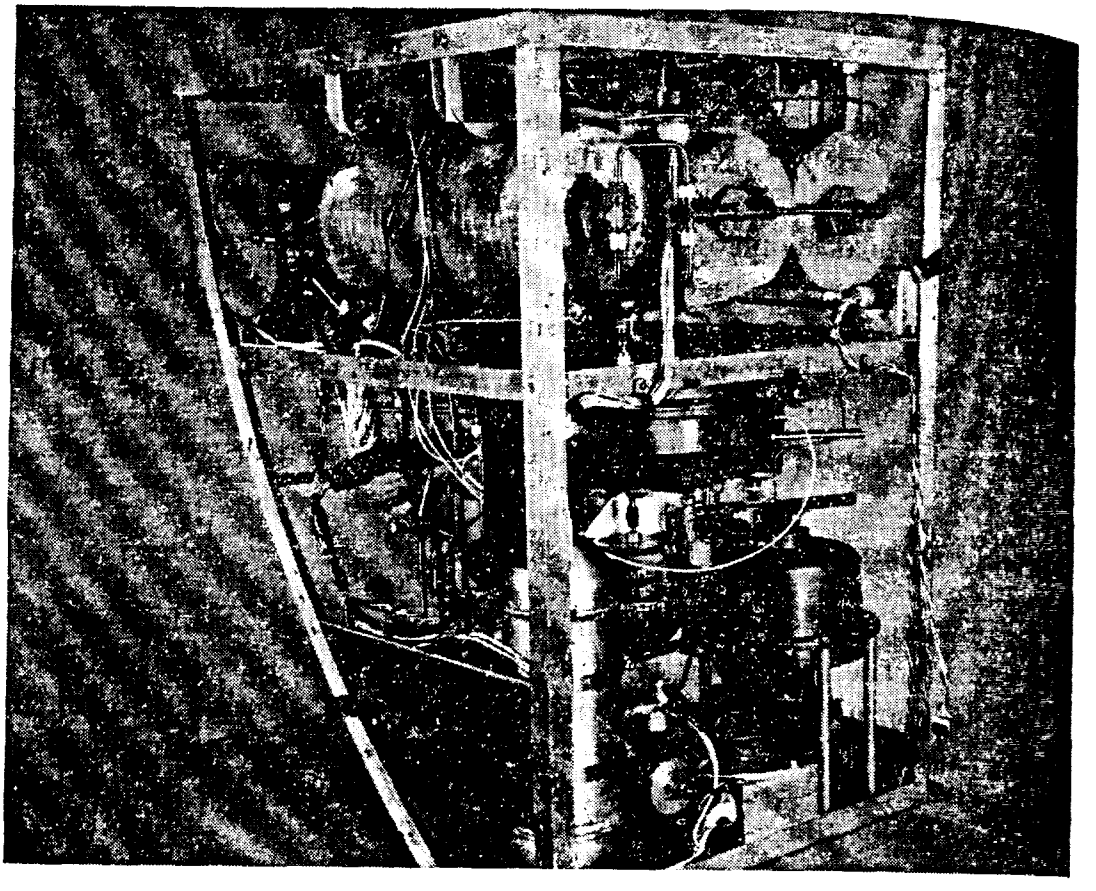
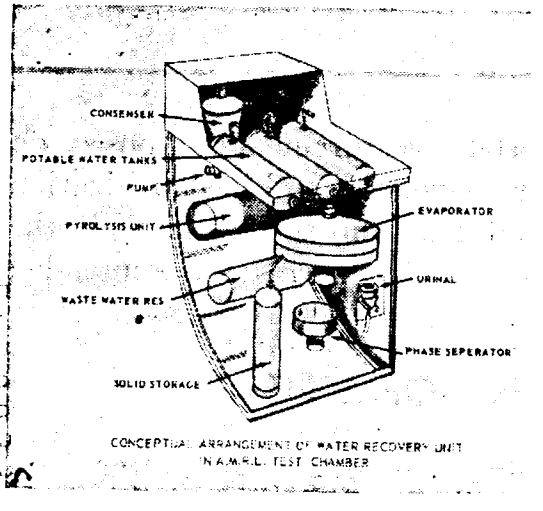
terials; (b) studies of fuel interaction with containment materials; (*c*) development of isotope processing and fuel source manufacturing facilities and techniques; and (*d*) manufacturing of prototype encapsulated fuel sources. Power sources have been fabricated using the metal or compounds of plutonium 238, polonium 210, curium 242, promethium 147, and strontium 90; development of encapsulated fuel forms of curium 244 and cobalt 60 is underway. In addition, cerium 144, cesium 137, thulium 170 and 171, and krypton 85 are under consideration as candidate heat sources.





Life Support System. Photo *above* shows the isotopic-powered life support system—a water reprocessing unit for a manned spacecraft, with capacity to recover 15 pounds per day of drinkable water from urine, wash-water, and condensate—built during the year by General Electric Co.'s Space Technology Center near Philadelphia, Pa., for the U.S. Air Force. Drawing at *left*, shows the major components of the system except for the four plutonium 238 sources which would provide a total of 280 watts of heat for the evaporator and pyrolysis units. The feasibility of the system was tested during the year at the AEC's Mound Laboratory where the plutonium 238 heat sources were fabricated.

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Plutonium 238

Process technology for the production of a satisfactory plutonium 238 fuel form has been developed at the AEC's Mound Laboratory. The new fuel form has been characterized and found suitable for application to space electric power systems. Attention has been directed specifically to the attractive properties of this plutonium fuel, which include a favorable half-life (87.5 years), relative inertness, stability, high melting point, and ease of production, handling, and encapsulation. Containment materials have been selected on the basis of compatibility experiments. Heat sources for support of programs of national interest, such as in defense, health and oceanography will be fueled with the metal or compound of plutonium 238.

It appears that the overall demand for plutonium 238 will exceed the supply for the isotope in the near future. Hence, efforts are underway to: (*a*) use lower grade plutonium 238 material; (*b*) increase the rate of recovery of plutonium 238 scrap generated in the fuel source manufacturing lines; and (*c*) explore alternative isotopic fuels such as curium 244.

Polonium 210

Polonium 210 (half-life of 138 days) is a radioisotopic power material applicable for short missions that demand a high specific activity and a minimum of shielding. Polonium compounds that exhibit high thermal stability under high vacuum or in an inert atmosphere are being studied at Mound Laboratory. These compounds have been dispersed in refractory materials which provide sufficient void volume to accommodate the helium gas decay product, and are more easily handled in larger quantities than polonium metal which has a low melting point and tends to migrate due to self-heating. Fundamental studies have provided a better understanding of fuel form properties and of encapsulation materials. A 3-year program has been initiated at Mound Laboratory to develop and provide a prototype polonium 210 fuel source for a Department of Defense space auxiliary electric power system.

Curium 242 and 244

Curium 244 has the unique combination of a reasonably high specific thermal activity, a relatively long half-life (18.4 years), and the availability of a high melting point compound (approximately 2,000° C.). These characteristics make it extremely desirable as an isotopic power fuel. However, shielding from the neutron radiation will present a

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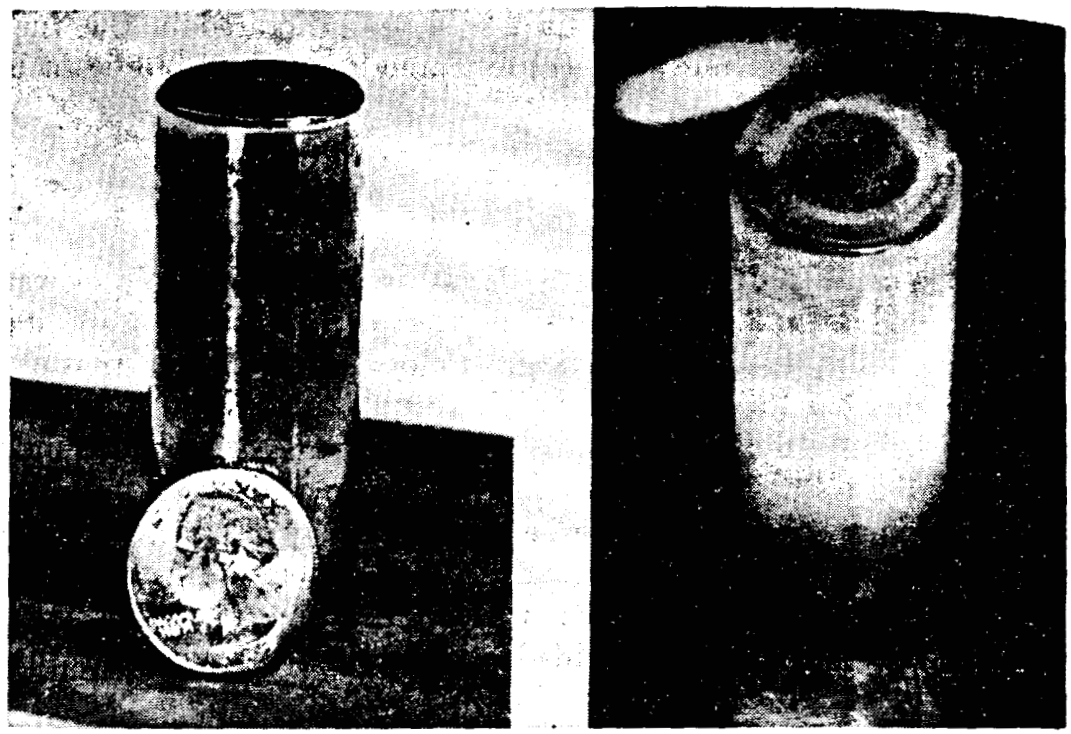
serious problem. Whereas polonium and plutonium fuel forms have been established and characterized, the curium 244 program has just been initiated at Oak Ridge National Laboratory (ORNL), and much work needs to be done to produce and characterize the fuel forms, and to establish the fuel-liner compatibility and source manufacturing techniques. The 4.5 kilograms of curium 244 expected to be available from Savannah River starting in October 1967 will be used to develop fuel forms for thermionic, thermoelectric, and microthruster applications.[3] Although the less easily produced curium 244 isotope will ultimately be used for space missions, valuable experience has been gained in working with the shorter half-life (163 days) curium 242. Sufficient curium 242 was produced at ORNL during 1966 to fuel developmental thermionic and thermoelectric generators and to test the operation of the former under simulated lunar day and lunar night environmental conditions (see previous "SNAP–11" summary).



Promethium 147 Fuel Source. The technology for processing promethium 147 (2.5-year half-life) to an oxide fuel form has been attained at the Pacific Northwest Laboratory which is operated for the AEC by Battelle Memorial Institute. The isotopic heat source will be used in a 60-watt (thermal) microthruster designed for NASA by General Electric's Space Power and Propulsion Section at Cincinnati, Ohio. At *left above*, a quarter indicates the approximate size of the 60-watt, rhenium-clad, promethium 147 heat source. At *right*, the heat source glows from self-generated heat while being held in a vacuum.

[3] *Thermionic* current is an electric current caused by directed movements of charged particles (electrons, ions) emitted by an incandescent substance. *Thermoelectricity* is a current produced by the direct action of heat, as by the unequal heating of a circuit composed of two dissimilar metals. A *microthruster* is a device to provide a relatively low directed reaction force produced as by a hot jet of gas discharged from a nozzle or orifice as in a rocket.

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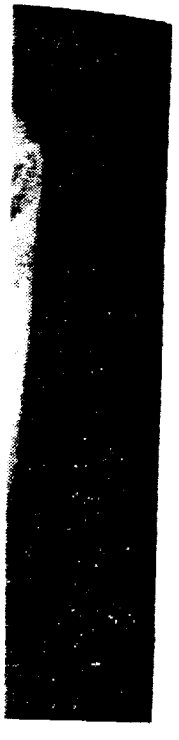

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Promethium 147

The techniques required for the effective separation of promethium 147 from other fission products have been developed at Pacific Northwest Laboratory along with fabrication of a 60-watt (thermal) source for low-power space thruster application. Laboratory-type facilities for producing this isotope have been placed in operation. The technology for processing promethium 147 to the oxide fuel form was provided by studies using samarium as a stand-in material.

Selection of a fuel cladding has been successful for promethium sesquioxide (Pm_2O_3), based on oxide-metal and metal-metal couple compatibility studies. The quality and characteristics of the source container following fabrication have been successfully determined using special ultrasonic techniques. The first application of a promethium-fueled heat source to provide power for a NASA-sponsored microthruster that was designed by General Electric (Space Power and Propulsion Section, Cincinnati) has been completed. The 60-watt system was tested at the Mound Laboratory in late 1966.

Strontium 90

Pilot-plant-scale processes for the production of isotopic power fuel forms were demonstrated during the year at Oak Ridge National Laboratory and at the Martin Co.'s Quehanna, Pa., facility with three compounds of strontium 90 (Sr^{90}). Notable success was achieved in exact dimensioning of fuels and increasing the power density of strontium titanate ($Sr^{90}TiO_3$) by densification of the compounds in a hot press and step processing. Strontium 90 oxide heat sources were successfully made for the first time by hot-press densification of the compound in a thin jacket of platinum metal. The platinum jacket protects the reactive strontium oxide from carbon dioxide and moisture in the air until the sources can be hermetically sealed in welded metal capsules. Three 200-watt (32,000 curies each) $Sr^{90}O$ heat sources were fabricated to demonstrate the process. Compatibility studies using nonradioactive strontium titanate ($SrTiO_3$), strontium fluoride (SrF_2), strontium oxide (SrO), and strontium metal in contact with super alloys at 1,832° F. and refractory metals and alloys at 3,362° F. identified suitable metals for containment of the fuels for more extensive testing.

Cerium 144

Isotopic fuel form studies of cerium 144 (Ce_2O_3) for high temperature applications were continued at the Oak Ridge National Laboratory.

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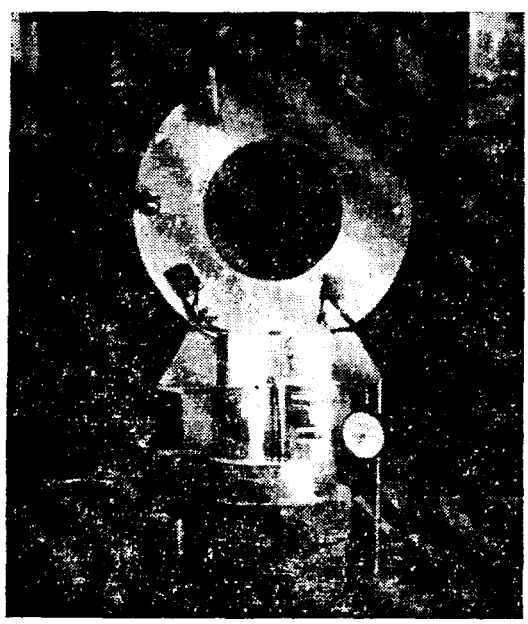
The most common oxide of cerium, CeO_2, was previously shown to decompose readily at temperatures exceeding 1,832° F. to liberate oxygen and yield Ce_2O_3. Oxygen release from isotopic power fuels results in incompatibility with refractory metals or alloys used to encapsulate the fuel and, therefore, cannot be tolerated. Compatibility tests with inactive Ce_2O_3 in contact with a number of super alloys and refractory metals and alloys resulted in identifying potentially suitable capsule materials for the $Ce_2{}^{144}O_3$ fuel form. A radiation source containing 87,500 curies of $Ce^{144}O_2$ was encapsulated for a low temperature application. The source was utilized at Oak Ridge National Laboratory in a cooperative experiment with the Allison Division of General Motors Corp. to determine the effect of radiation on the performance of a photovoltaic energy conversion device. The photovoltaic unit was developed by the Allison Division to determine the feasibility of this method for utilization of isotopic power.



Strontium 90 Sources. Production of strontium 90 heat sources on a pilot-plant-scale was demonstrated at Oak Ridge National Laboratory during the year. Photo on *left* shows two 32,000-curie sources of strontium 90 oxide. These sources were fabricated by a "hot press" technique using a platinum liner to contain the strontium 90 oxide during pressing and post examinations of the pellets. The pellets contain 533 grams of strontium oxide and about 95 grams of platinum; they are 5.56 cm in diameter and 5.43 cm in height. The power density is 1.54 watts/cm^3 and the activity concentration is 243 curies/cm^3. Even under normal lighting the decay heat is so intense that the sources are incandescent. Photo at *right* shows a strontium 90 heat source shield which was machined from a single uranium casting for use in developmental work at Oak Ridge National Laboratory by the Paducah Gaseous Diffusion Plant. The container was designed to be used under the sea. Heat from a strontium 90 source could be used to warm the surrounding water, thereby permitting workers to remain beneath the sea for extended periods of time.

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Cesium 137

Cesium 137 is abundantly available from chemical processing of radioactive wastes resulting from processing of irradiated nuclear fuels. Hundreds of thousands of curies of cesium 137 (Cs^{137}) in the form of sealed sources of cesium chloride ($Cs^{137}Cl$) have been utilized for medical radiation treatments, sterilization of surgical supplies, industrial radiography, and food irradiation. The application of cesium 137 as an isotopic power fuel has been hampered by low power density, higher radiation shielding requirement, and scarcity of cesium compounds that exhibit the necessary thermal and radiation stability at high temperatures. During the year, Oak Ridge National Laboratory studied a number of compounds of cesium having improved properties for high temperature applications. Methods for the synthesis of one compound—cesium pollucite ($Cs_2 \cdot OAl_2O_3 \cdot 4SiO_2$)—and fuel from fabrication were demonstrated using nonradioactive materials.

Thulium 170 and 171

The thulium radioisotopes, thulium 170 and thulium 171, have some potential advantageous characteristics for application as isotopic power fuels. Thulium 170 with a half-life of 127 days and a power density of about 17 watts/cubic centimeter seems to be a possible candidate as a fuel for short-lived space power systems. Thulium 171 with a half-life of 1.9 years and an extremely low penetrating radiation field makes it a possible candidate for biological applications. Refractory oxides of the rare earths, such as thulium sesquioxide (Tm_2O_3) which are stable at high temperatures (about 2,000° C.) under oxidizing conditions, are known.

Oak Ridge National Laboratory has completed a study determining the effective reactor production rates of these radionuclides (see "Special Reactor Products" section in Chapter 4—Source and Special Nuclear Materials). The practical modes of production study is being extended to determine the purity of the products, biological shielding requirement, and economic factors relevant to costs of isotopic power fuel forms. Among other things, consideration will be given to suitable fuel forms that have good thermal and radiation stability for applications at high temperature; in this connection, the AEC has received a proposal from Sanders Nuclear Corp., Nashua, N.H., for work in this field.

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Chapter 10

ISOTOPIC RADIATION APPLICATIONS

A primary purpose of the AEC's isotopes program is to develop and demonstrate radiation applications of isotopes and radiation technology that can be important to the Nation's economy and welfare. This is being accomplished through studies on the radiation processing of foods, chemicals, and materials and the development of isotopic systems that utilize the various types of radiation (alpha and beta particles, and gamma rays) for analytical processes.

RADIATION PROCESSED FOODS

The United States program for radiation processing of foods has two distinct, but parallel efforts. The first, under the AEC, has as its objective the development of radiation pasteurization techniques by which the fresh shelf-life of foods, such as fruits and marine products, can be extended significantly by reducing the spoilage rate. The second, under the Department of Army, is concentrating on radiation sterilization of meats so that they can be held indefinitely at room temperature. During the year, 15 tons of bacon were sterilized for the Army at Brookhaven National Laboratory's High Intensity Radiation Development Laboratory (HIRDL) in the largest food irradiation operation yet done. The HIRDL is the only facility at which such a large-scale project could be undertaken. The Army, with Food and Drug Administration approval, has been field testing irradiated bacon since 1963. Cobalt 60 and cesium 137 radioisotopes are being used as the radiation sources in the AEC effort, while the Army's research work uses cobalt 60 and an electron accelerator.

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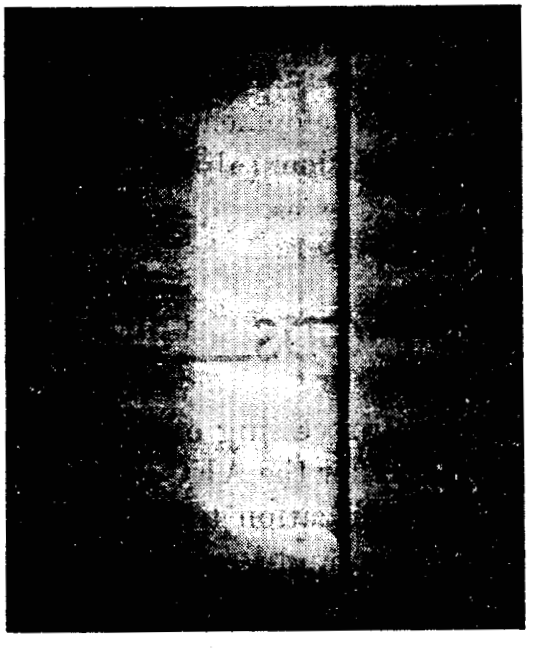

Bacon Sterilization. During mid-year, 15 tons of smoked, but uncooked, bacon was sterilized for the U.S. Army by irradiation in the High Intensity Radiation Development Laboratory (HIRDL) at Brookhaven. The Army, in its radiation program, has been sterilizing, by gamma irradiation, bacon and other meat products in small batches for test consumption at its food irradiation facility at Natick, Mass.; however, HIRDL is the only existing facility where the first such large scale processing of a perishable food could be done under the required stringent specifications for temperature, uniformity of exposure, retention time in the radiation field, and other criteria. Photo *above* shows the irradiation process being monitored through a heavy lead glass window. Photo at *left* shows a fully-loaded working plaque of cobalt 60 sources in the HIRDL irradiation cell. Photo *below* shows a case of the bacon which was packed in one-pound cans and kept under refrigeration before being irradiated; after the irradiation, it can be kept indefinitely without refrigeration.

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STATUS OF CURRENT RESEARCH

Research results from work under the AEC program continue to offer an optimistic outlook for the use of radiation for commercial processing of several kinds of fresh fish and fruits. The ultimate commercialization of these processes, however, depends upon clearance of such foods for human consumption by the Food and Drug Administration (FDA). Efficacy studies on six species of fish, petitioned to the FDA in September 1965, were completed by the end of November 1966. It is anticipated that some decisions on the clearance of one or more of the fish—cod, flounder, haddock, ocean perch, pollack, and sole will be made in 1967. A significant step during the past year was the submission to the FDA of a petition for clearance of radiation processed strawberries in May. Irradiation processing gives the fruit a two-week shelf-life, generally double that of unprocessed strawberries.

Fish Studies Expanded

During the past year, investigations on radiation processing of fish, which had previously been on a laboratory scale, were expanded to include the effects of commercial handling, shipping, and storing. Haddock fillets were commercially packed, given a dose of 250,000 *rad* of radiation, packed in ice along with suitable unirradiated controls, and shipped from Gloucester, Mass., to Seattle, Wash., for evaluation. The irradiated fish had a 17-day storage life while the nonirradiated controls were acceptable up to 11 days. These tests are now being expanded in conjunction with the fish industry. Currently, 10 large food chains—with over 8,000 retail outlets—are participating in this evaluation program through use of their shipping and storage facilities.

New Technique for Fruit

Textural damage caused by the levels of radiation required for effective rot and mold control has been a major problem in the irradiation of many soft fruits—for example, peaches and nectarines. Recent work has demonstrated that a combination hot-water dip plus a radiation dose one-half of that previously required to do the job yields equally effective control without textural damage. This new technique is important because it will permit an extended shelf-life due to reduction in spoilage for these relatively expensive foods. Another technique recently applied to table-quality cherries is the use of a calcium chloride dip prior to irradiation. Unfortunately,

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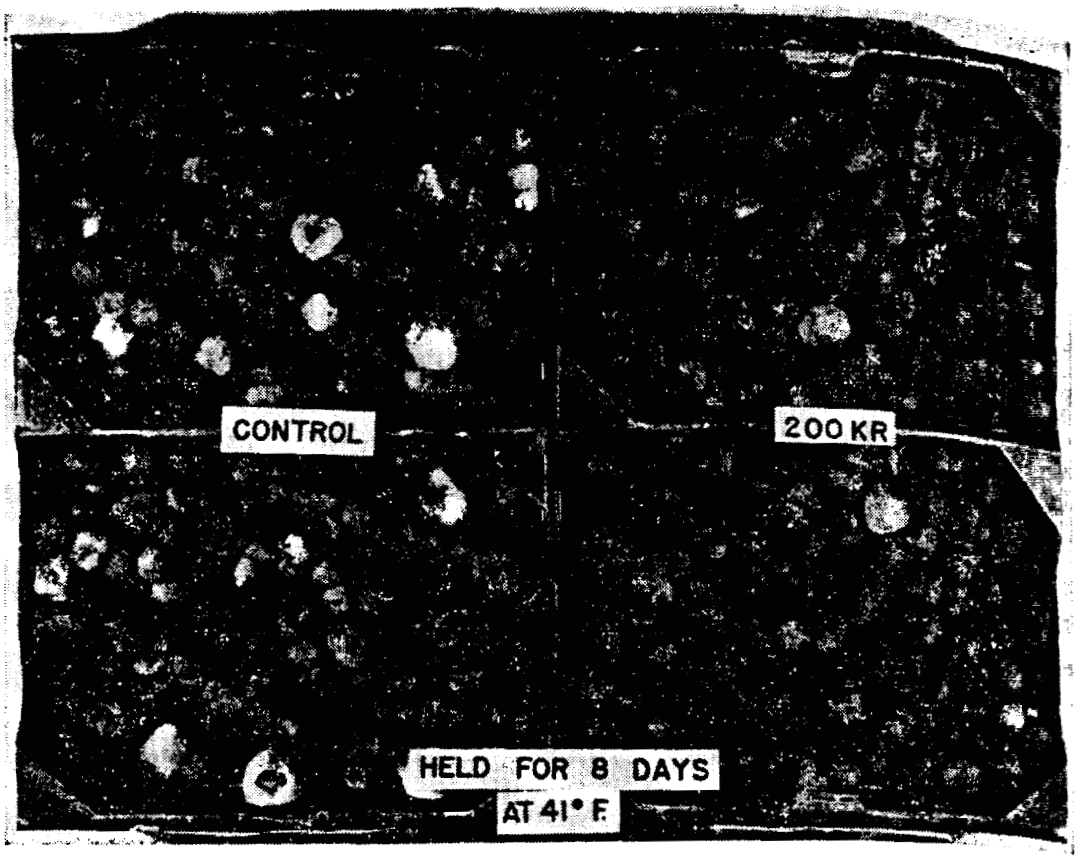

Pasteurized Strawberries and Fish. Normally, strawberries can be kept in storage from 7 to 10 days before they begin to spoil. After being pasteurized by irradiation, their shelf-life is extended to about 2 weeks—an economic factor of interest to fruit marketers since it doubles their store shelf-life. In photo *above*, the fresh-appearing strawberries on the *right* were processed with 200,000 *rads* (200 KR) of cobalt 60 gamma irradiation at the University of California's Davis campus; the moldy fruit on the *left* was not irradiated. During May, the AEC submitted a petition to the U.S. Food and Drug Administration (FDA) for approval of commercial sale of irradiation-processed strawberries. The process does not make the strawberries radioactive, nor does it detract from their taste. At *left*, a Bureau of Commercial Fisheries, Gloucester, Mass., technician compares samples of cooked pollock—one sample preserved by irradiation, the other not—to evaluate their taste. The AEC is seeking FDA clearance for human consumption of six species of ocean fish.

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progress in this area is limited by the seasonal availability of only a few weeks per year for many fruits.

Work at the University of Hawaii indicates a three- to four-day shelf-life extension in papayas subjected to a radiation dose of 75,000 *rad* when coupled with the hot-water treatment. Part of the food was shipped to the University of California's Davis facility for evaluation. Investigators at the University of Florida, Gainesville, have found that rot in mangoes can be controlled with the proper radiation dose.

Shelf-Life of Tomatoes Extended

Results of two years of work at the University of California (Davis) with tomatoes irradiated at the "pink" to "full-ripe" stage demonstrate a shelf-life extension of 8 to 15 days. These results differ appreciably from earlier work in which unsuccessful attempts were made to delay ripening of green tomatoes and have special significance when it is recognized that the present trend in the United States is to pick tomatoes in the "pink" stage. Tomatoes harvested at the "pink" to "full-ripe" stage offer a better quality fruit than tomatoes picked green and allowed to ripen during the period of distribution and marketing. The potential of this application is interesting on an economic basis, since fresh tomatoes are a large-volume vegetable commodity in the United States.

Economic Advantages Shown

Technology for both fish and fruits has developed to a point where a detailed analysis can be made to determine the relative costs and economic benefits of radiation processing of selected foods. This analysis of the potential input into the economy of selected food irradiation processes has been completed by Daniel Yankelovich, Inc., New York City. The results show favorable economic advantages for New England finfish and Hawaiian fruit. The screening criteria developed in the study also indicate that certain products—tomatoes and peaches, for example—should be studied further for possible market development. In the case of finfish assuming commercialization by 1970, reduced spoilage and short-buying benefits alone would provide net discounted benefits to the economy (after all government and private costs) in the order of $10 million by 1980. This figure is based on no increase in the *per capita* consumption of New England finfish. Under reasonable assumptions of market expansion in the midwest and conservative valuation of benefits, the net benefits could double.

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IRRADIATION FACILITIES

One of the major parts of the AEC's food irradiation program is the design and construction of irradiator facilities that can be used to advance the program from the laboratory to a commercial scale. Twelve irradiators have either been completed or are nearing completion. With these new devices, large quantities of material can now be irradiated near the point of production of the crops, which is important to the program. Irradiators have also been featured in the AEC's international "Atoms in Action" Science Centers (see Chapter 15—Information Activities).

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New Irradiators in Use

The Vitro Engineering Corp.-built Mobile Gamma Irradiator (MGI) was delivered to the University of California at Davis and, during the late summer, strawberries were irradiated in their shipping containers immediately after picking. The irradiator is mounted on a truck.

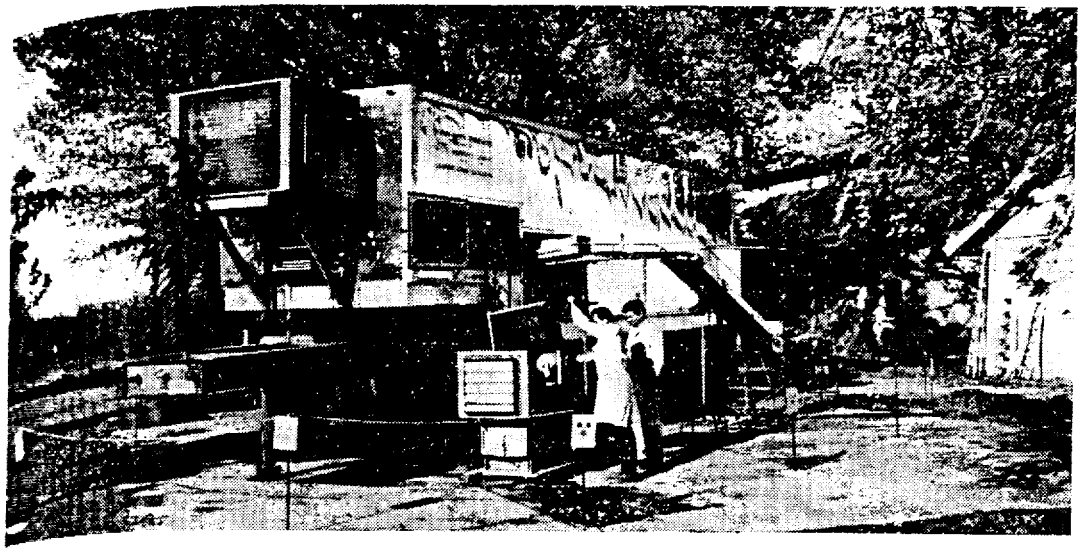
Three on-ship irradiators, based on a preliminary Brookhaven National Laboratory design, have been completed, two by Nuclear Materials and Equipment Corp. (NUMEC), Apollo, Pa., and one by Radiation Facilities, Inc., Lodi, N.J. One of these has been installed aboard the U.S. Department of Interior's trawler *Delaware* and used to irradiate fish at sea (off the coast at Gloucester, Mass.) immediately after they are caught. The second is in operation aboard Interior's trawler *Oregon* and is used to irradiate shrimp and other marine products from the Gulf of Mexico. The third is on loan to Israel and, although planned for use aboard ship, is being used as a land-based irradiator in a one-year cooperative food preservation program in which oranges and other fruits are being studied at the Nahal Soreq Reactor Center.

The Grain Products Irradiator was completed during the year at Savannah, Ga., by Vitro Engineering Corp., and will be used for insect disinfestation of grains both in bulk and in packages.

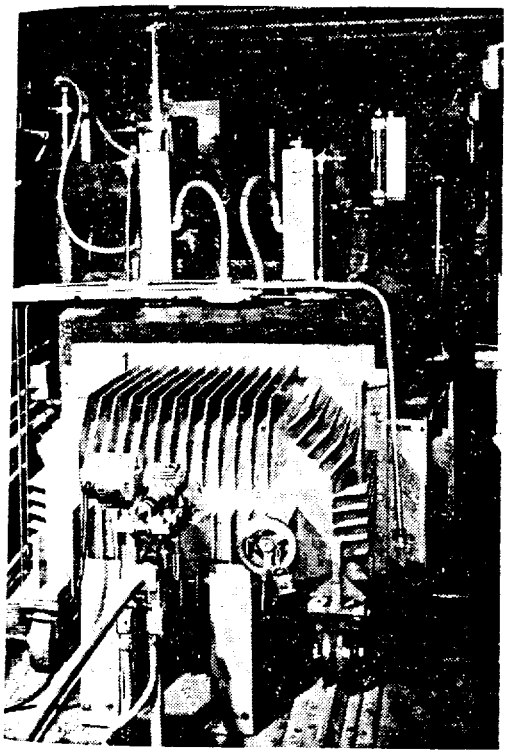
Irradiators Under Construction

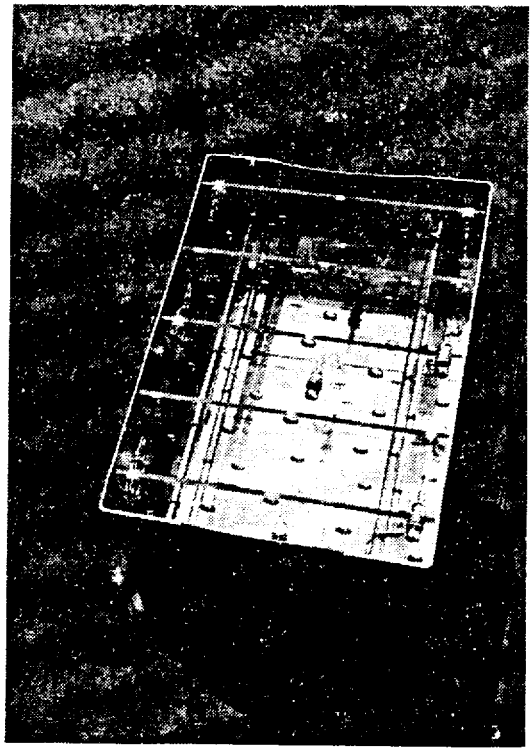
Another irradiator, similar to the on-ship irradiator but land based and fueled with a 150,000-curie cesium 137 source, is now being built for the AEC by American Nuclear Corp., Oak Ridge, Tenn., and should be in operation in early 1967.

Construction plans for the Hawaii Development Irradiator were completed and construction was started by NUMEC during the summer. This irradiator will be able to irradiate near-production quan-



Mobile Irradiator. During the year, the AEC's Mobile Gamma Irradiator was used under typical field conditions by the University of California at Davis to demonstrate the ease of irradiation processing of fruit immediately after it is picked. Photo *above* shows the irradiation van with a box of fruit (above the men) just going into the processing unit. Photo, *left below*, shows the cask that contains the 100,000-curie cobalt 60 irradiation source. Photo at *right below* shows how dosimeters (glass vials) would be placed among the fruit in the carrier box so the exact irradiation dose received by the fruit can be calibrated.





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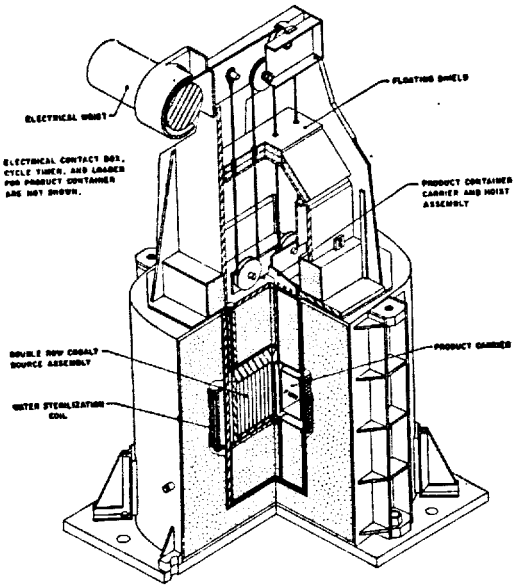
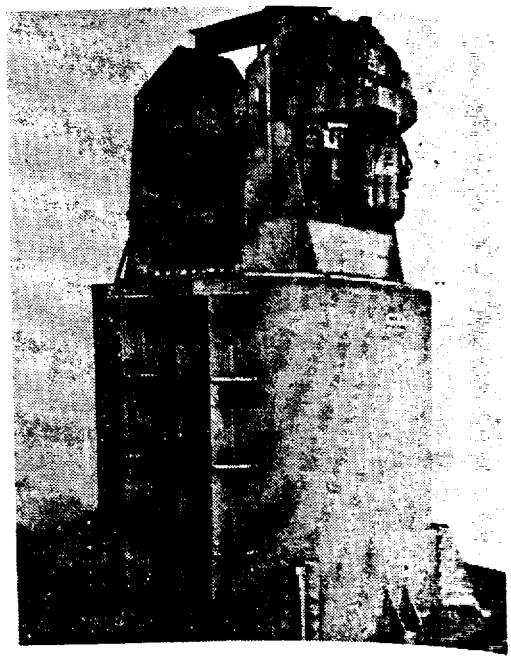
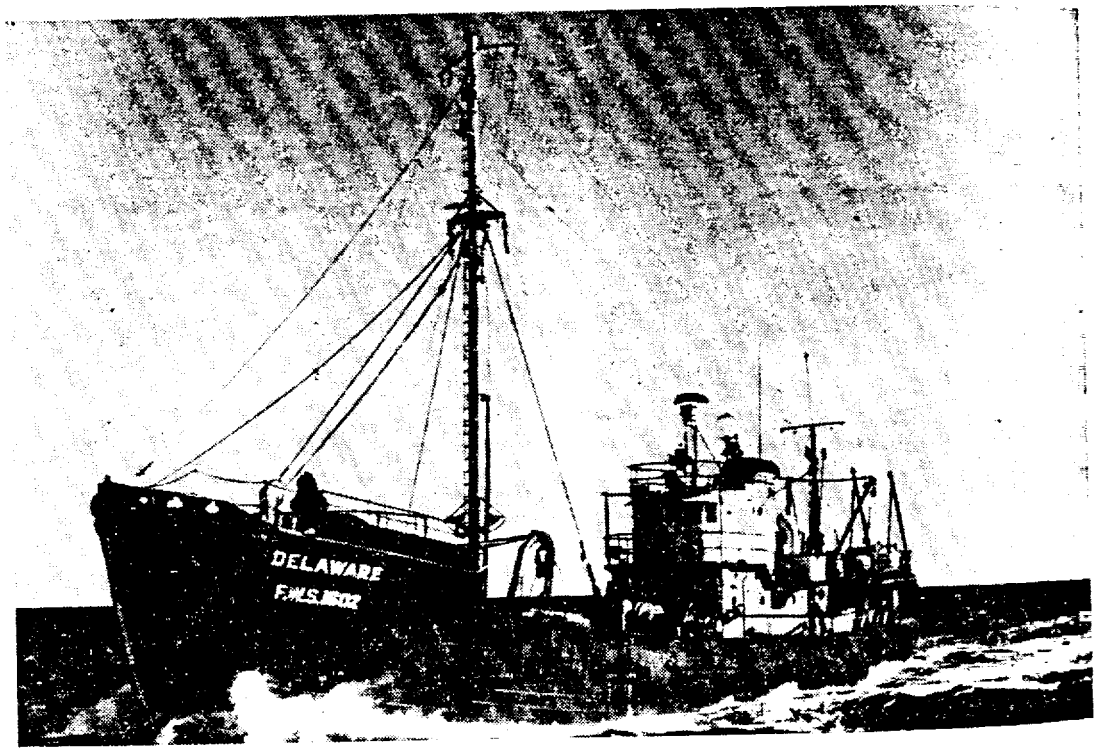




On-Ship Irradiator. The feasibility of irradiating fish as a means of extending the commercial shelf-life has been demonstrated and the Food and Drug Administration has been petitioned to approve six species of irradiation-processed fish for human consumption. Although the capacity of on-ship irradiators is somewhat less than the land-based facilities, they do make it possible to irradiate marine product immediately after catch. This permits extended storage at relatively low radiation doses. Diagram, *left above*, shows the major components of the 17-ton, cobalt 60 fish irradiation units now in demonstration operation aboard two U.S. Department of Interior trawlers. Photo, *right above*, shows a unit of the type installed aboard the trawler Delaware shown *below* which operates out of Gloucester, Mass.



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tities of Hawaiian fruits and other foods. It will be located on Oahu, near Pearl Harbor, and will be operated by the Hawaiian Department of Agriculture under contract to the AEC.

DEMONSTRATION PROGRAM

The AEC is cooperating with industry and with two other Government agencies—the Department of Commerce and the Department of Defense—to help establish a commercial basis for radiation processed meats. Involved is the possible construction and operation on a cooperative basis of a meat sterilization facility having a capacity of 1-to-5 million pounds a year. As an inducement for United States industry to provide the capital funds for construction of the facility, the AEC has offered to provide a major portion of the costs for engineering design and the radiation source, while the Department of Defense would guarantee purchase of a part of the production of the plant for a specified period of time. The specific goals are:

(1) Construction of a facility, to be operable in 1969, in which laboratory techniques will be scaled up to semi-commercial conditions;
(2) Provision of sufficient radiation-sterilized foods to fulfill military needs for logistical and test purposes;
(3) Determination of processing costs and economics of radiation-sterilized meats and poultry, with attendant extrapolation to full-scale commercial production conditions; and
(4) Introduction of a portion of the throughput into the civilian economy.

After interviewing a large number of food companies, many of which have expressed specific interest in the project as a result of a September 24, 1965, solicitation. The AEC on December 16, 1966, invited proposals from approximately 130 interested companies and organizations, with selection of the industrial participant scheduled for early 1967.

PROCESS RADIATION DEVELOPMENT

Radiation processing is defined as the production or processing of chemicals and materials using ionizing radiation as a source of energy to produce chemical, physical, or biological change.

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BASIC TECHNOLOGY

Projects within this area are aimed both at broadening the base of technology associated with process radiation and at identifying specific systems for possible future commercial application.

Industrial Studies

Considerable progress has been made during the past year on a number of systems. Industrial studies by Research Triangle Institute, Durham, N. C., under an AEC contract, of radiation-induced emulsion polymerization of vinyl acetate and its copolymers suggest application of the product in paint formulations. A preliminary evaluation shows the properties to be superior to those of many commercial formulations.

Advances have been made on the process for producing semi-conductor components using neutron transmutation doping by Fundamental Methods Associates Inc., New York City. A wide variety of transistors and diodes have been fabricated and now will be evaluated by industry in product form.

Studies on a new approach for inhibiting microbiological growth in liquid systems have been initiated by Atlantic Research Corp., Alexandria, Va. In this technique, radiation is applied in small periodic increments to inhibit bacterial growth rather than to sterilize or destroy the organisms. Many fields of application have been explored including systems for the maintenance of growth-free jet fuel and applications in the pulp and paper, petroleum production, and automotive industries.

Further progress has been made in the area of radiation engineering, the "hardware" of process radiation. Improvements have been made on the standard "BNL Flat" cobalt 60 source and extensive large-scale studies comparing cesium 137 and cobalt 60 sources for package irradiation are being carried out at Brookhaven National Laboratory. Strontium 90 sources for large-scale use for radiation processing also are undergoing evaluation studies.

SPECIFIC PROCESS APPLICATIONS

During the year, program efforts were directed toward the development and commercialization of two radiation processes—the production of wood-plastic materials and the synthesis of polyethylene and related copolymers. Expressions of interest in cooperative demonstration programs between industry and the AEC have been solicited for both the wood-plastics and the polyethylene processes.

Wood-Plastic Materials

The wood-plastics process involves impregnating wood with a liquid plastic monomer, then treating the wood with ionizing radiation from a cobalt 60 source.[1] The radiation polymerizes the plastic molecules, producing a solid wood-plastic material which has many improved properties but still retains the natural look of the original wood. As a result of the AEC's research program efforts, two private firms—Lockheed-Georgia Co., Marietta, Ga., and American Novawood Corp., Lynchburg, Va.—started producing radiation processed wood-plastic materials in developmental commercial quantities during 1966, and several others have announced their intention of doing so in the near future.

Polyethylene Synthesis

A continuous cycle flow system for the radiation synthesis of polyethylene with a capacity of one pound per hour is operating at Brookhaven National Laboratory and the product is being evaluated by commercial producers. It appears likely that at least one major polyethylene producer intends to construct and operate a pilot plant for the production of polyethylene by irradiation. This plant would probably be in operation by the end of 1967.

ISOTOPES SYSTEMS

The various types of radiation—alpha, beta, and gamma—given off by radioisotopes have been put to work in hundreds of different ways in the last 2 decades by industry and science. The AEC continues to sponsor studies that will lead to new uses. (See Chapter 9—Isotopic Heat and Power Applications, for uses of the thermal energy given off by decaying radioisotopes.)

TECHNOLOGY DEVELOPMENT

Two recent compilations of spectra information are expected to aid in technology needed for isotopes systems development. A process-control pilot plant for analysis of bulk materials and solutions has been put in operation.

[1] See pp. 212–213, "Annual Report to Congress for 1965"; pp. 189–190, "Annual Report to Congress for 1964."

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Spectra Compilations

Capture gamma ray spectra. A catalog of radiation spectra for thermal neutron capture gamma rays from the natural elements has been completed by Illinois Institute of Technology Research Institute under AEC contract. The availability of this new information [2] will help increase the potential of activation analysis for many applications. A continuing effort, under the sponsorship of the National Aeronautics and Space Administration, is being conducted for lunar analysis.

Neutron-deficient radioisotopes spectra. A special group of neutron-deficient radioisotopes (produced by particle accelerators and neutron generators) permits applications where neutron-excess isotopes (generally produced in reactors) are unsuited or unavailable. Successful developments in activation analysis and tracer techniques have extended the need to determine and to make available the spectral data for neutron-deficient nuclides. The gamma ray spectra for approximately 250 isotopes have been compiled and published. Further data will follow. Included are spectra compiled by both scintillation and semi-conductor—Si(Li) and Ge(Li)—spectrometers. More than 3,000 copies of the two-volume scintillation Gamma Ray Spectra Catalog, prepared by Phillips Petroleum Co., under AEC contract in 1962 have been sold,[3] and a third edition is in progress to meet the demand.

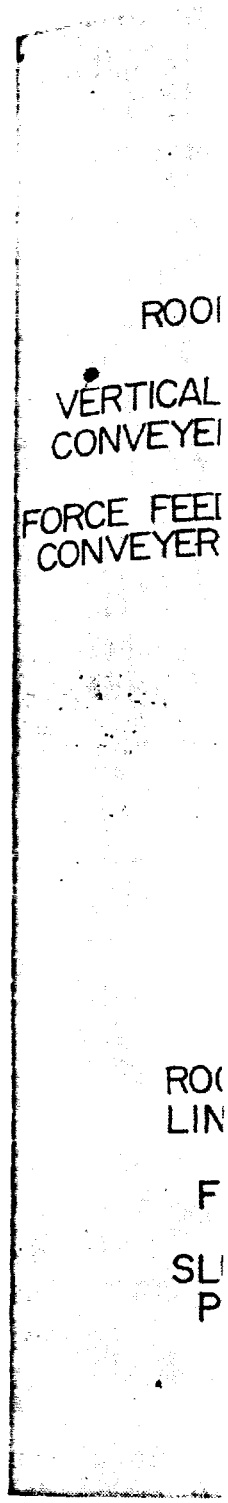
Analysis and Process Control

Process Control Facility

An on-line process-control pilot plant has been established to aid industry in evaluating process-control applications of neutron activation analysis. Particular products (coal, aluminum ore, fertilizer, and taconite) have been chosen for evaluations which will provide results having maximum industrial benefit when published. The work is being carried out by Texas Nuclear Corp. at Austin, Tex., under an AEC contract. A wide variety of product-flow conditions will be evaluated with solids and liquid slurries. Participating industrial concerns are supplying the bulk products for evaluation, plus whatever technical personnel and services are required to support the investigations.

[2] Available as "ITTR 1-1193-53" from the Clearinghouse for Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va. 22151 for $9.25.

[3] Available as "IDO-16880" from the Clearinghouse for Scientific and Technical Information, U.S. Department of Commerce, Springfield, Va. 22151 for $10.00.



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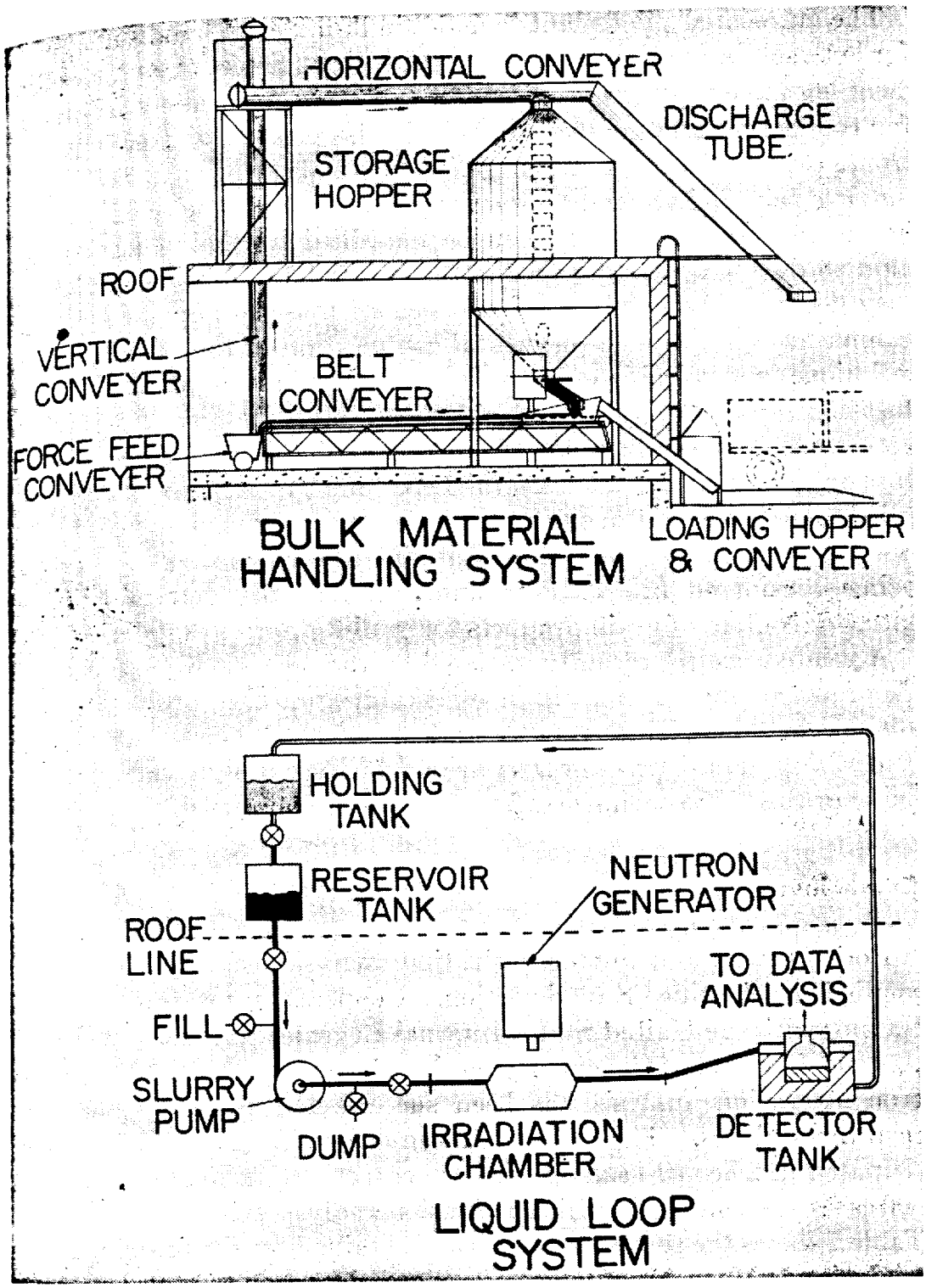

Process Control Facility. Drawings show the major components of the neutron activation process control systems, one for bulk materials and the other for liquids, being developed for the AEC by the Texas Nuclear Corp. In the process, a stream of neutrons, produced by a neutron generator, makes the material on the moving belt slightly and temporarily radioactive. The elemental composition of selected materials can then be determined by the characteristic gamma rays emitted by the material.

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The automated pilot plant includes bulk-material handling systems for both solids and liquids, neutron generators, detection and measurement equipment, digital computers, and a chemical assay laboratory for confirming nuclear techniques. In the process, a stream of neutrons, produced by a neutron generator, makes the material on the moving belt slightly and temporarily radioactive. Selected elements in the process stream can then be identified by their characteristic gamma rays which are emitted as they become radioactive and later as they decay. The number and energies of these prompt and delayed gamma rays indicate the elemental composition of the product. This technique is applicable only to elements that have a reasonably high fast-neutron cross-section (that is, those that react readily with energetic neutrons) such as oxygen, nitrogen, aluminum, silicon, carbon, copper, and sodium. To date, the technique has been successfully applied to measurement of ash and caloric content of coal and of the silicon and aluminum content of bauxite. Other processes currently being considered are taconite analysis, and the determination of nitrogen content of grain products for grading purposes.

A related project recently initiated by the AEC at Kaman Nuclear, Colorado Springs, Colo., will investigate the practical problems associated with industrial acceptance and use of this nuclear technique in controlling liquid processes. Various facility design variations are being evaluated to optimize safety, cost, and reliability of the system.

Crime Investigation

Both neutron and photon activation analysis techniques have been applied to scientific crime detection. Cooperative programs are continuing with the United States Internal Revenue Service, and General Atomic, Division of General Dynamics, Corp., San Diego, Calif. Neutron activation analysis has been successfully used in court room trial proceedings. The Internal Revenue Service (IRS) has now participated in 20 court cases involving neutron activation analysis; over 600 cases are pending in which activation analysis evidence will be used. Table I shows the type of information, obtained for the first time, on an analysis of "Moonshine" whiskey. These data are used to characterize and identify particular batches of whiskey. With this more detailed knowledge than heretofore possible, a sample of whiskey from an unknown source can be accurately matched with another sample from a known source: thus, very accurate identification can be made.

Cooperative Federal work. The IRS program has been extended to the examination of narcotic samples for the purpose of comparing and determining origin, hence making it possible to effectively prosecute

TABLE I.—COMPARISON OF "MOONSHINES" BY NEUTRON-ACTIVATION ANALYSIS AND GAS CHROMATOGRAPHY

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TABLE I.—COMPARISON OF "MOONSHINES" BY NEUTRON-ACTIVATION ANALYSIS AND GAS CHROMATOGRAPHY

		Elements (ppm)											Organic Congeners, g/100L				
Case No.	Sample No.	Na	Cu	Zn	Sr	Fe	Sb	Se	Au	Cr	Ce	Mn	Ethyl Acetate	Acetaldehyde	N-propyl Alcohol	Isobutyl Alcohol	Isoamyl Alcohol
107	1421	2.2	10.7	0.12	1.8×10^{-3}	T	T	*	*	*	*	6.3	3.8	28.0	5	18.5	72.5
	1422	3.0	11.7	0.13	2.0×10^{-3}	T	T	*	*	*	*	6.2	3.9	29.5	5	15.8	76.4
202	1472	1.0	15.6	T	*	*	*	3.0	T	*	*	10.2	28.0	47.5	4	18.8	56.4
	1473	1.1	15.8	T	*	*	*	3.2	T	*	*	10.3	27.0	47.2	4	19.5	56.8
	1474	1.1	16.0	T	*	*	*	3.8	T	*	*	10.2	27.5	47.0	4	19.2	57.0
	1475	1.1	15.7	T	*	*	*	3.2	T	*	*	10.1	28.2	47.5	4	19.7	56.9
342	985	4.0	0.07	1.3	*	*	*	*	*	0.32	0.90	1.4	0.9	5.2	5	15.8	39.2
	986	4.1	0.07	1.4	*	*	*	*	*	0.35	0.95	1.5	0.9	5.2	5	16.2	39.7
	987	4.1	0.08	1.3	*	*	*	*	*	0.31	0.90	1.6	0.9	5.3	5	16.2	39.8
	988	4.3	0.07	1.3	*	*	*	*	*	0.33	0.85	1.8	0.9	5.4	5	15.9	39.4
		By neutron-activation analysis											By gas chromatography				

*Not detected.
T = Trace, not calculable.

conspiracy cases. For the past 1½ years the crime laboratory, U.S. Post Office Department, has been actively using the IRS facility for examination of physical evidence connected with postal robberies and other such illicit activities. The IRS has also negotiated with the Department of the Army to permit the Army to carry out neutron activation analysis work at the IRS establishment. The cooperation of these agencies has resulted in substantial savings to the Government, since there is no duplication of facilities and personnel.

General Atomic program. The program at General Atomic, which is co-funded by the AEC and the Office of Law Enforcement Assistance of the Department of Justice, is using both neutron and photon activation to compile a catalog of statistical data on materials normally used as evidence—such as paint, glass, paper, gun powder, and lead. In conjunction with the technology development, a determined effort is being made to keep the forensic community informed. Seminars, meetings, papers, and visual aids are used to help promote the concept within the States as well as abroad.

Littoral (Sand) Transport

Nuclear applications and instrumentation are being investigated in a long-term AEC cooperative program with the U.S. Army Corps of Engineers to develop methodology suitable for measuring littoral drift along the California coast. Four agencies—the Department of Army, the Department of Navy, the Department of Air Force, the National Aeronautics and Space Administration—and the State of California are participating in this program to investigate littoral transport around Point Conception, about 42 miles northwest of Santa Barbara. Oak Ridge National Laboratory is providing guidance in the tracer area.

Oxygen Analyzer for Oceanographic Use

A deep-sea version of the dissolved oxygen analyzer [4] for accurate measurements of slow-moving water currents has been successfully constructed and tested by Research Triangle Institute, under an AEC contract. The system is based on the radio-release of thallium ions from a column consisting of metallic thallium deposited on copper turnings and the detection of the ions by a ring of radiation detectors surrounding the source. The unit has been field tested by the Duke University's Marine Laboratories at Beaufort, N.C., and is now undergoing extensive testing by the Navy Oceanographic Office. The results will serve

[4] See p. 204, "Annual Report to Congress for 1963."

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as the basis for the design and development of the final unit. The unit is to have an operational depth of over one mile.

Related to the oceanographic applications is the use of a deep water isotopic current analyzer (DWICA) in routine testing of flow patterns at Fontana Dam, N.C. No other method in the past has been satisfactory. This unit was developed under AEC contract by the William H. Johnston Laboratories, Baltimore, Md.; an earlier prototype had been successfully tested by the Navy Oceanographic Office at Argus Island in the Atlantic.[5]

[5] See pp. 206–207, "Annual Report to Congress for 1963."

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Chapter 11

THE PLOWSHARE PROGRAM

Private industry showed increasing interest in underground nuclear explosion engineering techniques for natural resources development and management during the year. A milestone was achieved in this area when negotiations were started between the Government and El Paso Natural Gas Co., El Paso, Tex., for the first joint industry-Government Plowshare experiment, Project Gasbuggy. Nuclear experiments and related studies were conducted during the year to support the continuing Plowshare excavation and scientific programs.

NATURAL RESOURCES DEVELOPMENT

The United States Bureau of Mines (USBM) has estimated there are 2 trillion barrels of oil locked in oilshale formations in Colorado, Utah, and Wyoming that await development of economic techniques for recovery. Also, in the Rocky Mountain States over 300 trillion cubic feet of natural gas is estimated to be in formations of low permeability which are not amenable to economic exploitation by existing means. As discussed below, Plowshare program investigations offer the possibility that nuclear explosives detonated deep in the earth may be the basis for developing new techniques to recover such oil and gas, as well as other natural resources, economically, and more completely.

PROJECTS AND STUDIES

At year's end, with site preparation for Project Gasbuggy underway, three other possible projects involving recovery or storage of natural resources were under study.

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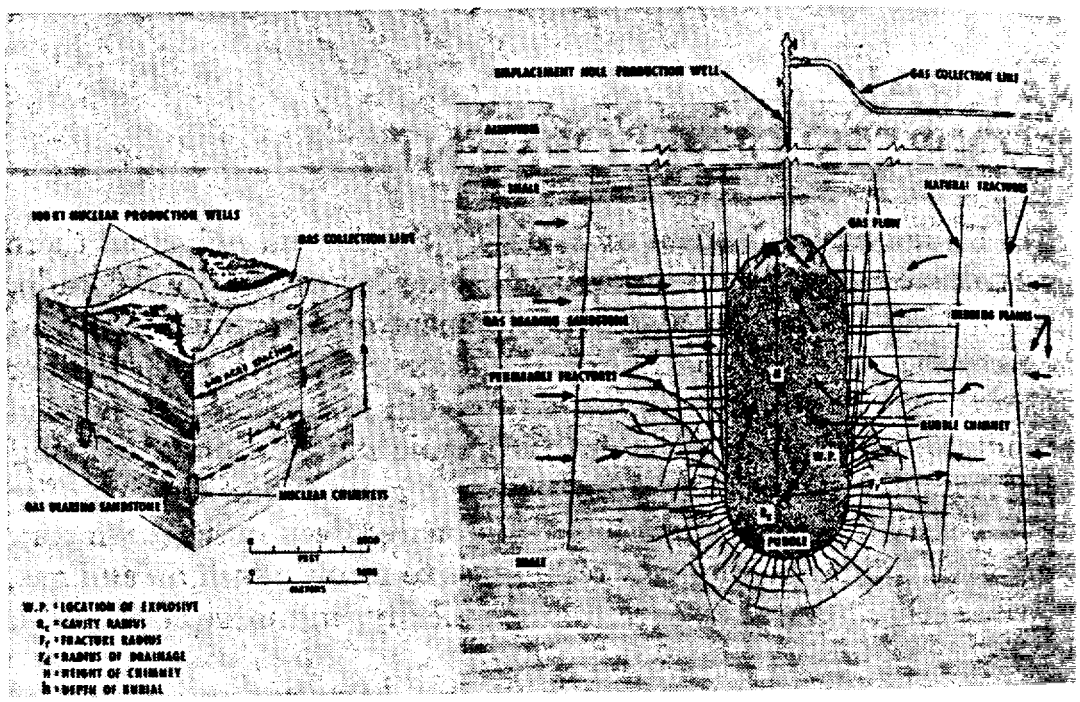
Natural Gas Stimulation

Natural gas is produced commercially from underground reservoirs of permeable rock in which the gas has been trapped. Normally, when a well as drilled into the reservoir rock, natural pressure causes the gas to flow freely into the well from the pores in the rock. In this way, a single well can drain the gas from a large volume of reservoir rock at a rate fast enough to be economically worthwhile.

In many areas in the western United States and Canada, however, natural gas is found in reservoir rock of such low permeability that the gas cannot be produced economically from a normal well. The trapped gas, if it flows at all, does not flow freely enough into the well to give a useful rate of production. Nuclear explosions may be used to increase, or stimulate, the production of gas from such tight reservoirs. In the proposed method, nuclear explosions would be set off in the reservoir rock to create large zones of fractured and broken rock into which the gas could flow more freely.

The Green River Basin in Wyoming, the Piceance Creek Basin in Colorado, and the San Juan Basin in New Mexico and Colorado are the most prominent of the sedimentary basins in the Rocky Mountain



Gas Reservoir Stimulation. In many areas, relatively impermeable rock prevents the economical recovery of natural gas by conventional means. The Lawrence Radiation Laboratory, Livermore, drawings show how nuclear explosives might be used to enhance the recovery of gas from impermeable rock by creating large "chimneys" into which the gas can flow from the surrounding fractured rock. Site preparation has begun in the San Juan Basin, in the northwestern area of New Mexico, for Project Gasbuggy—the first experiment to develop such a peaceful use for nuclear explosives.

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[1] See pp. 193–194, "An

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states containing gas-bearing reservoirs of low permeability with sufficient thickness to warrant consideration for nuclear stimulation. In addition, areas in western Canada and in parts of Kansas, Oklahoma, and Texas, may also be amenable to this technique. If Project Gasbuggy, the first nuclear gas stimulation experiment, and subsequent experiments show the technique to be feasible, the Nation's recoverable natural gas reserves will be greatly increased.

Project Gasbuggy

Gasbuggy is the first of several experiments to evaluate the use of completely contained nuclear explosions for increasing productivity of natural gas in formations of low permeability. The project is being conducted jointly by the El Paso Natural Gas Co., the USBM, and the AEC. The project resulted from an 18-month feasibility study by representatives of the three organizations, following which El Paso made a proposal to the AEC in 1965 to carry out such an experiment as a jointly sponsored venture.[1]

Initial site preparations have begun in the San Juan Basin, about 55 miles east of Farmington, N. Mex. The first phase involves drilling two wells to measure pre-shot gas production and to obtain additional geological, geophysical, and hydrological information required to establish the pre-shot characteristics of the site and the gas formation to be stimulated. The pre-shot measurements will be used as a basis for evaluating the post-shot results, including increases in gas production.

Radioactive Contamination of the Gas

In the stimulation of gas production with nuclear explosions, the possible concentration of radioactive isotopes in the natural gas produced must be carefully considered. It is known that after 6 to 12 months the short-lived radioactive isotopes will have decayed to acceptable levels, leaving essentially only longer-lived krypton 85 (10-year half-life) and tritium (hydrogen 3) (12-year half-life). Laboratory studies are now being conducted by the U.S. Bureau of Mines and Lawrence Radiation Laboratory, Livermore, to determine the best methods of reducing the concentrations of these two products in the gas produced. Actual concentrations and the effectiveness of control measures will be verified in Project Gasbuggy and other field experiments.

[1] See pp. 193–194, "Annual Report to Congress for 1965."

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Other Gas Stimulation Proposals

In the latter half of the year, the AEC received two additional proposals from industry to join in cooperative experiments to stimulate natural gas reservoirs using nuclear explosives. One proposal, named Dragon Trail, was submitted by the Continental Oil Co., Houston, Tex., together with CER Geonuclear Corp.,[2] Las Vegas, Nev.; the other, named Rulison, by the Austral Oil Co., Houston, Tex., and CER Geonuclear Corp. Both proposals involve sites in western Colorado for the experiments. The AEC is currently conducting a comprehensive review and evaluation of these proposals as possible gas stimulation experiments which would be based on and extend the Gasbuggy results.

Recovery From Oil Shale

A recent theoretical study at Lawrence Radiation Laboratory, Livermore (LRL–L) examined the problem of extracting oil from the broken oil shale rock in the "chimney" created by an underground nuclear explosion. Results of the study suggest that a large part of the shale oil, including that in chunks of shale as large as several feet across, can be removed by igniting the broken shale and by maintaining combustion with air supplied to the chimney through drill holes—a process known as "retorting". Heat from the burning front would decompose the solid hydrocarbons in the shale to produce liquid oil, which would collect in the lower portion of the chimney. The oil could then be removed through drainage wells and pumped to the surface.

50–70 Percent Recovery Potential

The proposed nuclear-chimney "retorting" system may use temperatures considerably lower (750° F.) than those in most previously suggested retorting schemes, and thus, could require a lower pressure level of forced air with resultant lower compressor costs. It is estimated that 12 to 18 months would be required to retort completely the broken oil shale in a chimney formed by a 100-kt nuclear explosion. Recovery of 50- to 70-percent of the oil is expected.

Results of the LRL–L theoretical study are in excellent agreement with experiments being conducted at the U.S. Bureau of Mines (USBM), Petroleum Research Center, Laramie, Wyo., in which frag-

[2] In 1965, three firms—the Continental Oil Co., Edgerton, Germeshausen and Grier, Inc. (now formally known as EG&G, Inc.), and Reynolds Electric Co.—formed CER Geonuclear, Inc., to provide a complete "Plowshare Service" to interested firms; see p. 37, "Annual Report to Congress for 1965."

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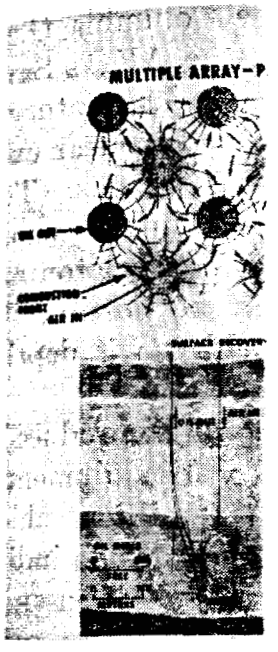

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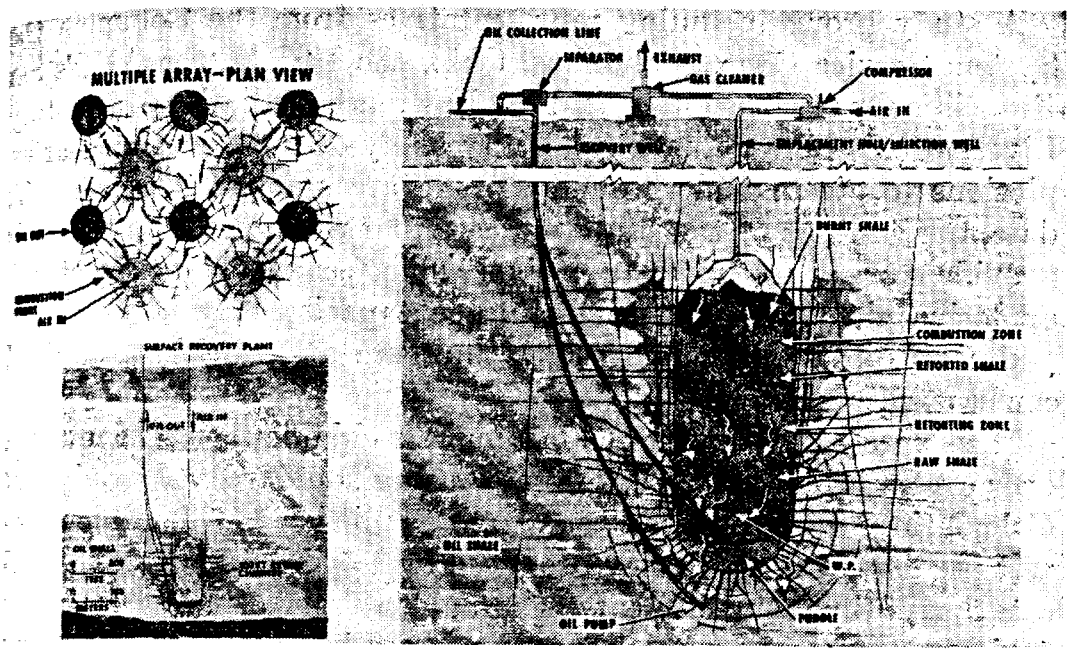
ments of oil shale in the range of sizes anticipated in the nuclear-chimney were retorted in a 6-foot-diameter, 12-foot-high vessel.

It has been estimated that the Piceance Basin in western Colorado contains 320 billion barrels of oil in shale formations of 500 feet or thicker, with an average oil content of 25 gallons per ton. A successful nuclear-chimney retorting system would be a way of recovering at least half of this reserve, or 160 billion barrels.

Proposed Oil Shale Experiment

Twenty-four domestic oil and allied companies have joined with the CER Geonuclear Corp., to consider making a proposal to the USBM and AEC to conduct a joint nuclear explosion experiment in oil shale. The first step will be to undertake a joint Government-industry feasibility study including the companies, AEC, and the USBM. Such a study would include the development of a technical concept by LRL–L for an experiment to test the use of an underground nuclear explosion



Retorting of Oil Shale. Presently, the Nation's oil reserves take into account only the pools of liquid oil from which the oil can be recovered by conventional wells. However, great quantities of oil are "locked" in deep underground oil shale formations. By breaking this rock and heating it, decomposition occurs and oil is produced. A joint study by the AEC and U.S. Bureau of Mines indicates that it may be economically and technically feasible to use nuclear explosions to break up the oil shale. In this approach—as envisioned in the Lawrence Radiation Laboratory, Livermore, drawings—the broken oil shale rock would be ignited, and burning maintained by forced air injection. The oil produced would be pumped to the surface. A group of over 20 oil companies has indicated an interest in conducting an experiment to test this theory.

to prepare an oil shale deposit for *in-situ* (in-place) retorting. If a sufficient volume of broken shale were produced by such an explosion, retorting techniques could be tested in a second phase of the experiment.

Underground Gas Storage

Increasing use of natural gas has brought a demand for more storage capacity than can be met by existing underground storage reservoirs, such as depleted natural gas fields and aquifers near major consuming methods. Present indications are that the demand for gas storage capacity will grow by at least 175 billion cubic feet per year. Creating large underground chimneys by nuclear explosions appears to be one promising method of providing new storage capacity near the consumer-end of gas transmission lines.

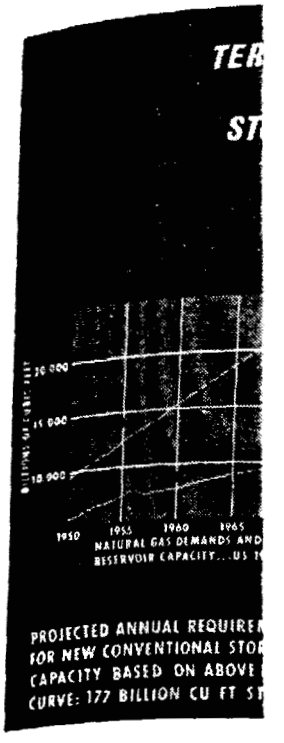
Study Shows Feasibility

A study group including representatives from the Columbia Gas System Service Corp., Columbus, Ohio, the USBM, the AEC's San Francisco Operations Office, and the Lawrence Radiation Laboratory, Livermore, is completing a feasibility study of the use of nuclear explosions to create underground storage areas for natural gas. To date, the findings of the study indicate that a nuclear-chimney could provide storage for up to 10 million cubic feet of gas per kiloton of explosive yield. Even greater storage capacity may be possible if pressures higher than hydrostatic pressure at the chimney's depth can be used.

It is expected that gas stored in a nuclear-chimney could be produced over a very wide range of flow rates using standard well equipment. Calculations made for flow rates from 10 million to 500 million cubic feet per day from a chimney produced by a 50 kiloton explosion indicate that optimum investment costs would be from $2 to $4 per thousand cubic feet of usable gas storage capacity at hydrostatic pressure and even less, if higher pressure can be used. This compares with costs of $0.50 to $1 for storage in depleted gas fields; $1 to $2 for storage in natural aquifers; and $6 to $12 for storage of liquified natural gas.

Project Ketch

The joint Government-industry feasibility study of the gas storage application includes a technical concept of an experiment to test the findings of the study. The experiment, named Project Ketch, would use a 20-to-30-kiloton nuclear explosive emplaced at a depth of about 3,300 feet in a drilled hole about 18 inches in diameter. The under-



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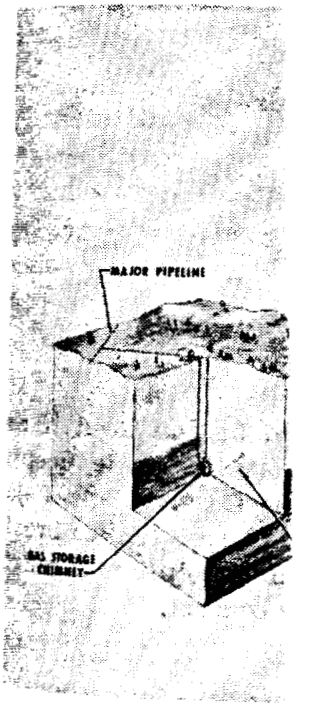

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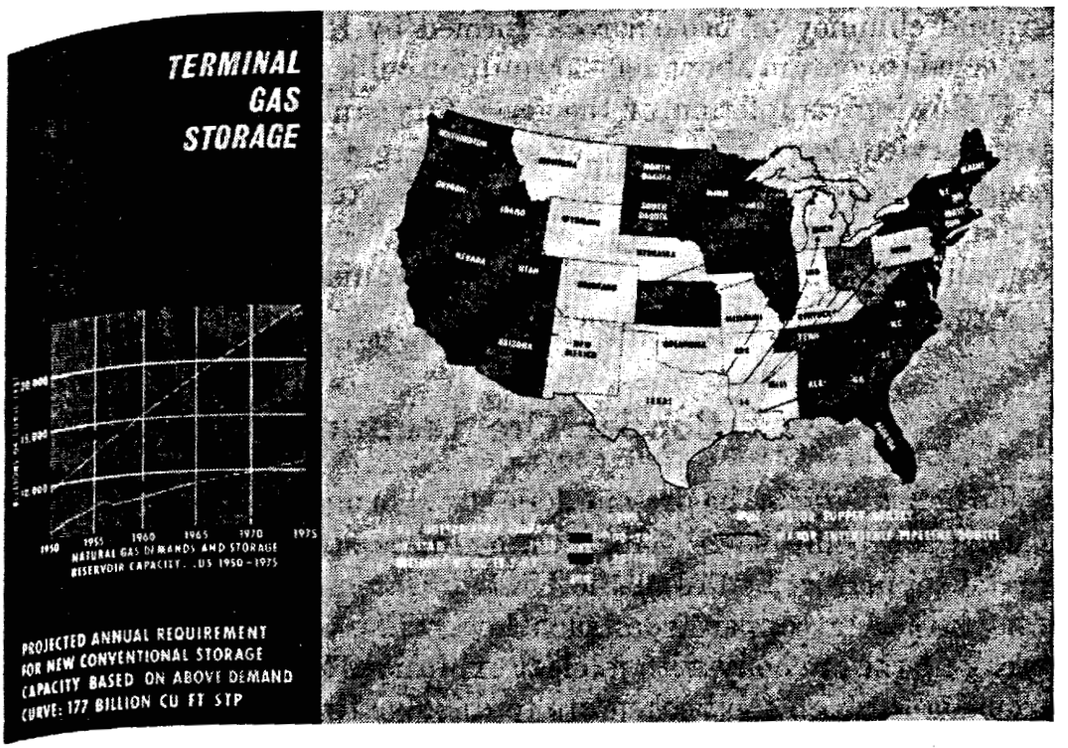
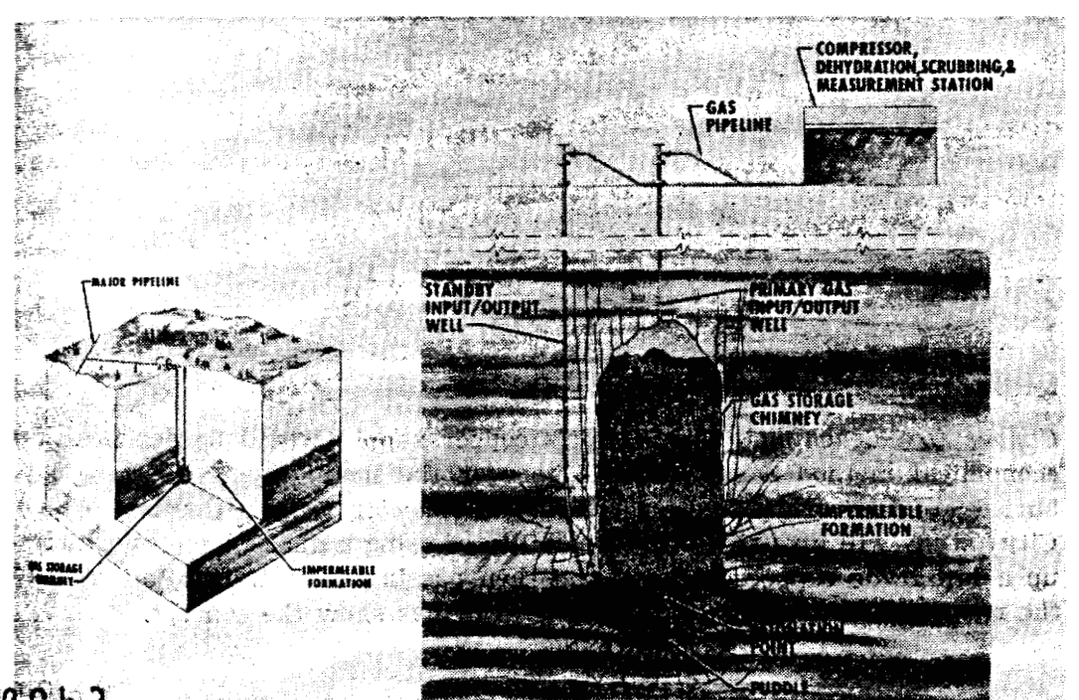


Terminal Gas Storage. In recent years, the natural gas industry has used underground caverns and depleted natural gas wells to supplement conventional aboveground facilities to store natural gas near consumers in order to meet peak demands. Present, and foreseen increases in use of natural gas indicate that a much greater storage capability will be needed at the end of, or adjacent to, transmission lines. The Columbia Gas System Service Corp., Columbus, Ohio, has suggested to the AEC that a nuclear explosive be used to create a "chimney" in a relatively impermeable rock formation which could be used for storing gas. The drawing *above* shows the relationship of the gas-producing and user States, the major transmission lines, and the projected demand and required storage curves. The drawing *below* portrays the concept for creating terminal gas storage reservoirs by nuclear means.



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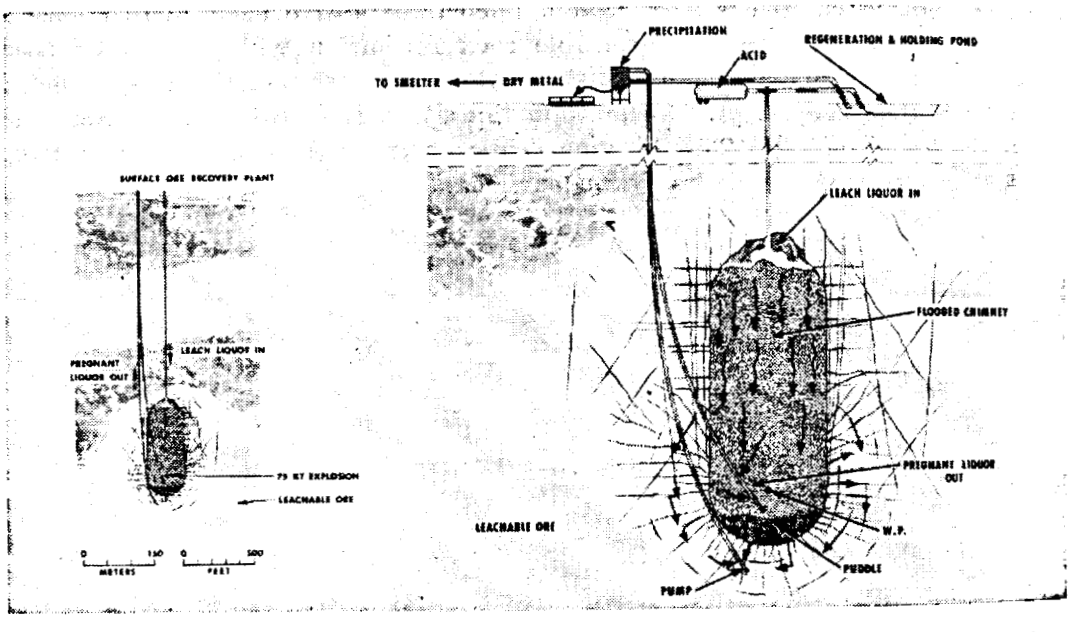
ground chimney of broken rock formed by the detonation would be expected to contain about 200–300 million cubic feet of storage capacity.

Following completion of the feasibility study, Columbia Gas System Service Corp., will consider submitting a proposal to the AEC to conduct Project Ketch at a site locally remote, but regionally close to population centers in its service territory. Columbia's service territory includes parts of New York, Pennsylvania, Ohio, Maryland, West Virginia, Virginia, and Kentucky.

Copper Ore Leaching

To help alleviate the present domestic shortage of copper, economical means are being sought for mining increasingly deeper and lower grade copper ore bodies in the United States. A proposed technique for extracting copper from such low-grade, deeply buried ore, is to break up the ore body with nuclear explosions and to pass a "leaching" solution through the broken ore to dissolve the copper. The copper-bearing solution would then be recovered from the ore body for processing to separate the copper from the solution. The advantage of dissolving the copper ore in place is that it eliminates the necessity of mining and bringing to the surface the huge quantities of low grade



Copper Ore Leaching. The Nation's copper supply would be enhanced if an economical method were found to recover the metal from low-grade deeply buried ore bodies. A joint Government-Kennecott Copper Corp. (Salt Lake City) study will investigate the feasibility of using a nuclear explosion to break up a low-grade copper ore body and then passing a leaching solution through the rubble to recover the copper. The drawings show the concept.

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ore that must be treated for extraction of the copper and then disposed of as was the material.

Leaching of low-grade copper ore, broken but left undeveloped during the mining of higher grade ore has been practiced for many years. The key to such "solution" mining is the breaking of the ore, to permit the leaching solution to come in contact with the copper. Until the development of nuclear explosives there has been no method to break the low grade ore deposits other than mining and this has been too costly in relation to the small amount of copper that could be recovered.

Personnel from the Salt Lake City, Utah, office of the Kennecott Copper Corp., the AEC's San Francisco Operations Office, the USBM, and LRL–L, are conducting a detailed feasibility study of this application. After completion of the study, a field experiment in nuclear ore-breaking and leaching, to be called Project Sloop, may be proposed to verify the study's findings.

Project Sloop

Project Sloop is conceived as a 20- to 30-kiloton nuclear detonation at a depth of about 1,200 feet in a low-grade copper deposit. The experiment would be designed to determine whether copper can be produced economically from ore broken by a contained underground nuclear explosion. After the ore-breaking (explosion) phase of the experiment would come a leaching test to evaluate leaching techniques and radioactivity levels. A primary site in the Safford, Ariz., area has been identified for study.

The question of radioactive contamination of copper ore has also been studied, with the general conclusion that it is a manageable problem since:

(1) Concentrations of radioactive isotopes in the leach solution would be sufficiently low so that special shielding to protect against radiation exposure would not be needed; and

(2) The most troublesome radioactive isotopes would probably be those of metals, such as silver 110, zirconium 95, niobium 95, and ruthenium 106. Fortunately, the relatively non-volatile radionuclides would be locked in the congealed "puddle glass" at the bottom of the cavity and only a small percentage would enter the leach solution. Subsequent metallurgical processing by a newly developed solvent extraction process may remove virtually all radioactive contaminants from the finished copper.

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OTHER ENGINEERING ACTIVITIES

In addition to laboratory studies in support of specific proposed underground engineering projects, general research and development activities were continued in 1966 to increase the understanding of the effects of underground nuclear explosions and to improve excavation technology.

CAVITY AND CHIMNEY STUDIES

Studies of past underground detonations as well as current experiments are providing information on cavity and chimney development on a practical as well as theoretical basis.

Handcar Chimney Studies

To learn more of the shape, volume and composition of chimneys produced by underground nuclear explosions in hard rock, a vertical exploratory hole was drilled into the top of the chimney created by the November 1964 Project Handcar [3] experiment—12 kilotons at a depth of 1,320 feet in dolomite at the Nevada Test Site (NTS). The top of the chimney was found to be 223 feet above the shot point, a height about 23 percent less than had been expected on the basis of experience in granite.

Pressurization tests indicate a total void volume in the chimney, including the empty spaces between the rubble particles, of about 1,315,000 cubic feet. This corresponds to a radius of about 68 feet for the initial cavity produced by the shot. An optical survey and stereophotographs show that the void space at the top of the chimney above the rubble is more than half the volume of the original cavity.

Cavity Collapse and Chimney Development

To improve understanding of how chimneys develop above the cavity produced by an underground nuclear explosion, LRL–L, performed a NTS experiment in which information was obtained on the collapse of the alluvium overlying a nuclear explosion at a depth of 1,125 feet. As is typical of underground explosions in alluvium, the collapse of the material above the cavity extended all the way to the surface and produced a "subsidence crater." Collapse data were obtained for points on the surface and beneath the surface down to a depth of 750 feet. Surface collapse was monitored by photographing

[3] See p. 162, "Annual Report to Congress for 1964", and p. 208, "Annual Report to Congress for 1965."

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[4] See pp. 163–164

a series of targets resting on the surface above the shot; underground collapse, by special detectors. Particle velocity and acceleration measurements were also made.

As expected from earlier studies, the collapse was massive and rapid once it began; the propagation rate of the collapse front was 100 to 150 feet per second. At a given depth, the collapse was found to start about three seconds earlier in the center of the chimney than at the edges. This lag continued as collapse progressed upward from the cavity to the surface.

Similar chimney development studies are needed for other materials besides alluvium, particularly for materials that are likely to be encountered in some of the proposed underground applications of nuclear explosions.

Prediction of cavity size. A study conducted at LRL–L, has shown that the water content of the host rock affects the size of cavities produced by nuclear explosions. An equation was derived which describes the cavity dimension when the rock density, water content, depth of the explosion, and explosive energy are known.

Re-Entry Technique

During the year, LRL–L, developed a cost-saving technique for re-entering the cavity produced by a nuclear explosive through the original device emplacement hole. Using this technique to re-enter the cavity produced by the Salmon event,[4] a saving was made of approximately 50 percent of the cost of drilling a second hole of the same size and depth. (See discussion on "Project Sterling" in Chapter 5—The Nuclear Defense Effort.) With an emplacement hole and emplacement hardware designed specifically for re-entry purposes, an equivalent or greater saving could be realized on future Plowshare projects, particularly those in which a relatively large diameter hole can be useful for commercial purposes after the explosion.

EXCAVATION TECHNOLOGY

For nuclear excavation technology to advance to the stage where it can be used in large construction projects, the following major technical questions must be answered:

(*1*) How does crater size depend on geologic properties?

(*2*) Can data on crater size, seismic effects, acoustic waves, and radioactivity distribution of low yield experiments be extended to yields in the megaton range?

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

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(*3*) How do nuclear charges in a row interact?

(*4*) Can projects for nuclear excavation of channels through terrain varying in rock type and elevation be designed with confidence?

To answer these questions a number of excavation experiments are required and, to this end, the nuclear cratering experiment Cabriolet was designed by LRL–L. In addition, the U.S. Army Corps of Engineers' Nuclear Cratering Group (NCG) initiated Pre-Gondola,[5] a series of chemical high explosive experiments near Ft. Peck, Mont.

Project Cabriolet

Cabriolet, a low yield nuclear cratering event in hard, dry rock was readied at NTS during 1966 and has been authorized for execution early in 1967. The Cabriolet explosion, which is expected to release an energy equivalent to 2,500 tons (2.5 kilotons) of TNT, will occur 170 feet underground and is expected to form a crater with a depth in the range of 115 to 145 feet, and a diameter of 425 to 460 feet.

Project Cabriolet is an important step in providing essential data on basic cratering effects and the distribution of radioactivity released from a nuclear explosion occurring at what appears to be the best depth underground in a hard, dry rock. Cabriolet will release six times more energy than the largest experiment previously conducted in hard rock at an equivalent depth of burial—Project Danny Boy[6] which released 0.4 kilotons. Although the largest Plowshare cratering experiment to date—Project Sedan[7]—released 100 kilotons of energy, it was done in desert alluvium, a loose sand and gravel material. Thus, Cabriolet will be the largest yield cratering experiment conducted to date in hard rock, the material expected to be the most frequently encountered in future excavation projects.

The information obtained from the experiment will be used in developing further the understanding of how craters are formed. In turn, this understanding is expected to result in increased confidence for predicting the characteristics of craters in other types of rock and from larger explosions. Data from field experiments, such as Cabriolet, combined with the most advanced knowledge of the physical and chemical properties of rock materials and explosion phenomena, provide the input to complex computer calculations which produce a description of the entire cratering process. Thus, each cratering experiment improves the computer calculations, and hence, the overall description of the cratering phenomenon.

[5] While no specific "Gondola" experiment is currently scheduled, the "Pre-Gondola" term is used to identify this particular series of non-nuclear experiments.

[6] See p. 250, "Annual Report to Congress for 1962."

[7] See pp. 159–161, "Annual Report to Congress for 1964."

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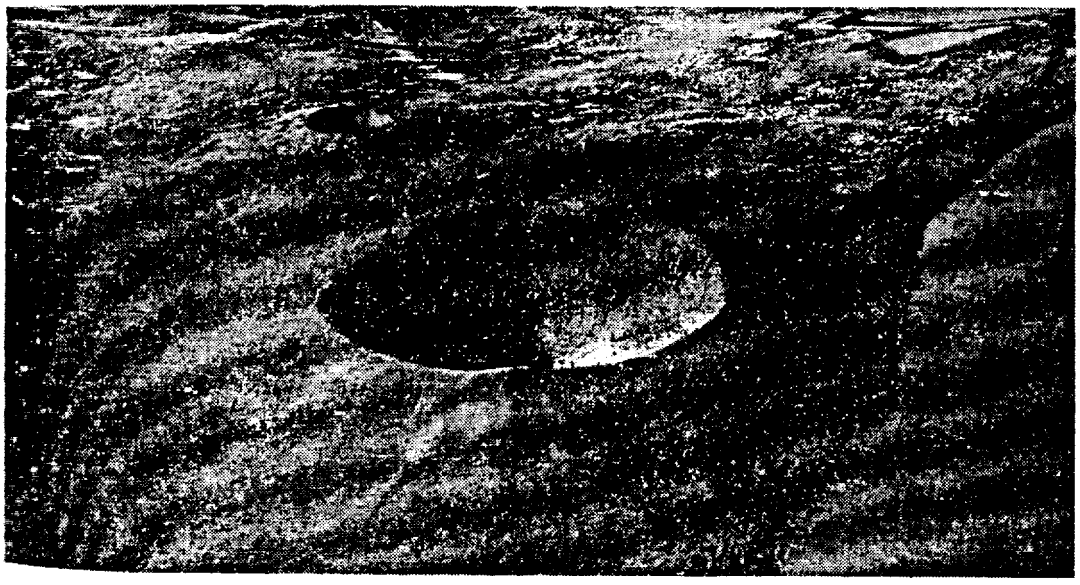
Cratering Experiments. The AEC and the U.S. Army Corps of Engineers are jointly developing experience and information on the cratering and seismic effects of explosives as a prelude to the possible use of nuclear explosives for civil engineering purposes. During 1966, the Corps of Engineers began Project Pre-Gondola, a series of chemical high explosives cratering experiments in weak wet clay shale near Fort Peck, Mont. Shown in the foreground in photo *above* is the crater from a shot detonated below the level of the Fort Peck Reservoir at a total depth of 15.8 feet. Indicated by the arrow is the crater from a shot, detonated at a depth of 23.3 feet in the saturated clay shale. Photo *below* shows the result of a 20-ton nitromethane cratering charge detonated on October 28, at a depth of burst of 42.5 feet in clay shale. It produced an apparent crater 80.6 feet in radius and 32.6 feet deep. The crater in the background is from a 1,000-pound nitromethane charge at a lesser scaled depth of burial.



Pre-Gondola Experiments

Project Pre-Gondola was initiated in 1966 by NCG as part of the joint AEC-Corps of Engineers' research program to develop the feasibility, costs, and other factors involved in nuclear methods of excavation.

This series of high explosive cratering experiments, adjacent to the Fort Peck Reservoir, Valley County, Mont., will extend cratering experience to a weak wet clay shale at the ½, 20, and 100-ton level for single and row charges. The Pre-Gondola series includes single-charge cratering calibration experiments, a row-charge cratering experiment to produce a linear excavation in a varying terrain, and a connecting row-charge cratering experiment.

Following four 1,000-pound seismic calibration detonations in June, NCG conducted Pre-Gondola I, a series of four 20-ton high explosive detonations in October and November. The purpose of Pre-Gondola I was to calibrate the cratering characteristics of the project site and to provide a basis for the design of the 100-ton Pre-Gondola row charge cratering detonations.

Interoceanic Sea-Level Canal

The AEC has undertaken studies and surveys to provide information which the Atlantic-Pacific Interoceanic Canal Study Commission may use to evaluate the safety and cost of using nuclear explosives to excavate a sea-level canal. These activities, which are integrated with other investigations being conducted by the U.S. Army Corps of Engineers and the Panama Canal Co., are part of the over-all engineering feasibility study being conducted for the Canal Study Commission ". . . To provide for an investigation and study to determine a site for the construction of a sea-level canal connecting the Atlantic and Pacific Oceans . . ." in accordance with Public Law 88–609.[8]

On-Site Surveys Authorized

Exchanges of notes between U.S. Ambassadors and the Foreign Ministers of Panama and Colombia were concluded on February 15 and October 25, respectively, authorizing the Government of the United States to engage in on-site surveys in those countries. These agreements enabled the AEC to begin on-site safety feasibility surveys in the area of proposed Route 17 (Sasardi-Morti) in the Darien

[8] See pp. 196–197, "Annual Report to Congress for 1965."

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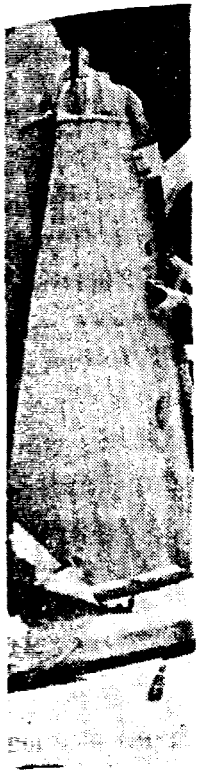

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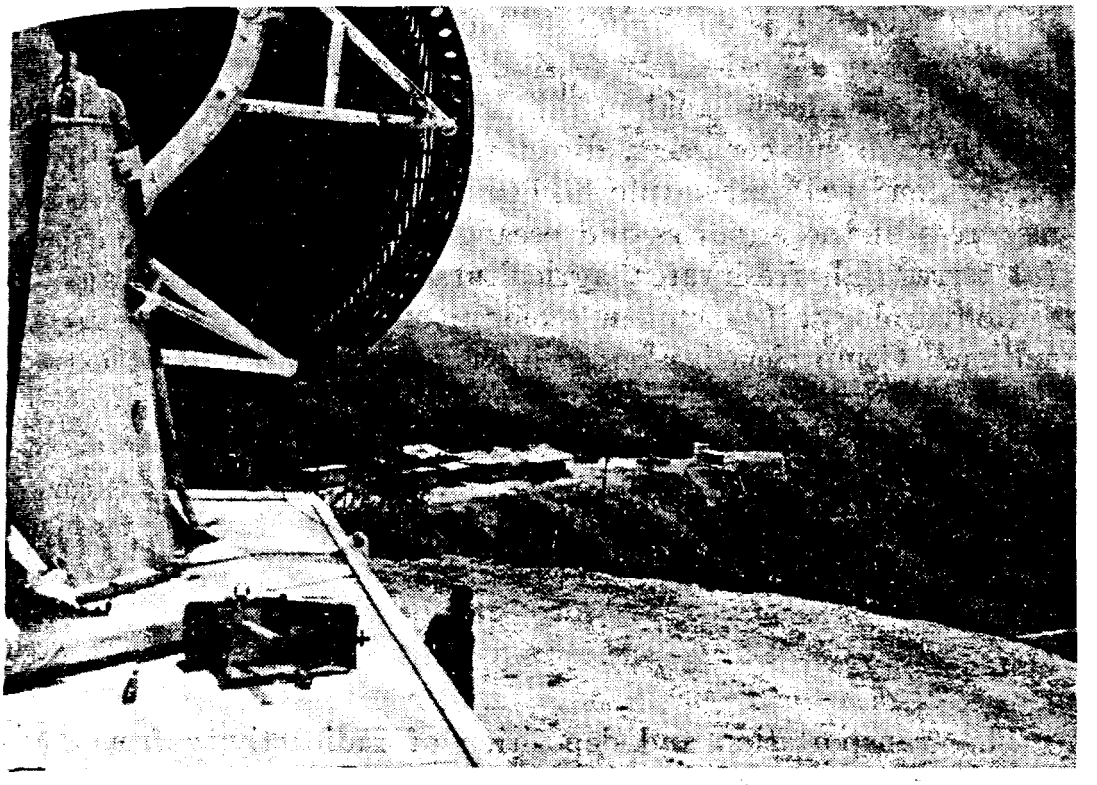
region of eastern Panama and will permit initiation of full-scale field activities both there and at Route 25 (Atrato-Truando) in Colombia beginning in January 1967.

Acoustic Wave Program

Soundings of the upper atmosphere were begun in Panama on March 9, with the firing of the first stratospheric weather rocket. These rockets, which will be fired weekly over a two year period, release metallic chaff at high altitudes. The chaff is then tracked by radar in-



Canal Study. A tracking radar station is shown at a remote meteorological observation outpost established by the Environmental Science Services Administration (ESSA) within the jungle of Darien Province, Panama, to support United States sea level canal feasibility studies. The U.S. Atlantic-Pacific Interoceanic Canal Study Commission is carrying out feasibility studies to determine where and by what method, conventional or nuclear, a sea level canal should be excavated. The AEC is responsible for conducting safety feasibility studies with respect to possible effects of radioactivity, air blast, and ground shock that might be associated with possible nuclear excavation; these studies are part of and support the over-all engineering feasibility studies. The AEC meteorology program being conducted by ESSA is studying wind directions and velocities, and precipitation. The radar unit shown here tracks wind patterns to as high as 60,000 feet. A second nearby radar unit scans the horizon as far away as 100 miles looking for rainfall. Data developed by these activities will be evaluated to establish weather patterns which would be necessary to safely conduct nuclear excavation if it is decided to construct a sea level canal using nuclear explosives.

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dicating the speed and direction of winds at altitudes of 100,000 to 200,000 feet. Other rockets are also being sent aloft to obtain temperature ranges at high altitudes and to supplement wind direction and velocity data obtained from the chaff rockets. This information will be evaluated to provide a capability to predict long-range transmission of acoustic waves from nuclear cratering explosions, and their possible effects on man-made and natural structures.

Bioenvironmental Program

The Battelle Memorial Institute (BMI) of Columbus, Ohio, under an AEC contract, is managing the bioenvironmental studies to determine the radiological-safety feasibility of using nuclear explosives to excavate a sea-level canal in the American Isthmian region. BMI will through sub-contracts, direct studies and the necessary on-site surveys on: (*a*) marine physiochemistry and biology; (*b*) fisheries resources of the estuaries and oceans on both sides of the isthmus; (*c*) terrestrial, freshwater, agricultural, and marine ecologies; (*d*) radiohydrology; (*e*) human ecology; and (*f*) radiation dose estimation. Comprehensive research has been undertaken to determine the essential information which could be obtained from site surveys and detailed plans made for collecting data in the probable route areas. Scientists will go into the field to collect specimens and develop information during the January through March dry season in 1967.

Meteorology

The transportation and deposition of radioactivity from nuclear cratering explosions depends to a large extent on meteorological conditions at the time of the detonations and for an indefinite period afterward. The Environmental Science Services Administration (ESSA), under AEC contract has designed, and is conducting, a two-year meteorological program to develop sufficient information for a safety feasibility study of this question.

Two weather stations have been constructed and were placed in operation on Route 17 in the Darien region of Panama. One is located at Pidiaque, a few miles in from the Pacific Ocean and the other on Soskatupu Island in the Caribbean Sea. These stations, operating 24 hours a day, are collecting data on wind patterns and rainfall. Wind measurements are made by tracking balloons with radar four times daily at altitudes up to 60,000 feet. Low-level measurements are also made on 150-foot towers to determine local wind flow. The Pidiaque station, near the Pacific, makes continuous observations of precipitation within a radius of 60 miles. Information is obtained in-

dicating density and location of the rain and the altitudes to which the rain extends.

Similar stations will be constructed and manned in Colombia near Route 25 in 1967.

Excavation Research and Development

Special Explosives and Emplacement Techniques

One major goal of the excavation development program is to reduce the amount of radioactivity released to the atmosphere to an absolute minimum. Efforts have continued on the development of explosives with a minimum of fission and induced radioactivities and on special emplacement techniques. Three tests related to this program were conducted by LRL–L with very encouraging results.

Cratering Calculations

LRL–L, has developed a computer-based technique for calculating the mound and cavity growth during nuclear and high explosive cratering explosions. The calculations feature a standard numerical approach to high intensity stress-wave propagation, coupled with a unique model of material behavior. The properties of the earth materials are determined from geophysical logging at the site of the event and from laboratory tests of rock samples. With this information, the computer code calculates the extent of the ejected material, the resulting crater radius, and the mass deposition. The calculations since made with this technique for the 1962 Danny Boy experiment are in good agreement with the actual radius and ejecta deposition. A next step in the calculation effort is to determine the bulk volume of material that falls back into the crater to obtain crater depth. This then will lead to studies of the stability of the slope of the resulting crater.

Acoustic Wave

Acoustic waves emitted from a nuclear explosion at excavation depth produce an effect, similar to a "sonic boom," close to the explosion and sometimes, at more distant locations where the acoustic waves may be focused by atmospheric conditions. This effect of nuclear cratering explosions is being examined at LRL–L where scientists are calculating both the close-in air shock and the long-range acoustic signal refracted in a layered atmosphere. LRL–L is using these calculations to develop computer codes which will be applied in making acoustic

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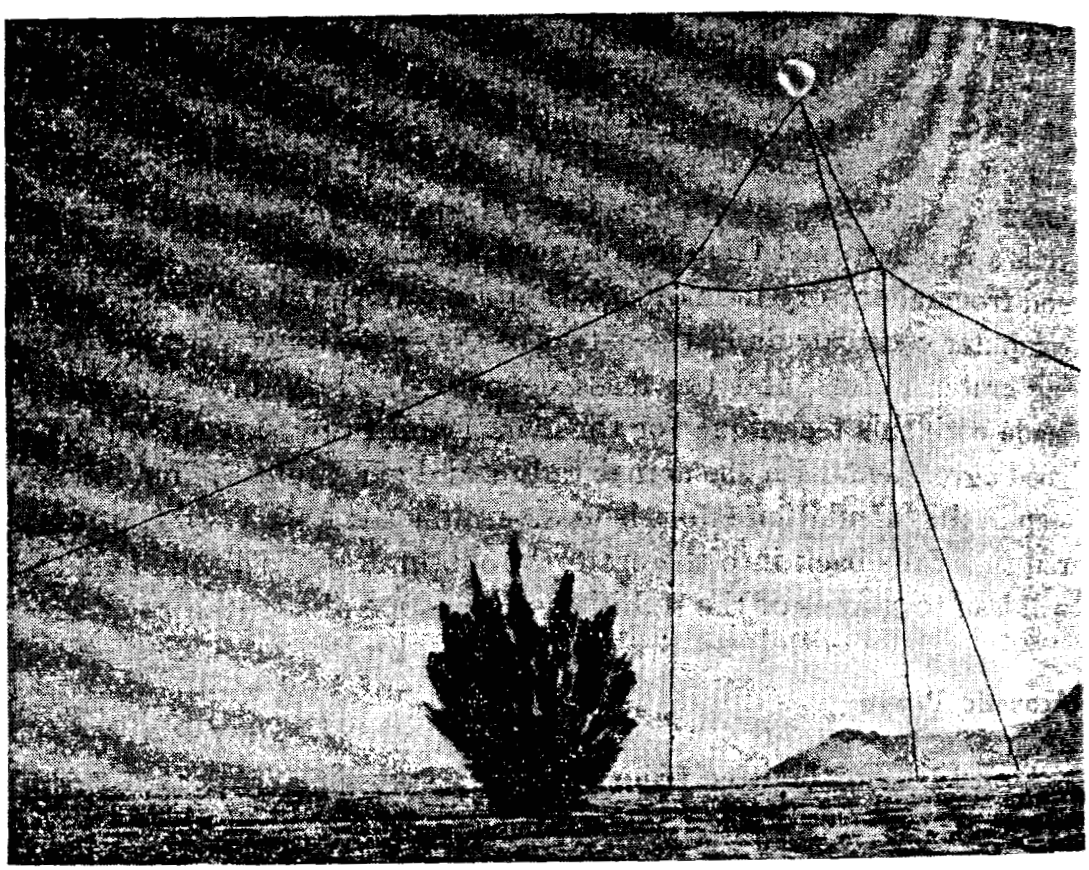
ave predictions for various sizes of explosions under various atmospheric conditions.

Also during the year, the Sandia Laboratory, operated for the AEC by the Sandia Corp., performed field studies of acoustic effects near the explosion. To determine the relationship of the strength of the acoustic wave to the depth of the detonation, single charges of 1,000 pounds of high explosives were detonated at Sandia's Coyote Canyon test area near Albuquerque, N. Mex. Gauges were suspended under balloons to measure the energy released from the explosion and to determine its geometry. In addition, Sandia examined variations in air effects from simultaneous and sequentially fired row charges. This series of experiments was conducted at the Tonopah Test Range in Nevada using 64-pound charges, spaced six to eight feet apart and buried six feet deep.

Sandia's close-in measurements, coupled with distant recordings, will aid in the further understanding of acoustic wave transmission and thus will enhance the ability of project designers to avoid damage from this source.



Air Blast Experiment. As a part of developing the use of nuclear explosives for earth moving, the Sandia Laboratory has been conducting a series of chemical (high explosive) experiments to determine various effects. The retouched photo shows gauges (*small dots*) attached to balloon-supported guy lines to measure the acoustic effect from a 1,000-pound high explosive cratering experiment near Albuquerque, N. Mex. Such experiments provide information that can be scaled-up to predict the effects from nuclear detonations.

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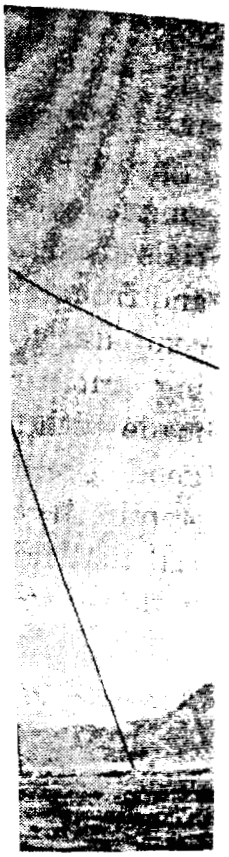

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High-Explosive Cratering Experiments

The Sandia Laboratory's small-scale, high-explosive cratering investigations using single and multiple charges, ranging from 8 to 256 pounds each, continued during the year.

These experiments, conducted since 1959 as a part of the Plowshare Program, are generating the preliminary information for the design of larger-yield high explosive and nuclear excavation experiments which will follow. For example, in one experiment, twenty-five 64-pound charges in a spread pattern of three offset rows were detonated one at a time, followed by 11 charges placed beneath the crater of the first 25, also detonated one at a time. The resulting crater compared favorably with one resulting from simultaneous detonation of eight 256-pound charges. The use of 15 percent more total charge weight (2,304 pounds) reduced the amount of high explosives fired at one time from 2,048 pounds to only 64 pounds to achieve the same results. This is important from both acoustic and seismic wave safety considerations, and it also suggests that deep excavations through high terrain, might be achieved as well by a series of smaller detonations fired one at a time as by larger simultaneous row-charge detonations.

During 1966 studies of the effects of one misfire in a row-charge explosion, emphasized the distribution of ejected material, and the interaction of intersecting single-charge and row-charge excavations.

SCIENTIFIC STUDIES

Heavy Element Research

Plowshare experiments in the heavy element program were aimed at learning more about the exact capture path for producing very heavy isotopes, the extent of fission losses in heavier targets, and improvements in the nuclear explosive to increase the neutron flux. It has been concluded from these investigations that neutron capture in protactinium is the chief source of very heavy isotopes when uranium 238 is the initial target. On experiments in which plutonium 242 and americium 243 were used as target materials, excessive fission losses in the neutron capture sequence prevented significant amounts of very heavy nuclides from being formed. In an experiment performed by Los Alamos Scientific Laboratory as part of the Cyclamen event (see "Production of Heavy Elements" item, Chapter 5—The Nuclear Defense Effort), an improvement in the design of the nuclear explosive increased the attainable flux levels.

There is now some evidence that increased flux levels may not produce continually increasing heavy nuclei as easily as was once expected, particularly at atomic mass 259 and beyond. Neutron exposure in the uranium 238 target of the Cyclamen experiment was sufficient to have made detectable amounts of fermium 259 and/or mendelevium 259. However, neither was detected within a wide range of half-life limits. Possible explanations are being studied, and new investigations into the stability of heavy nuclides are being started. Nuclear explosive design changes are contemplated which should markedly increase the neutron exposure and extend the expected heavy element yield well past atomic mass 259.

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Chapter 12

INTERNATIONAL COOPERATION ACTIVITIES

The AEC's program for international cooperation in the peaceful uses of atomic energy continued to support cooperative programs and projects, the exchange of technical information, and sales abroad of U.S. nuclear equipment and materials under the "Atoms For Peace" program. The sale of U.S. power reactors and fuel not only aids the U.S. balance of payments position, but assures that the reactors will be placed under safeguards against diversion to military purposes. In February, the President announced an increase to 250,000 kilograms of uranium 235 (U^{235}) in enriched uranium for distribution abroad, the seventh such allocation since the beginning of the "Atoms For Peace" program in 1954. This announcement again indicated the importance the United States attaches to providing long-term fuel supplies to foreign countries. The United States is now committed under Agreements for Cooperation to the transfer of over 200,000 kilograms of U^{235}.

COOPERATION WITH INTERNATIONAL ORGANIZATIONS

The United States continued to provide strong support to the International Atomic Energy Agency and to urge the transfer of U.S.-administered bilateral safeguards to administration by the Agency. To date, 15 countries have signed such arrangements. Cooperation with other international organizations continued.

INTERNATIONAL ATOMIC ENERGY AGENCY

The International Atomic Energy Agency (IAEA) held its 10th General Conference in September 1966, and the achievements of the IAEA, since its inception, were given special recognition by Member

States. President Johnson, in a message to the General Conference, expressed the United States' views, as follows:

> "The IAEA has provided the means whereby all of its members can work together and share the scientific developments of many nations. Exciting advances in nuclear applications have been made in the service of mankind. The atom has been unlocked and its energy harnessed; the technologies of nuclear power and desalting can be joined to convert saline water to freshwater, and the isotopes that come from nuclear research offer unusual applications and promise in medicine, and agriculture and industry. This work is of the utmost importance to the future of mankind and must be continued with increasing effort and support . . ."

Nuclear Power and Desalting Studies

A significant example of the IAEA's activities in the nuclear power field is reflected in the IAEA report, issued in 1966, of a recently completed 2-year preinvestment study on power, including nuclear power, on the island of Luzon, the Philippines. The study was jointly financed by the United Nations Development Program and the Philippine Government, with the IAEA serving as executing agency. The report concluded that the Luzon electric power grid would require 1,000 megawatts (Mw) of additional electrical capacity in the period 1971–75, that the grid could absorb 300-Mw thermal stations, and that in this size range nuclear plants had a clear economic advantage over oil-fired plants.

The IAEA continued to serve as an important focal point for international cooperation in the field of nuclear applications to desalting. The United States participated in Agency panel meetings, and provided technical reports on work underway in the United States and on studies undertaken with other countries, in many of which, such as the study with Mexico, the IAEA is playing a significant role.

Safeguards System Extended

In parallel with the promotion of the peaceful uses of nuclear energy, the IAEA has developed an effective safeguards system to assure that projects with which it is associated are used only for peaceful purposes. Agency safeguards, which are applicable to all sizes of nuclear reactors, were extended during 1966 to cover processing plants, a development which was proposed and strongly supported by the United States. The significance that the U.S. attaches to the IAEA safe-

guards system was expressed by President Johnson in his message to the 10th General Conference, as follows:

> ". . . the Agency has a crucial responsibility to see that the vast beneficial uses of nuclear energy are not diverted for military purposes. I cannot say often enough that the prevention of the spread of nuclear weapons is one of the most important tasks of our times. We look on the Agency's safeguards system as one of the principal instruments for accomplishing this task. The U.S. Government fully supports the Agency system and we will do all in our power to support the continued growth and technical effectiveness of the system . . .".

U.S. Financial Assistance

The U.S. policy of strong support for the IAEA and its programs was demonstrated through the provision of financial support to the IAEA's budget, cost-free experts, fellowships, equipment grants, technical information, and special nuclear material, an amount totaling close to $4 million. For the eighth successive year, the U.S. donated approximately $50,000 worth of special nuclear material for use in IAEA research and medical therapy projects, as follows: $35,153 worth of material for use in the Finnish research reactor; $3,440 of materials for use in a Mexican subcritical assembly; $3,440 of materials for use at the Nuclear Energy Institute of Technical University, Istanbul, Turkey; and $3,440 of materials for use in connection with the Rajasthan Atomic Power Project at Trombay, India.

OTHER INTERNATIONAL GROUPS

The United States maintains strong working relationships with two European organizations and one inter-American organization to further nuclear knowledge and technology.

European Atomic Energy Community (Euratom)

Cooperation between the United States and the European Atomic Energy Community (Euratom) continued primarily in the major research areas of: (*a*) the Joint Research and Development Program, which is directed toward reduction of fuel cycle costs associated with U.S. light water-type reactors built and operated in Europe under that program; and (*b*) fast breeder reactors. As an outgrowth of the development of fast breeder reactors by the United States and Euratom within the cooperative arrangements for joint development of ad-

vanced technology, additional quantities of plutonium were requested from the United States to permit continuation of the Euratom fast breeder reactor development program. After considering domestic material requirements and supply, proposed legislation was introduced in the Congress, which is expected to be acted upon during the 1967 session.

Additional cooperation in the area of heavy-water moderated, organic-cooled reactor systems is contemplated in current negotiations with Euratom.

European Nuclear Energy Agency (ENEA)

The AEC continued its cooperation with ENEA through information exchanges and participation in specific projects and in numerous study groups. The United States has participated in the joint Halden Heavy Boiling Water Reactor Project in Norway since 1958. Two other joint projects of the ENEA in which the AEC is associated are the Dragon program, a high temperature reactor project at Winfrith, England, and the Eurochemic Chemical Processing Plant in Mol, Belgium.

Arrangements were completed for AEC participation in the International Food Irradiation Project at Seibersdorf, Austria. This six-year program, which is a joint international activity of the ENEA, the IAEA, and the Austrian Studiengesellschaft für Atomenergie (Study Group for Atomic Energy), will do research on the use of fruit and fruit juices as model systems for research on food pasteurization by irradiation (see also Chapter 10—Isotopic Radiation Applications). The AEC is assisting the project by providing information and guidance and has assigned a histopathologist to the program for a two-year period.

Inter-American Nuclear Energy Commission (IANEC)

The Sixth Inter-American Nuclear Energy Commission Meeting was held in Washington, D.C., June 28–July 1, with 16 Western Hemisphere countries, including the United States, represented. The delegates gave particular attention to the importance of nuclear energy in desalting water, development of inter-American research and training centers, and the adequacy of financing IANEC's programs. For the fiscal year 1968, IANEC approved a budget of $68,000, an amount substantially higher than in previous years.

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AGREEMENTS FOR COOPERATION

At the end of 1966, the United States had 16 Agreements for Cooperation for civil uses in effect with both nations and groups of nations (see Table 1 of Appendix 7 for listings). In accordance with U.S. policy of assimilating the bilateral agreements with individual Member States of Euratom into the broader context of the U.S.-Euratom Agreements, the French Agreement for Cooperation was permitted to expire in November by mutual consent as was done with the Belgian Agreement in 1965. Following the uniform pattern, direct technical cooperation will continue with the French in areas of mutual interest, while special nuclear materials required by the French program will be channeled entirely through Euratom.

New Power Agreements

New superseding Agreements for Cooperation for Civil Uses of Atomic Energy, covering both power and research activities, were concluded with Switzerland and Sweden and a new agreement for civil power applications was concluded with the United Kingdom. These new agreements provide for the supply of quantities of special nuclear material sufficient to cover the long-term requirements of enriched uranium fuel for nuclear power programs planned by the three countries. The agreements with Switzerland and Sweden are for 30 years, while that with the United Kingdom is for 10 years. The agreements also reflect changes in the Atomic Energy Act of 1954, as amended, which permit private ownership of special nuclear materials, and provide for enabling arrangements between private parties in the United States and private parties in these three countries to form arrangements for the transfer, including the export, of special nuclear material. Such arrangements will be undertaken pursuant to applicable laws, regulations, policies, and license requirements of the United States and the other concerned governments. The agreements also provide that the IAEA will promptly be requested to assume responsibility for applying safeguards to the material transferred under the Agreements. In addition, the agreements provide for the United States to enter into contracts for the production or enrichment, or both, in facilities owned by the United States, after December 31, 1968, of special nuclear material for the accounts of these governments subject to such terms and conditions as the United States may establish.

Amendments to Agreements

Amendments to existing bilateral Agreements for Cooperation were concluded with Spain, the United Kingdom (U.K.), the Republic

of China, Israel, the Philippines, and Turkey. The amendment to the Spanish bilateral contained features similar to the superseding agreements mentioned above in that its principal purpose was to provide for the long-term supply of enriched fuel for designated power reactors. The amendment to the United Kingdom research agreement was to extend the term of that agreement and to provide additional material for the U.K.'s civil research and development programs. The major purposes of the other amendments were to extend the term of the agreement in the case of Turkey and to modify provisions respecting fuel quantities and enrichments, as well as to incorporate the benefits concerning privately arranged transfers of special nuclear material which resulted from the 1964 "Private Ownership" Act.

INTERNATIONAL SAFEGUARDS

Processing Plant Safeguards

In April, the United States offered at the 18-Nation Disarmament Conference in Geneva, in cooperation with Nuclear Fuel Services, Inc. (NFS), West Valley, N.Y., to make the NFS plant for chemical processing of irradiated fuel available to the IAEA to develop and test safeguards techniques and to gain experience and training for Agency safeguards inspectors. This supplemented existing arrangements under which the IAEA will apply its safeguards to NFS when fuel from the Yankee power reactor—already subject to IAEA safeguards—undergoes processing there.

A handbook for international safeguards inspection at NFS was prepared by the NFS research and development staff. It consists of the detailed step-by-step procedures for inspecting that and similar plants.

A working group, established by the IAEA Board of Governors to develop guidelines for extension of the Agency's safeguards system to chemical processing plants for irradiated fuel, met in Vienna, Austria, May 11–13, and made recommendations. The provisions explicitly recognize the need for continuous inspection of chemical processing plants of significant capacity. At its June meeting, the Board of Governors acted favorably on the Working Group's recommendations.

Trilateral Agreements

The United States continued the transfer of the safeguards provisions of certain bilateral Agreements for Cooperation to the International Atomic Energy Agency. To date, there are 13 countries with which the United States has trilateral safeguards agreements and 9

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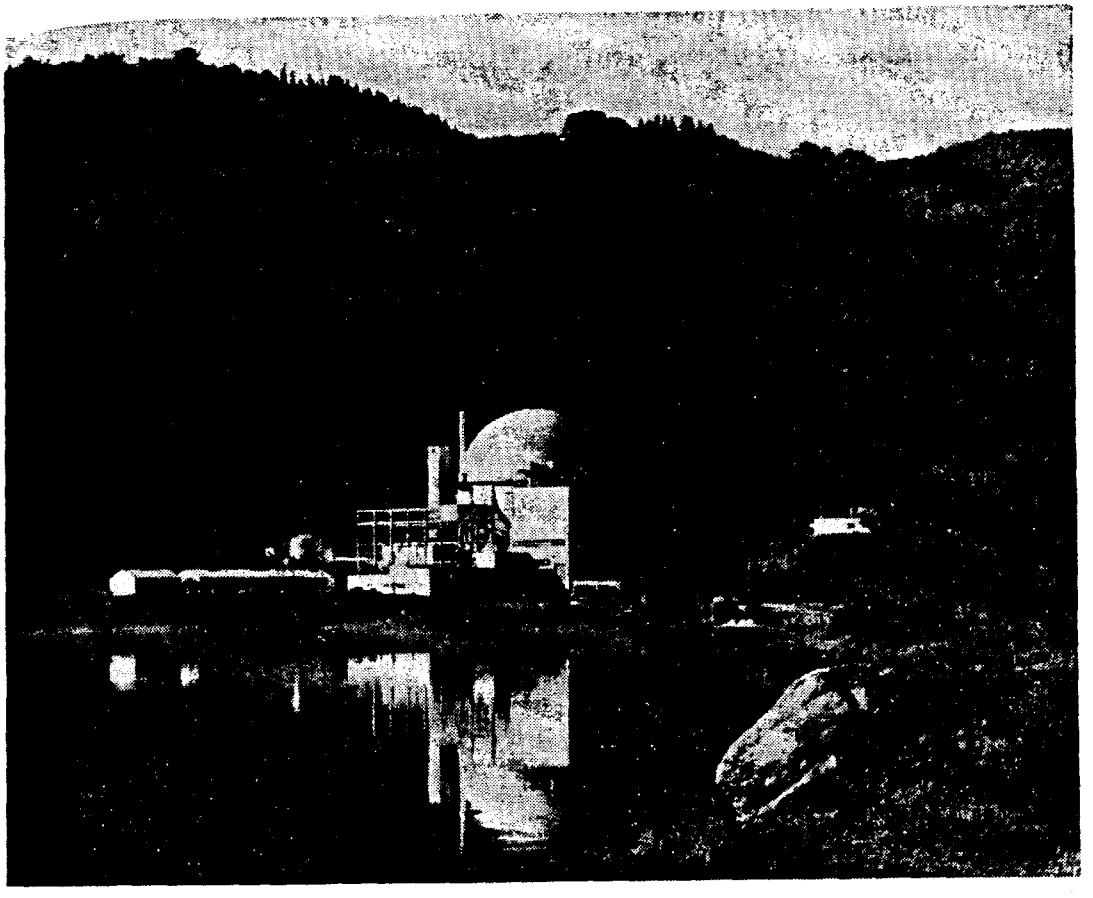
others are in various stages of negotiations. The AEC's safeguards staff made bilateral inspections of 130 facilities in 12 countries during the year.

Yankee Experience With IAEA Safeguards

The Yankee Atomic Electric Co. reactor at Rowe, Mass., was inspected by the International Atomic Energy Agency (IAEA) four times during the year. With the agreement of the Yankee Atomic Electric Co., this reactor was placed under IAEA safeguards in 1964, and the first inspection was carried out in November of that year. Of the 10 inspections to date, 4 were unannounced as provided for in the IAEA inspection procedures which permit access at all times for



Yankee Plant. Shown above is the 175 Mwe Yankee Nuclear Power Station at Rowe, Mass., which has been open to International Atomic Energy Agency (IAEA) safeguards inspection since 1964 to aid the IAEA to develop and demonstrate the effectiveness of its inspection techniques. Many of the inspections have been made unannounced and William Webster, president of the Yankee Atomic Electric Co., has commented on several occasions, including the 1965 White House Conference on International Cooperation, that the IAEA inspections do not present any interference with the operation of the plant. The Yankee plant, in operation since 1960, was the first to be completed under the AEC's Power Reactor Demonstration Program.

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reactors of this size. The inspections have caused no interference with plant operations.

U.S.-Euratom Joint Technical Working Group

Close cooperation with Euratom in the field of safeguards continued. Agreement was reached that continuous inspection would be employed by Euratom during reprocessing of U.S. supplied material at the Eurochemic reprocessing plant located at Mol, Belgium.

TECHNICAL COOPERATION

Since the inception of the "Atoms for Peace" program in 1954, more than 40 technical information exchanges have been developed on specific scientific and technical topics. New arrangements during the year included Argentina, India, Japan, and the United Kingdom.

Technical Exchange Arrangements

Argentina. Arrangements were made to carry out the provisions of a December 1965 agreement with the Comisión Nacional de Energia Atómica of Argentina to engage in increased cooperation in reactor development, raw materials, physical research, radiation and radioisotopes, biology and medicine, and health and safety. Besides documentary exchanges in these areas, two-way communication will be supplemented by conferences, visits, and personnel assignments in both countries.

Canada. Cooperation with Canada was active in reactor development and testing pursuant to the 1960 and 1965 agreements which provide for collaboration in the development of heavy water reactors. The Whiteshell Reactor–1 (WR–1) in Manitoba, which became operational in 1966, and the U–3 loop in the NRU reactor are being utilized by the AEC for in-pile testing of HWOCR (Heavy Water Organic-Cooled Reactors) fuel elements.

India. General understanding was reached on the terms of a 5-year informal technical exchange agreement through which the United States and Indian Atomic Energy Commissions would cooperate and exchange unclassified information in areas of common interest. The areas are: (*a*) technology in the use of thorium in producing electric power; (*b*) technology on the use of recycled plutonium in thermal neutron reactors; (*c*) parametric studies of reactor systems and nuclear fuel cycles in relation to technical feasibility, economic potential, and resources of nuclear materials; (*d*) use of radiation in the improvement of the production of food products; (*e*) techniques for the dis-

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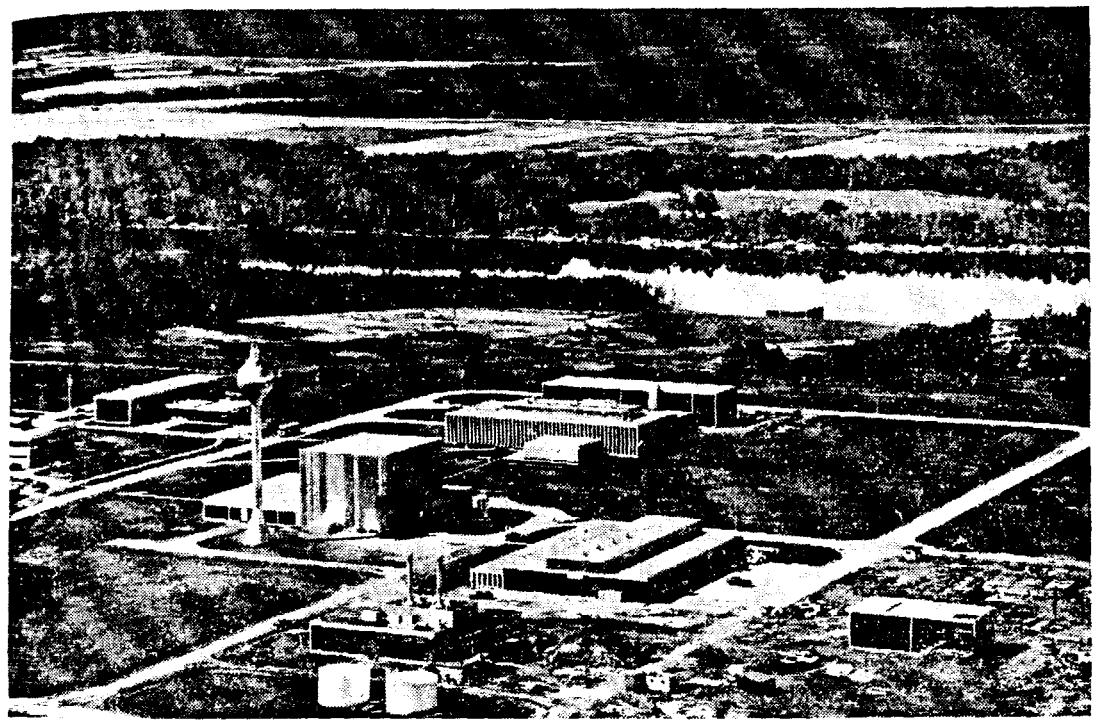
Japan. A mutual technology exchange program has been agreed upon between the Japanese Atomic Energy Research Institute (at Takasaki) and the High Intensity Radiation Development Laboratory at the AEC's Brookhaven National Laboratory. Research results in the area of process radiation will be exchanged with primary emphasis on the work pertaining to the polymerization of ethylene. In the field of reactor safety, an information exchange is envisioned on such subjects as earthquake data, fatigue and embrittlement of pressure vessels, transient pressure and temperature effects following loss of coolant accidents, pressure suppression in containment, and reactor kinetics and stability.

United Kingdom. Exchange arrangements between the AEC and the United Kingdom Atomic Energy Authority previously provided for collaboration in the following areas of basic research and development: (*a*) controlled thermonuclear reactions, (*b*) gas coolant compatibility (with graphite and metals), (*c*) uranium dioxide fuel, (*d*)



Canadian Research Center. Aerial view of the Canadian Whiteshell Nuclear Research Establishment, about 65 miles northeast of Winnipeg, Manitoba. The Whiteshell research reactor, the WR–1, a 40 thermal megawatt heavy water reactor which achieved criticality in 1965, is being partially used by the AEC for in-pile testing of fuel assemblies being developed for the heavy-water organic-cooled reactor (HWOCR) concept. Canada and the United States have conducted a joint development effort on heavy water reactor since 1960. The WR–1 reactor building is located near the 150-foot combined ventilating stack and water tower.

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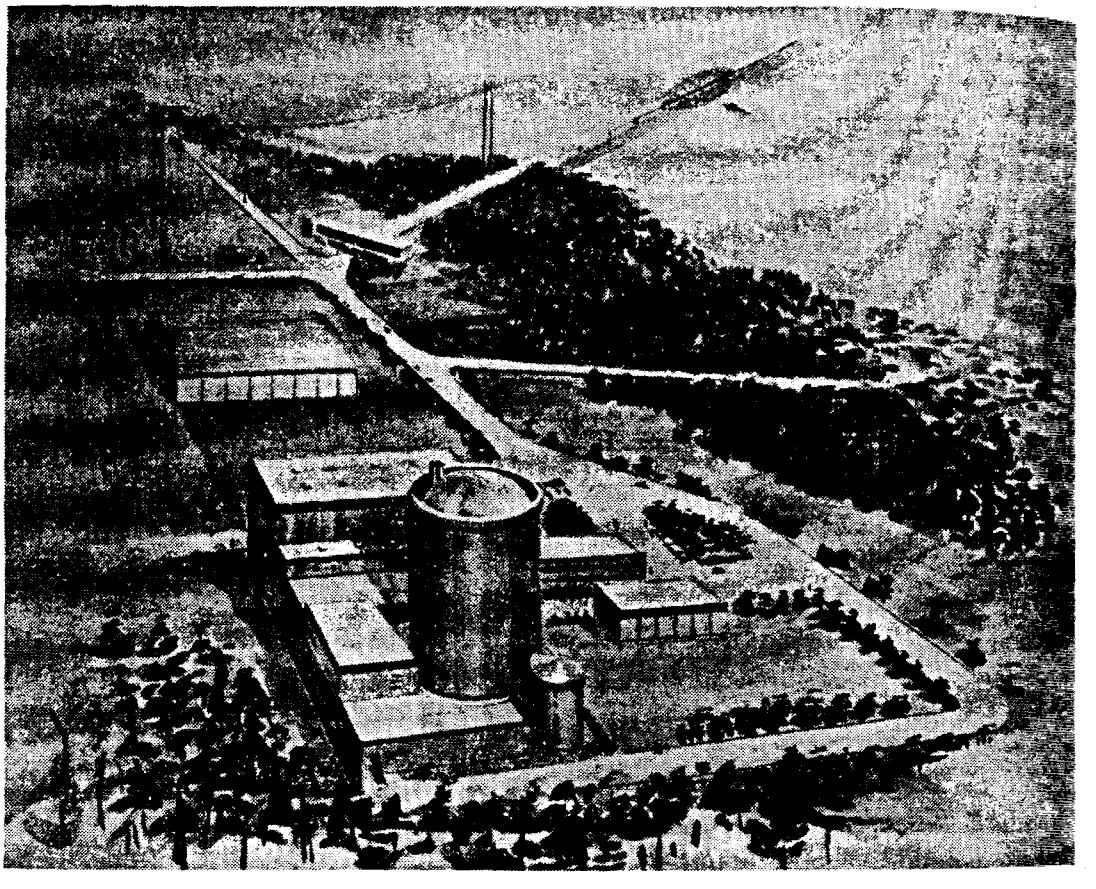
plutonium metallurgy, and (*e*) beryllium. In January, agreement was reached to add as a sixth area of cooperation, namely an exchange on "Effects of Irradiation on Structural Materials", *e.g.*, pressure vessel steels and fuel element cladding materials.

Personnel Assignments

The AEC continues to provide facilities at which qualified foreign nationals can pursue individual unclassified research programs. Oak Ridge Associated Universities, Inc., offers some short-term courses in varying areas of interest which are open to qualified foreign nationals, and the Puerto Rico Nuclear Center continues to offer formal courses in nuclear science, nuclear engineering, nuclear medicine, and agricultural bio-sciences in both Spanish and English. The level of foreign participation at all AEC facilities runs approximately at 13 percent of the total participation load. Since 1955 AEC facilities



Nuclear Power in Japan. One U.S.-built power reactor is in operation, and three more are under construction or contract for construction in Japan. The above is an artist's concept of the Mihama Nuclear Power Station Unit No. 1, a 300 Mwe pressurized water reactor to be built at Tonkin, about 220 miles west of Tokyo. The decision to award this contract to the Westinghouse Electric International Co. was made in the spring of 1966.

have accommodated over 3,500 foreign nationals. During 1966, nearly 400 foreign nationals were assigned to various AEC facilities (see also Chapter 14—Nuclear Education and Training).

Cooperation With the U.S.S.R.

The exchange of technical teams, research specialists, and recent scientific reports with the Soviet Union continued during 1966. These exchanges were conducted in the manner provided for by the U.S.-U.S.S.R. Memorandum of Cooperation in the Peaceful Uses of Atomic Energy of May 21, 1963, which has since been extended.

In February, a United States delegation of low energy physics specialists visited facilities in the Soviet Union; in June, a Soviet team of specialists in radioneurological research visited medical facilities in the United States; and in October, a United States delegation of medical tracer specialists visited medical facilities in the Sovet Union. Two United States specialists in controlled thermonuclear reactions research completed assignments of three months at the Lebedev Institute in Moscow and six months at the Physical Technical Institute in Kharkov, respectively. In December, two Soviet specialists in this field reported at the Princeton Plasma Physics Laboratories to begin four to five months of research.

Through an exchange of notes the U.S.–U.S.S.R. Desalination Agreement of November 18, 1964, was extended for another two years.

Laboratory-to-Laboratory Arrangements

Cooperative laboratory-to-laboratory arrangements—referred to as "sister laboratory" arrangements—are now in effect between AEC national laboratories and nuclear research centers in the Republic of China (Taiwan), Colombia, Greece, Korea, and Thailand. Under these arrangements, the Argonne, Brookhaven, and Oak Ridge National Laboratories, and the Puerto Rico Nuclear Center provide periodic consultation and also small items of not readily available equipment to the foreign cooperating laboratories' staff.

The Republic of China agreed to finance the costs of its cooperative project. Costs of the other arrangements are funded by the United States.

Under the Thai-Oak Ridge National Laboratory program initiated in 1966, Oak Ridge assigned one member of its staff to Thailand for six months, and another for three weeks, to assist in the development of a program for the Thai research reactor at Bangkok with particular emphasis on the usage of radioisotopes.

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COMMERCIAL ACTIVITIES ABROAD

Countries that are more advanced in nuclear technology began to compete for export markets and for nuclear fuel services. The performance records of, and operating experience with, U.S.-built reactors has been such that the United States has been able to maintain its strong position in international markets. Fifteen U.S.- and U.S.-licensed power reactors are operating or being built abroad, and at least two more are in the planning stage.

POWER REACTORS

Two reactors built under the U.S.-Euratom Joint Power Reactor Program achieved criticality in 1966: the 237 Mwe KRB (Kernkraftwerk-RWE-Bayernwerk GmbH) boiling water reactor at Gundremmingen, West Germany, achieved criticality on August 14; and the 266 Mwe SENA (Societe d'Energie Nucleaire Franco-Belge des Ardennes) pressurized water reactor at Givet, France, on October 18. Previously, U.S.-built power reactors at Kahl-am-Main, West Germany (1960); Punta Fiume, Italy (1963); Tokai-Mura, Japan (1963); and Trino Vercelles, Italy (1964) had started operation in the years indicated.

Reactors Under Construction

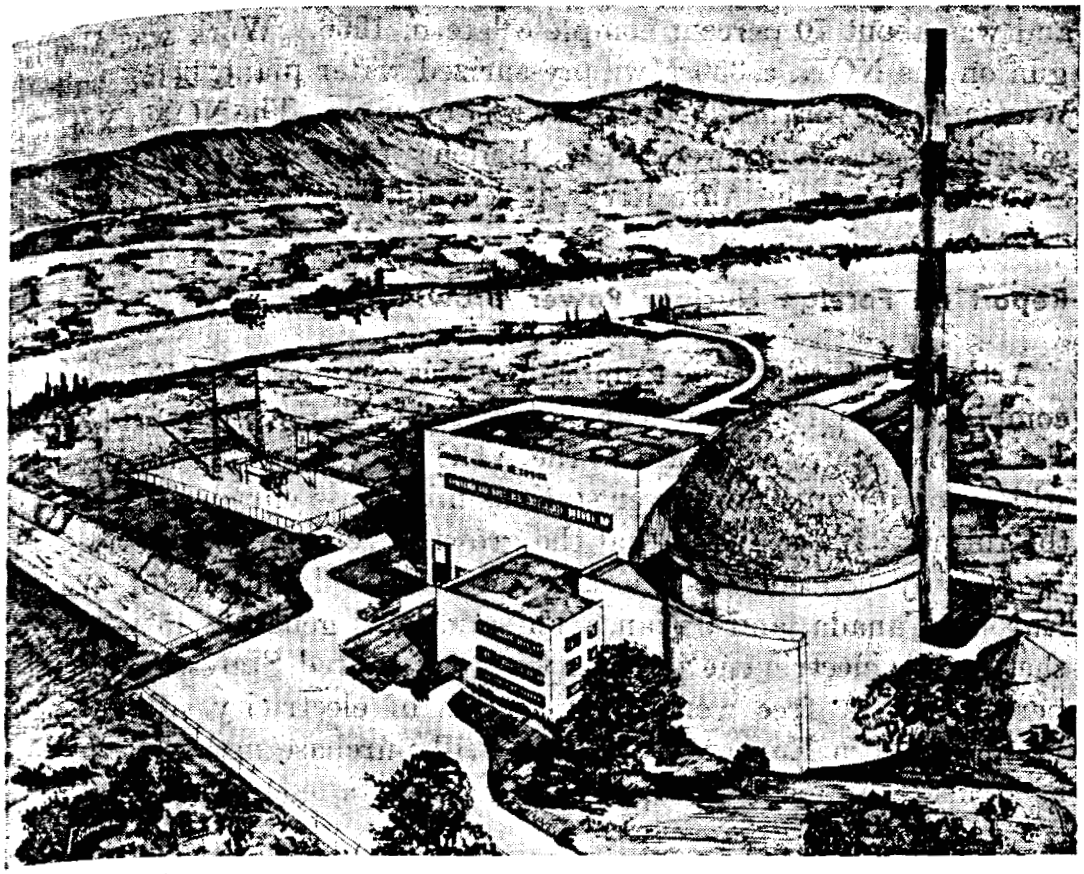
Construction began, under contract with General Electric, on the Japan Atomic Power Co.'s second plant, a 400 Mwe boiling water reactor located on the Tsuruga Peninsula. Plant completion is scheduled for 1969. General Electric also received the contract for Tokyo Electric Power Co.'s 400 Mwe plant to be built in the Fukushima Prefecture. It is scheduled for completion in 1971. Japan's Kansai Electric Co. has selected a Westinghouse-built pressurized water reactor for a 300 Mwe plant to be located at Fukui, Western Honshu, and completed in 1970.

Spain's first nuclear powerplant, the Zorita, being built near Madrid by Westinghouse was about 50 percent completed at year's end, with completion scheduled for 1968.

The Spanish Government granted a construction permit for the 460 Mwe boiling water reactor being built for Nuclenor by General Electric. The plant will be located at Santa Maria de Garona in Northeastern Spain on the Ebro River.

Construction on the 380 Mwe twin boiling water reactor plant being built by General Electric at Tarapur, India, also made good progress

Spanish Station nuclear power Corp. at Zorita water reactor v when completed requirements fo *below* at the sig of the Spanish Merry Del Val; R. E. Hollingsw Corp.

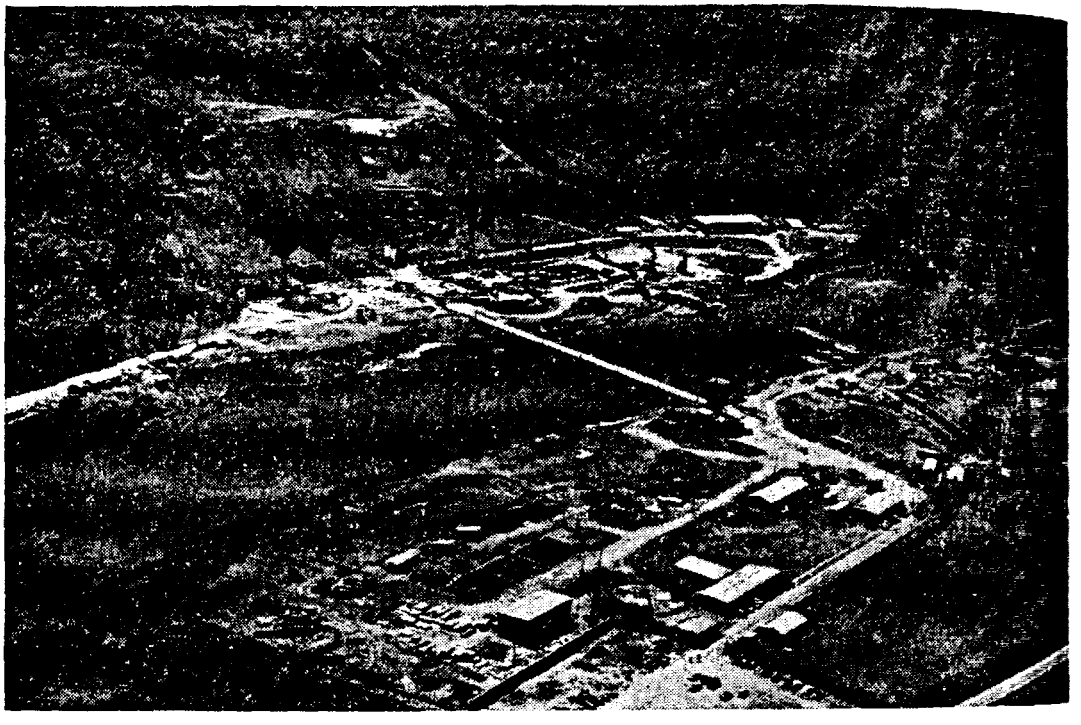


Spanish Station. Shown *above* is an artist's sketch of Spain's first commercial nuclear power reactor now under construction by the Westinghouse Electric Corp. at Zorita de los Canes, 40 miles east of Madrid. The pressurized light water reactor will deliver 150 Mwe of net electrical power to the Madrid area when completed in 1968. The contract covering the initial enriched uranium requirements for the Zorita plant was signed on November 17, 1966. Shown *below* at the signing, *left* to *right*, are: Prof. José M. Otero Navascues, President of the Spanish Nuclear Energy Board; H. E., the Ambassador, The Marquis de Merry Del Val; AEC Commissioner James T. Ramey; AEC General Manager, R. E. Hollingsworth; and J. P. Farrell, Vice President for Sales, Allied Chemical Corp.

and was about 70 percent complete late in 1966. Work was also begun on the NOK, a 350 Mwe pressurized water plant, being built by Westinghouse for the Northeast Swiss Power Co. The NOK (Nordostschweizerische Kraftwerk A.G. Baden) plant located at Beznau, Switzerland, on the Aare River, is scheduled for completion in 1969.

Report on Foreign Nuclear Power Growth

Arthur D. Little, Inc., Cambridge, Mass., under an AEC contract, completed a study [1] of nuclear power growth in the free world outside the United States as an aid to the AEC in determining the extent to which foreign nuclear power stations might use enriched uranium in the future. It concluded that the growth over the next 20 years will be heavily concentrated in the industrialized nations of Western Europe, Canada, and Japan. These nations generate 45 percent of the world's electric energy, and with the United States, represent 85 percent of the free world's production of electricity. Over the 20 years, Western European countries will purchase nearly three times as much equipment as they have now installed. The table below



Unique Location. View of the site of the Franco-Belgian reactor SENA, a 210 Mwe pressurized water reactor plant at Givet, France, near the Franco-Belgian border. The Westinghouse-built reactor is housed deep in a stone cliff (*center left*) at a bend in the Meuse River, and is the third reactor under the U.S.-Euratom Joint Program to achieve criticality.

[1] Available through the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Virginia 22151, at a cost of $4.00.

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shows the estimated 20-year cumulative installed nuclear generating capacity envisioned by the study.

Most Probable Cumulative Installed Nuclear Generating Capacity
(in thousands of megawatts)

Year Ending	*Foreign Free World*
1970	14
1975	51
1980	130
1985	280

The report anticipates that, with the exception of France, over 85 percent of Europe's nuclear power generating capacity will use enriched uranium and that, except for Britain, most of these plants will use light water technology.

POWER-DESALTING PROJECTS

International interest in the use of nuclear power-desalting plants continued to grow in 1966. President Johnson's continuing interest in ways of solving man's water problems and the United States desire to share its desalting technology with other nations was expressed on many occasions.

Nuclear Desalting Studies

The International Atomic Energy Agency continued to serve as a focal point for United States cooperation abroad in nuclear applications to desalting.

Mexico. The U.S.-Mexican-IAEA nuclear desalting study group met in December 1965, and in April 1966. On April 16, President Johnson and the President of Mexico, Gustavo Diaz Ordaz, issued a joint statement, which stated, in part, that:

> "The two Presidents agreed on the importance for their countries of the study which, under the auspices of the International Atomic Energy Agency, is being carried out to determine the technical and economic possibilities of installing, at some point in Mexico near the United States border, a plant to desalinate sea water through the use of nuclear energy."

Greece. The United States participated in a preliminary study with Greece on the feasibility of desalting, possibly in combination with an electric powerplant, as a means of providing needed supplies of freshwater for the Athens area.

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Israel. A jointly-financed engineering feasibility study by the United States and Israel of a large-scale nuclear power-desalting plant concluded that a dual-purpose 200-Mwe/100 million gallons of water per day plant—to be in commercial operation by 1972—was technically feasible, assuming early initiation of design and the successful completion of a water plant module development program. At a news conference on October 14, President Johnson announced the assignment of Ambassador-at-Large Ellsworth Bunker to begin to review proposals which have been made for a desalting-electric power project in Israel.

Others. Discussions and consultations were also held with other nations interested in the field including the United Arab Republic, Italy, and Tunisia. (See also Chapter 7—Reactor Development and Technology.)

Water for Peace Program

An Interagency Committee, of which the AEC is a member, was established following the President's announcement of the "Water for Peace" program at the First International Desalination Conference in October 1965.

An International Conference on Water for Peace has been scheduled for May 23–31, 1967, at Washington, D.C. The conference will bring together representatives of many governments to discuss and explore the world's water problems, the opportunities and means available for attacking the problems, and international cooperation required to stimulate effective programs of water development on both national and international levels.

SUPPLY OF MATERIALS ABROAD

The year was significant for foreign nuclear electric power as well as the domestic industry. In February, President Johnson increased the allocation of enriched uranium available for distribution abroad to 250,000 kilograms. Criteria for the supply of uranium enrichment services to foreign customers, which the AEC developed after consultation with and comments from American industry and interested foreign groups and, after approval by the Joint Committee on Atomic Energy, were issued as official U.S. Government policy on December 23 (see also Chapter 4—Source and Special Nuclear Materials). The two cornerstones in U.S. fuel supply policy, now further implemented by the offer of enrichment services, are: (*a*) the assurances of long-term availability at stable prices of enriched uranium for periods of

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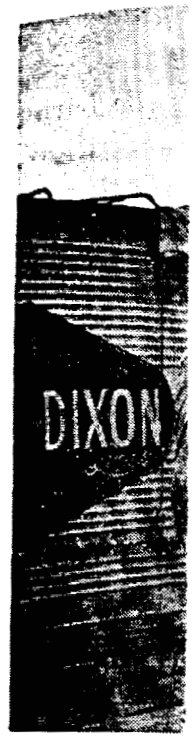

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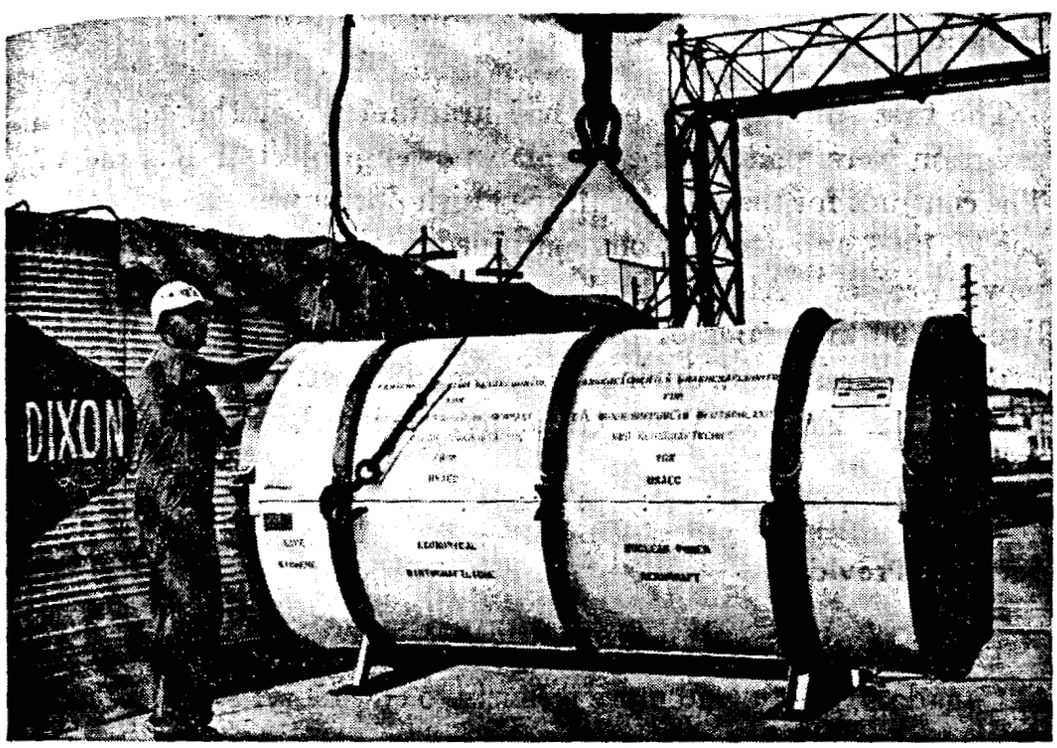
time equivalent to the reasonable economic life of the facilities supplied, and (*b*) the principle of nondiscriminatory terms and conditions of supply as nearly as possible identical between foreign and domestic customers.

Under appropriate Agreements for Cooperation and pursuant to the private ownership law, the United States is now able to transfer enriched uranium to foreign customers through government-to-government transfers as heretofore, but also through government-to-private and other combinations of government-private relationships. Since an Agreement for Cooperation is for a fixed period of time (up to 30 years), individual contracts for the supply of enriched uranium may be for the same term. First deliveries of enriched uranium through use of enrichment services may be made beginning January 1, 1969, although contract negotiations may be undertaken and completed at any time.



Overseas Bound. This protective package encloses a cylinder containing approximately 2½ tons of uranium hexafluoride bound for the West German KRB nuclear power station, near Gundremmingen, which went into operation during 1966. Unprecedented safe and economical shipments such as this represent a major contribution to the upswing in global acceptance of nuclear energy as a highly competitive, low-hazard source of power for peaceful applications. Developed at the AEC's Oak Ridge Gaseous Diffusion Plant, the unit is designed to withstand any conceivable accident occurring in transit or storage; this includes a major impact, an ensuing fire, and immersion in water. Most significant of the design features incorporated in the package is a high temperature foam plastic lining. The plastic is used as a cushioning structural member highly effective in heat insulation and neutron absorption. Should the package be enveloped in the flames of an accidental fire, the heat insulation will protect the cylinder of uranium.

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Barter Arrangements

In March, the Commission announced the sale of enriched uranium on a barter basis for five power projects (two in Spain, two in the Federal Republic of Germany, and one in Switzerland). Under these arrangements, the AEC will accept, as partial payment for the enriched uranium needed, appropriate quantities of natural uranium, with the remainder of the payment being made in U.S. dollars. Cash revenues to the AEC from these transactions will amount to approximately $22,600,000. These barter arrangements were an exception to the policy of providing enriched uranium for foreign power reactors under regular sale arrangements until 1969 when toll enrichment services become available under the private ownership act of 1964. No further barter arrangements are to be considered.

Material Supplies

The first shipments of enriched uranium under the *ad hoc* barter program were made to the German power projects KRB and VEW. The contract for the fuel for the Spanish Zorita was signed on November 17, 1966, and negotiations continued on the fuel for the Swiss NOK power project. Also, up to the end of 1966, the AEC had sold and delivered 390 kilograms of plutonium to Euratom for the latter's fast reactor program, and, during 1966, some 281 metric tons of heavy water to Canada, France, West Germany, Switzerland, and the United Kingdom.

Services Provided

The United States continued to provide chemical processing services to Canada, Sweden, and more recently to Germany, France, and Japan for their materials testing reactor type spent fuel elements. During 1966 there were 21 shipments of spent 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 Plant until such services become reasonably available commercially.

Degraded heavy water from Canada and France was upgraded at the Savannah River Plant on a routine basis and with guaranteed tritium content not to exceed 30 microcuries per milliliter.

From Oak Ridge, the AEC made available for foreign distribution limited quantities of the transuranium elements californium 252 and curium 244 as sources for research purposes.

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Exports and Imports

The AEC assisted local and U.S. Coast Guard officials in the clearance of 9 additional ports to handle shipments of radioactive materials, bringing to 44 the number of United States ports so cleared (see Table 2, Appendix 7 for a list of cleared ports). The safety of shipping arrangements of special nuclear material was evaluated by the Interstate Commerce Commission (ICC) in accordance with new ICC and AEC regulations issued during 1966 (see Chapter 3—The Regulation of Radioactive Materials).

A detailed study on improving the international shipments of radioactive materials was completed in July by the Southern Interstate Nuclear Board under a contract with the AEC. The study concluded that the extension of the Price-Anderson Act to international ocean shipment of nuclear materials would improve flow of materials to and from the United States.

Value of Materials Distributed Abroad

As of mid-1966, the AEC had distributed abroad through sale, lease, and deferred payment sales, special nuclear and other materials to the approximate total value to date of $214.4 million, resulting in revenues to the United States of $126.4 million, of which $4.2 million will be paid in the form of natural uranium. (See Table 3, Appendix 7, for a listing of U.S. nuclear materials distributed abroad.)

Chapter 13

RESEARCH FACILITIES AND PROJECTS

The AEC conducts a broad range of basic research studies in the physical, biological, medical, and environmental areas. The recent noteworthy advancements made in these areas are summarized in the supplemental report, "Fundamental Nuclear Energy Research—1966."[1] This chapter devotes itself only to the new major facilities being provided, or proposed, for basic research and to civil defense-related projects.

PHYSICAL RESEARCH

The AEC conducts a vigorous and productive program in basic physical research. This scientific endeavor covers a broad range of subjects including high, medium, and low energy physics, mathematics and computer research, chemistry, metallurgy and materials, and controlled thermonuclear research. This program reflects also a continuing effort to maintain the rapid pace in scientific and technological advancements by having advanced research facilities and tools available to the scientists conducting basic research.

NEW FACILITIES

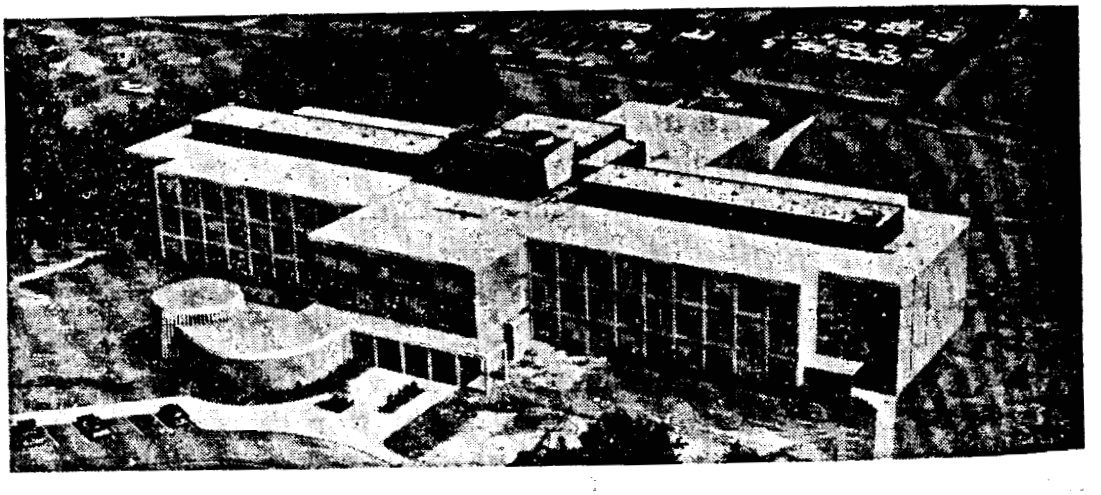
During the year, the new two-mile-long Stanford Linear Accelerator Center (SLAC) in California became operational, and a unique group of production and research facilities at Oak Ridge, Tenn., was dedicated as the center for the "National Transplutonium Program".

Stanford Linear Accelerator Center

A major milestone in high energy physics in the United States during 1966 was the successful operation of the world's highest energy

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

New Facilities at BNL. On April 22, 1966, the Brookhaven National Laboratory High Flux Beam Reactor was dedicated. Highlights of the day were the dedication address by AEC Commissioner Gerald F. Tape and a Technical Session on the HFBR jointly sponsored by Brookhaven National Laboratory and the New York Metropolitan Section of the American Nuclear Society. Shown *above* are the dedication speakers from *left* to *right:* Dr. T. Keith Glennan, President of Associated Universities, Inc.; Commissioner Tape; Dr. Maurice Goldhaber, Director, Brookhaven-National Laboratory; and Mr. Emery L. Van Horn, Manager of the AEC's Brookhaven Office. *Below* is an aerial view of the new $6 million Chemistry Building which was also put into use at Brookhaven during the year. Several World War II wooden buildings previously housed the chemistry operations.



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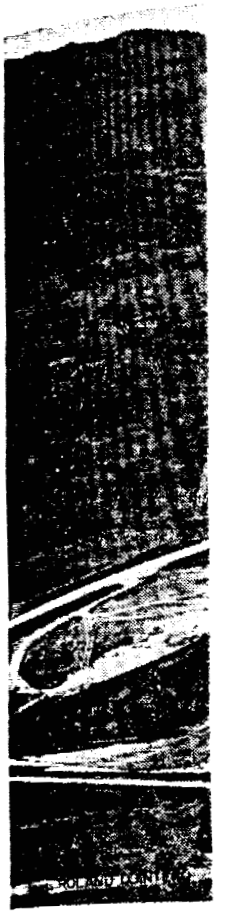

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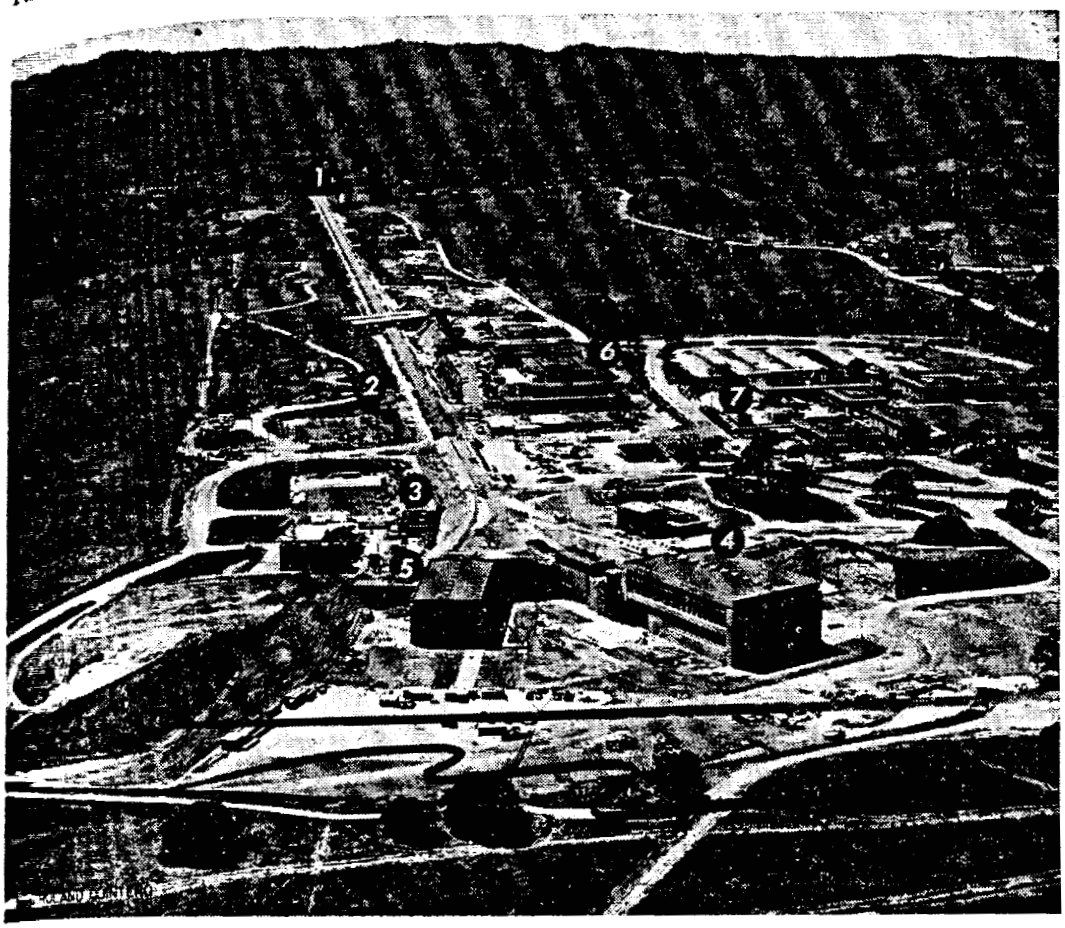
electron accelerator. The two-mile long, 20-Bev[2] microwave linear machine is located at Stanford University near Palo Alto, Calif. This research complex, built at a cost of $114 million, is the culmination of three decades of work at Stanford University in the development of high energy electron linear accelerators. Congress authorized and funded SLAC in 1961 and the ground breaking took place in July 1962.



SLAC in Operation. The 2-mile-long, $114 million linear accelerator at the Stanford Linear Accelerator Center (SLAC) is shown stretching off into the distance in this photo taken at the target end of the accelerator. The beam will start from "1"; the power station for the accelerator is at "2"; and at the underground beam switchyard (3), the electrons will be sent to either End Section "A"(4) or End Station "B"(5). Occupying 480 acres of land, a dozen major buildings beside the accelerator provide office, laboratory, and shop facilities (6 and 7) for the SLAC staff. SLAC, located near Palo Alto, Calif., began preliminary operation during 1966 and will be operated as a national facility for the AEC by Stanford University.

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[2] The first particle accelerator to attain energies above one billion electron volts (Bev) was retired from service on December 31, 1966. The 14-year-old, 3-Bev Cosmotron at the AEC's Brookhaven National Laboratory had been instrumental in the discovery of important sub-nuclear particles and made major contributions to elementary particle physics. While the Cosmotron, a proton accelerator, was still doing good work, not only in high energy physics but also in nuclear structure physics and nuclear chemistry, funds for its continued operation were not available. Limitations on research funds, whether AEC or not, and the priorities for research to be undertaken with available funds resulted in the Cosmotron's retirement.

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On May 21, a beam of electrons was accelerated for the first time along the 10,000-foot length of the accelerator tube achieving an energy in excess of 10 billion electron volts (10 Bev). Later this energy was increased to about 18.4 Bev (and to 20.2 Bev on January 9, 1967).

Equipment. In End Station "A" (see illustration), the larger of the target buildings, experiments will be conducted primarily with electron and gamma ray beams. This structure houses three huge spectrometers which are capable of analyzing particle momenta with high precision up to 1.6, 8, and 20 Bev/c, respectively. Another experimental area, End Station "B", will primarily be used for those experiments in which the electron beam will create secondary particles. During 1967, two hydrogen bubble chambers are expected to be in operation at End Station "B". One is the 72-inch long bubble chamber which is being transferred from Berkeley where it has been used with the Bevatron (6.2 Bev) proton accelerator, and which will be converted into an 82-inch bubble chamber before it is transferred. SLAC is building the second, a 40-inch diameter bubble chamber scheduled for completion in June 1967.

Experiment planning. From its inception, the Stanford Linear Accelerator Center has been conceived as a national facility for research in high energy physics. Experimental time is to be granted on the basis of scientific merit. Experimental proposals and the allocation of time in the beam and major facilities are considered by a program advisory committee. The present committee includes representatives from SLAC (3), Stanford University (1), Massachusetts Institute of Technology (1), University of California at San Diego (1), Yale University (1), and Cornell University (1). SLAC has held two "users" conferences for prospective experimenters, one in October 1965 and another in June 1966. "A SLAC Users Handbook"[3] is available for those institutions wishing to file an experimental proposal with SLAC.

The initial experiments planned fall into three categories: (*a*) electron and muon scattering, (*b*) production of secondary particles, and (*c*) photoproduction. Thus far, approved experiments include the participation of such institutions as the Massachusetts Institute of Technology, the California Institute of Technology, and the University of California, as well as Stanford University.

National Transplutonium Program Center

The transplutonium element production and research facilities at Oak Ridge National Laboratory have been completed and put into operation as a center for the AEC's National Transplutonium Program. On November 8, the High Flux Isotope Reactor (HFIR),

[3] Potential users can acquire this handbook by writing to: The Director, Stanford Linear Accelerator Center, P.O. Box 4349, Stanford, Calif. 94305.

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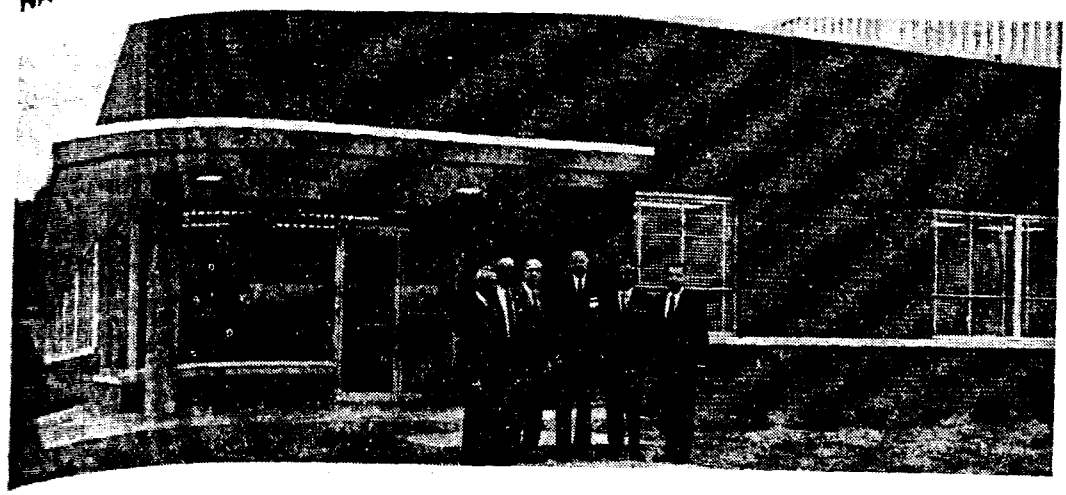
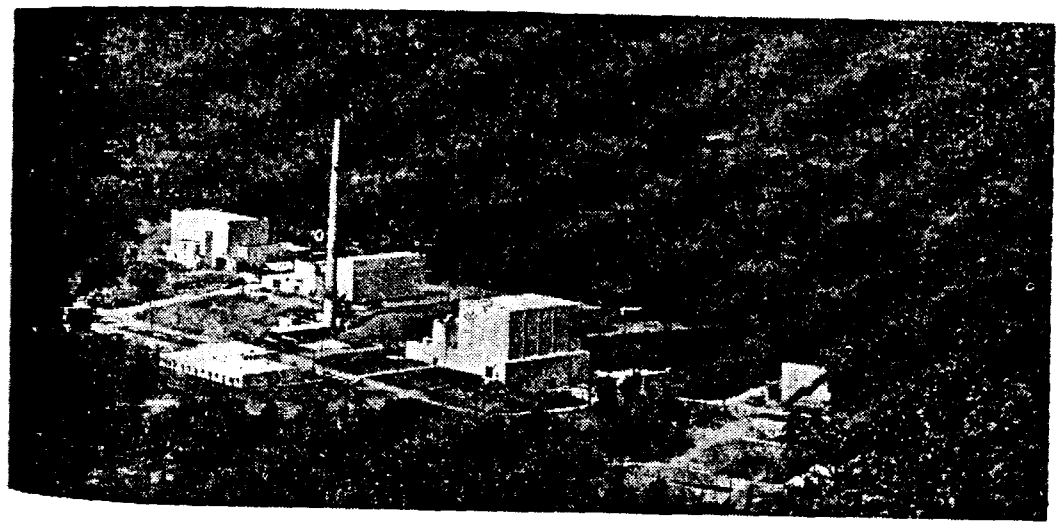
NATIONAL TRANSPLUTONIUM PROGRAM



Transuranium Complex. The new $25,270,000 National Transplutonium Program production and research center at Oak Ridge National Laboratory (ORNL) was completed during the year and dedicated on November 8. Photo *above* shows (*left to right*): Dr. Alvin M. Weinberg, Director of Oak Ridge National Laboratory; Dr. George E. Boyd, Assistant Director of ORNL; Dr. E. H. Taylor, Director of Chemistry Division, ORNL; AEC Chairman Glenn T. Seaborg; Mr. Don E. Ferguson, Director of ORNL's Chemical Technology Division; and Dr. O. Lewin Keller, Acting Director of the Transuranium Research Laboratory, standing in front of the new building. Photo *below* shows the production facilities of the new center. The building at the *far left* is the Thorium-Uranium Fuel Cycle Development Facility. In the *left foreground*, is the High Flux Isotope Reactor (HFIR) Office Building with the HFIR itself housed in the building at *right*. The Transplutonium Processing Plant (TRU) is located behind the stack which serves both the reactor and processing plant for waste gas disposal. The TRL is not shown below. In addition to permanent staff members, visiting scientists from universities and other laboratories are expected to use the facilities at TRL for studies in the new research areas opened up by the availability of relatively large quantities of the transuranium elements.



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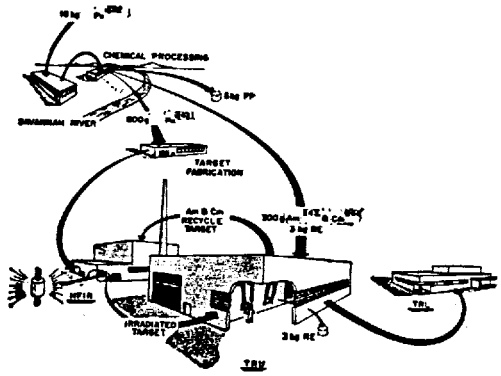
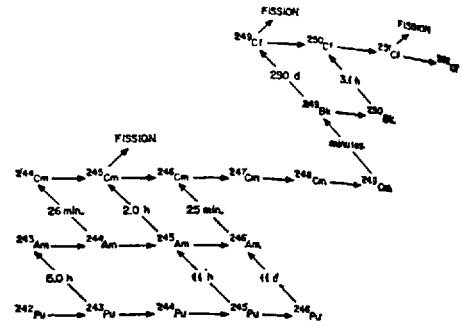
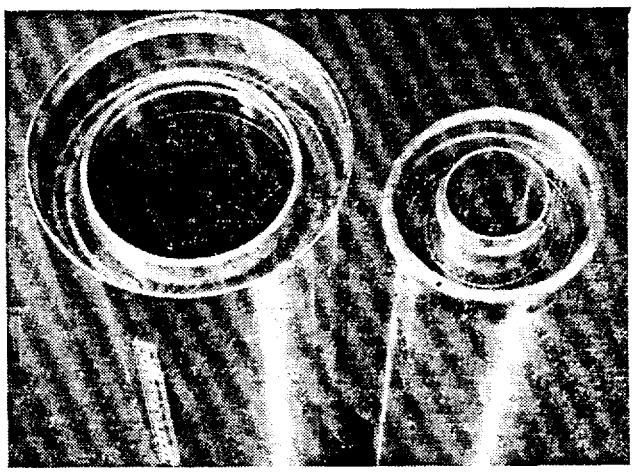
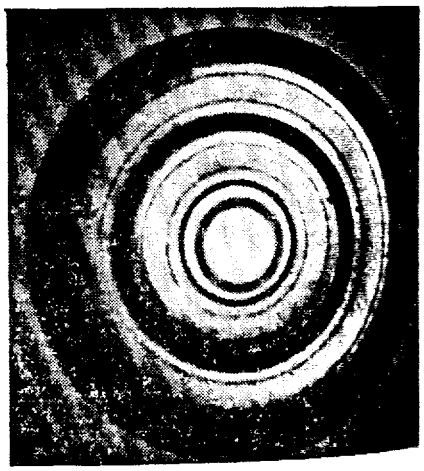




Production Systems. Drawing *above left,* shows the method used for the production of transplutonium elements for research. The production started by irradiating 10 kg. batches of plutonium 239 (Pu^{239}) at the Savannah River plant. After most of the Pu^{239} has been either fissioned or converted to heavier isotopes, it is chemically processed to obtain about 600 grams of Pu^{242}, 300 grams of americium 243 (Am^{243}) and curium 244 (Cm^{244}). The material is shipped to Oak Ridge, where the Pu^{242} is made into irradiation targets for the HFIR and irradiated to produce such heavier transplutonium elements as curium, berkelium, californium, einsteinium, and fermium. After the HFIR irradiation, the desired isotopes are isolated in the TRU facility for use in research in the TRL and throughout the USA. Chart at *above right* illustrates the production scheme for transplutonium elements starting with irradiation of Pu^{242} with neutrons (in this chart, the isotopic number precedes the element symbol). Upon successive capture of a neutron the next heavier isotope of the same element is produced until a point is reached at which beta decay transmutes the isotope to a higher atomic number element. For example, in the plutonium chain this beta decay transforms Pu^{243} to Am^{243} during a 5-hour half-life. In some cases, *e.g.*, Cm^{245} and Cf^{249}, most of the neutrons captured cause fission instead of a heavier isotope. As a result, only about 3/10 of 1 percent of the original Pu^{239} reaches californium 252 (Cf^{252}). Photos *below* show a HFIR fuel element before, and after, insertion in the reactor. Made in two concentric rings to facilitate handling (inner ring, 101 fuel plates; outer ring, 369), the fuel is uranium 235 (U^{235}) containing cermet and sandwiched between aluminum sheets. At full power, the reactor generates 100,000 kilowatts of heat and the fuel element, containing about 20 pounds of U^{235}, lasts about 23 days. On the *right,* is a discharged element shown under 25 feet of water and self-illuminated by the *Cerenkov* radiation.





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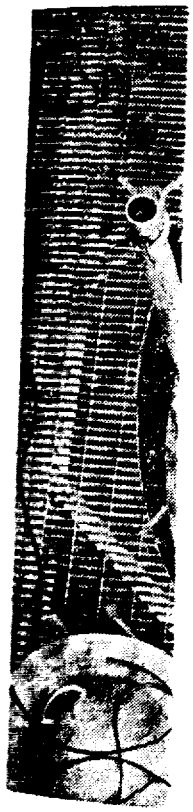

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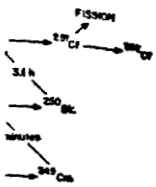

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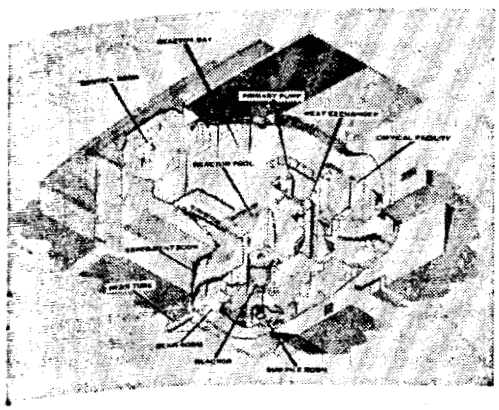
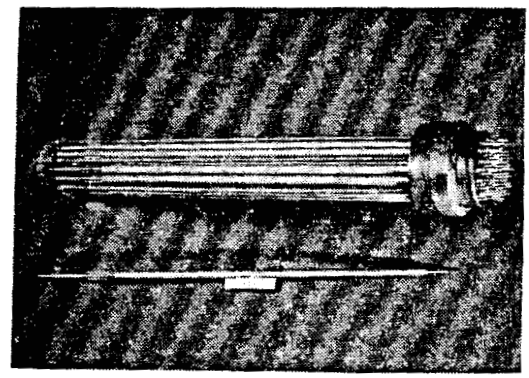
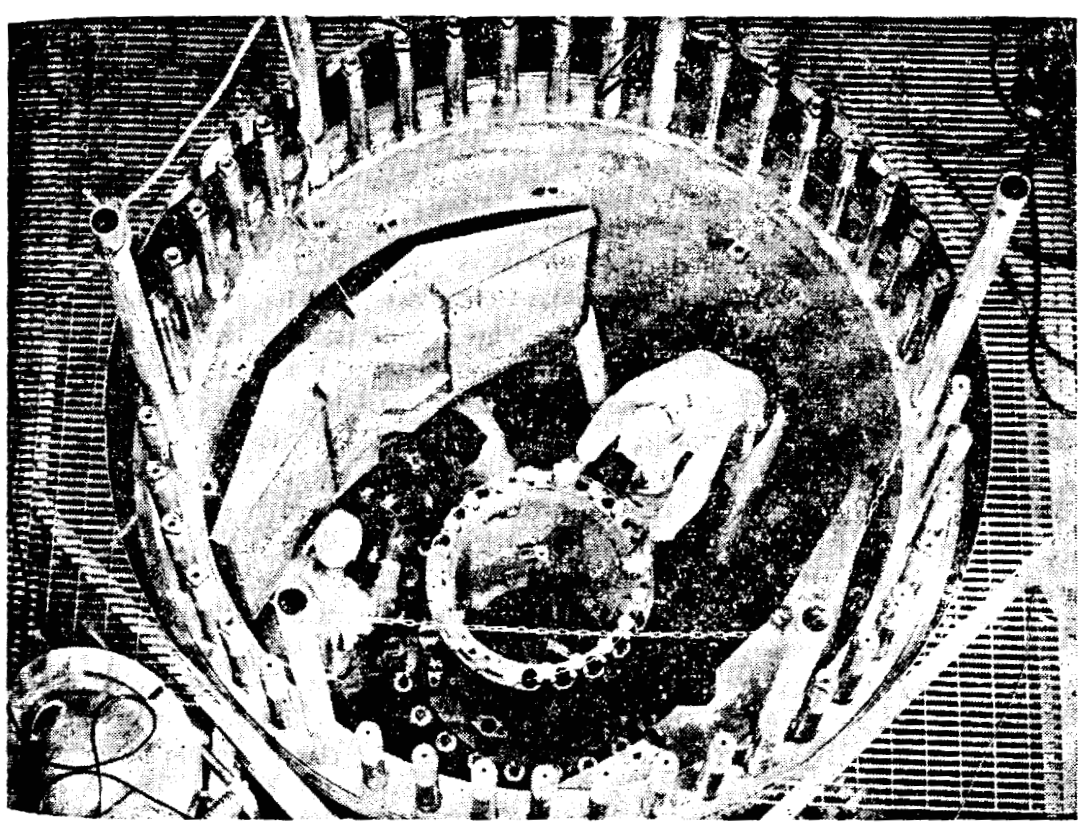




HFIR Operation. Drawing *above left* shows a cutaway view of the High Flux Isotope Reactor (HFIR) building. The entire building is sealed and the reactor operating area is kept under a negative pressure to prevent accidental release of activity. Photo *above right,* shows a model HFIR irradiation target assembly containing 31 individual rods such as the one shown individually. The actual targets contain plutonium 242 and very radioactive americium and curium oxide particles. The shroud positions the targets in the reactor and controls the flow of cooling water around the tube during irradiation. *Bottom* photo looks down directly into the HFIR with its top removed. The large tank contains the water used to cool the reactor at a pressure of 750 lbs/sq in. Pumps circulate the cooling water from the reactor to heat exchangers containing about 40 miles of tubing to dissipate the 100,000 kilowatts of heat from the reactor. In actual operation, the top of the reactor tank need not be removed; a movable flange allows replacing the fuel element or the irradiation targets.



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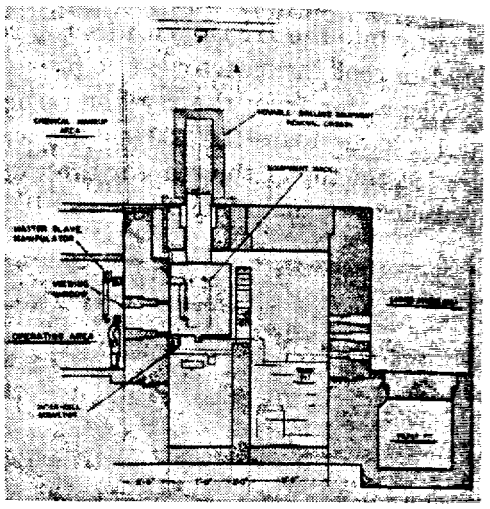
NATIONAL TRANSPLUTONIUM PROGRAM



TRU Facility. Photo *above* shows the interior of one of the chemical processing cells in the Transuranium Processing Plant (TRU) Facility. Operations within the cell are conducted with the remote-controlled arms which are covered with polyethylene to protect the mechanisms from the very high levels of radioactivity. At the *left* is a rack of equipment designed for solvent extraction. This entire rack can be remotely removed from the cell if it becomes defective. At the rear of the cell is located the equipment used to take samples of the process solution. This, too, can be repaired or replaced without personnel entering the cell. The actual process equipment shown is constructed of tantalum and Zircaloy since the solutions used are very corrosive to stainless steel and glass, which are the usual materials of construction for chemical equipment. Drawing at *right* illustrates, in cross section, the cells used in the TRU Facility to contain the process equipment. Each cell is surrounded by five feet of concrete to protect the operators from the radioactivity associated with the irradiated HFIR targets. Because of the intense radioactivity of the transplutonium elements, accidental escape of these materials to the environment is hazardous. Provisions have been made so that these cells, which are doubly enclosed, need never be opened to the outside. Routine maintenance is performed by the manipulators installed through the cell front, and defective equipment can be removed and replaced through the top of the cell in such a manner that the interior of the cell and the equipment is never exposed to the atmosphere.

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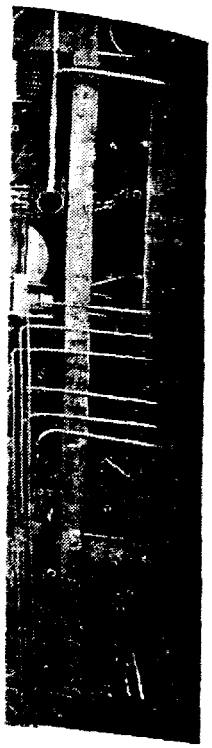

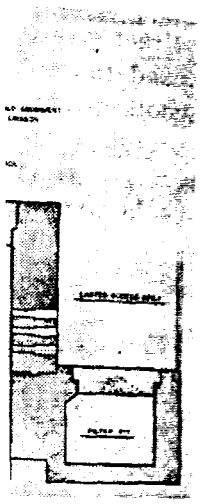

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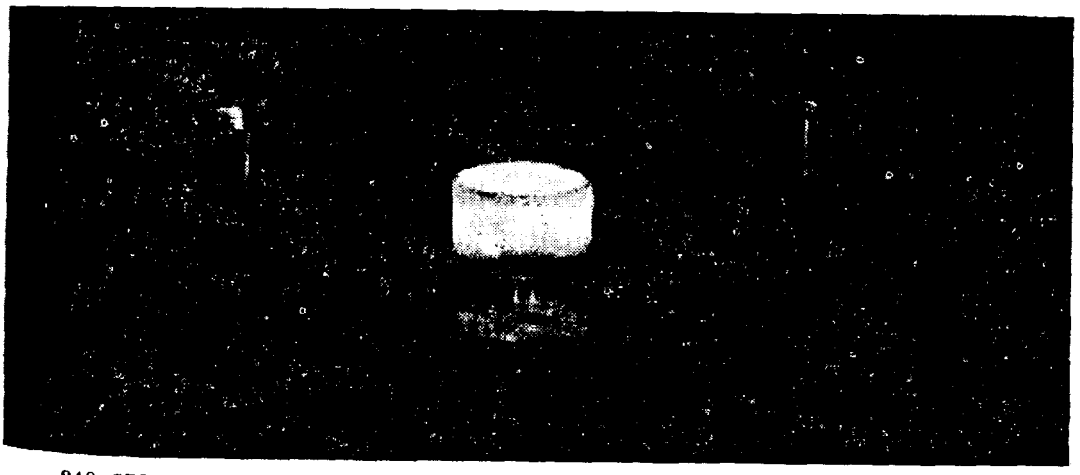
TRU Operations. Photo *above* shows the operating area in the TRU Facility. The cells in the foreground to the right contain the equipment necessary for the chemical separation of the transplutonium elements produced in the HFIR. The cells in the background house the equipment used for making HFIR irradiated targets from the highly radioactive americium and curium being recycled to the HFIR. Operation of the process equipment in the cells is carried out and monitored from the panel-board to the left, and the master slave manipulators installed in all the cells are used for adjusting and maintaining the process equipment. Photo *below* shows a pellet of curium 242 (Cm^{242}) oxide which was produced during early operation of the new National Transplutonium Center at Oak Ridge.. The photograph was taken by the light emitted from the pellet itself. Curium 242, with its half-life of 160 days, is of interest as a source of heat for supplying power for applications in the space program. Each gram of Cm^{242} generates about 120 watts of heat. The pellet in this picture is sitting on a block of copper which is cooled with water. In turn, the block cools the bottom of the pellet so that it is barely visible in the picture. The top of the pellet, because of the heat being generated within it and the absence of an efficient means of heat removal, has a temperature of about 1,000° C.



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Transuranium Processing Facility (TRU), and the Transuranium Research Laboratory (TRL) were formally dedicated by Chairman Seaborg. The first two of these facilities, HFIR and TRU, are now producing transplutonium elements, and the facilities provided in TRL form a focal point for both chemical and physical research with these elements. This unique scientific complex was built at a cost of approximately $25.3 million.

Some isotopes of the transuranium elements such as neptunium 237, plutonium 239, and americium 241, are available in quantities sufficient to supply present and anticipated research needs. The higher isotopes of plutonium and americium and the remainder of the transplutonium elements are not; their production in research quantities is the objective of the AEC's transplutonium program which was instituted in 1959.

Proposed Physical Research Facility

Weston, Ill., Picked for Proposed 200-Bev Accelerator

On December 16, 1966, the Commission announced the decision as to the location of the proposed 200-Bev National Accelerator Laboratory. An unincorporated village near Chicago, Ill., known as Weston, was chosen unanimously as the site for the proposed research facility.

In March, the AEC had received a report from the National Academy of Sciences' Site Evaluation Committee (NAS/SEC) recommending sites for this facility at the following six locations: Ann Arbor, Mich.; Brookhaven National Laboratory, Upton, Long Island, N.Y.; Sierra Foothills (near Sacramento), Calif.; Weston (near Chicago), Ill.; and Denver, Colo. The Commission undertook a comprehensive review of the NAS/SEC report and the mass of data independently collected by the AEC staff. Several of the Commissioners visited the potential sites. After weighing all factors, the Commission determined that the Weston site was the most suitable location for the facility.

Near Argonne National Laboratory. Located about 20 miles southwest of Chicago's O'Hare Airport, the Weston site consists of approximately 6,800 acres of nearly flat privately owned land and has a total elevation differential of about 50 feet. Limestone bedrock ranges approximately 50–125 feet below the surface. The bedrock is covered with glacially deposited material and is easily excavated and suitable for shielding and backfill.

Visiting scientific user groups will find the laboratory can easily be reached by air with only a 40 minute drive from the airport. Also,

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there are good highways and a major tollroad within two miles of the site, all contributing to ease of travel.

A large number of universities and colleges, with strong graduate and undergraduate programs in the physical sciences and liberal arts, are in close proximity to Weston. The proximity of AEC's Argonne National Laboratory is also an asset to the Weston site, especially during the build-up period.

Design funds requested. The principal facility of the new laboratory will be a 200-Bev proton synchrotron. This accelerator will provide an important increase in energy over the present highest energy machine, the 33-Bev Alternating Gradient Synchrotron at Brookhaven National Laboratory, and the U.S.S.R.'s Serpukhov 70-Bev proton synchrotron, near Moscow, which is expected to come into operation by the end of 1967. Detailed reviews by both the scientific community and the government have established that an increase in proton energy is the most important requirement for continued advancement in high energy physics research.

The Commission has requested authorization and funds in the amount of $10 million for initial design work in the Fiscal Year 1968 budget. Funds for construction will be requested at a later time.

LASL Visitors. The photograph shows *left* to *right:* Dr. R. E. Schreiber, Technical Associate Director of Los Alamos Scientific Laboratory (LASL); Dr. N. E. Bradbury, Director, LASL; AEC Commissioner Gerald F. Tape; and Chairman Glenn T. Seaborg being briefed by Dr. D. E. Nagle, Associate Division Leader, Meson Physics Division, LASL, on the high power radiofrequency equipment for the planned Los Alamos Meson Physics Facility during a December visit to the New Mexico laboratory.

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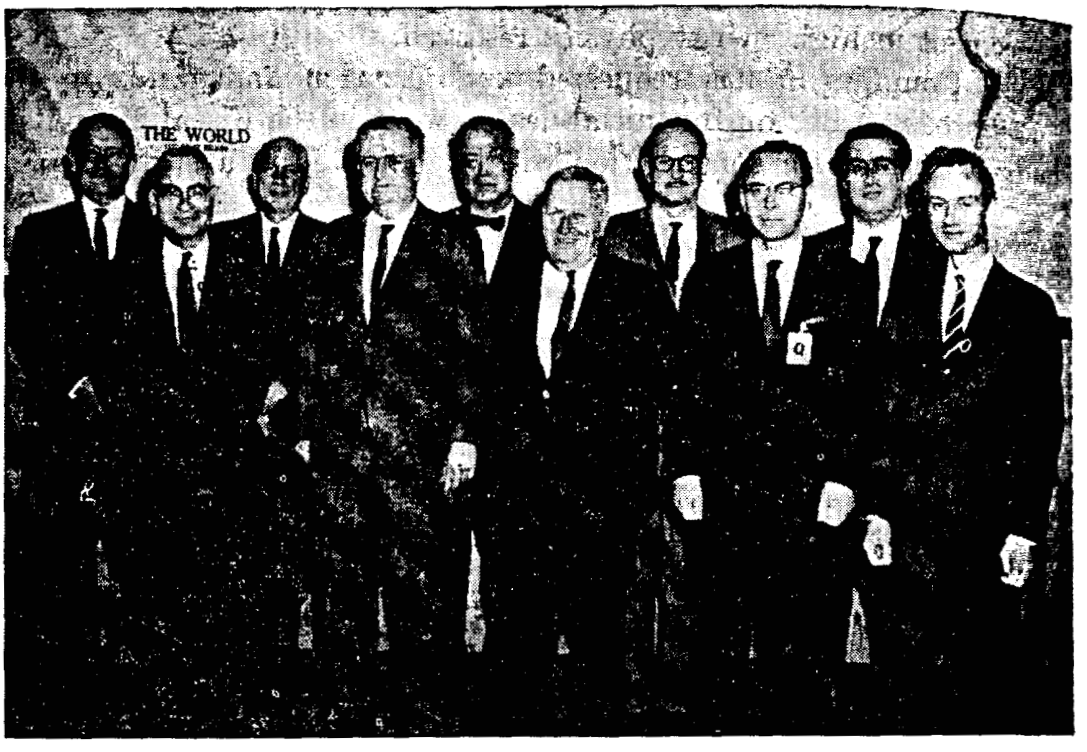
CTR COMMITTEE FORMED

Pursuant to Section 161(a) of the Atomic Energy Act, the AEC established, on June 21, a Standing Committee for Controlled Thermonuclear Research to review, on a continuing basis, the controlled thermonuclear program and provide advice and recommendations relative to this program. The committee will ensure a closer cooperative effort within the program and provide guidance on implementing major program decisions.

The committee has nine members, four of whom are directors of the CTR work in laboratories pursuing major programs in this field, and four prominent members of the scientific community outside of the AEC and its major laboratories. The chairman of the committee will be the AEC's Assistant Director of Research for Controlled Thermonuclear Research (see Appendix 2 for list of members).



Research Leaders. Directing the AEC's research and development programs and multi-program laboratories are (*left to right*): Brig. Gen. Delmar L. Crowson, USAF, Director, Division of Military Application (Headquarters); Dr. Alvin M. Weinberg, Director, Oak Ridge National Laboratory; Dr. Norris E. Bradbury, Director, Los Alamos Scientific Laboratory; Dr. George M. Kavanagh, Assistant General Manager for Reactors (Headquarters); Dr. Spofford G. English, Assistant General Manager for Research and Development (Headquarters); Dr. Frank H. Spedding, Director, Ames Laboratory; Dr. Edwin M. McMillan, Director, Lawrence Radiation Laboratory; Dr. Maurice Goldhaber, Director, Brookhaven National Laboratory; Dr. Albert V. Crewe, Director, Argonne National Laboratory; and Dr. Michael M. May, Associate Director of Lawrence Radiation Laboratory and Director of its Livermore Laboratory. (Dr. Crewe resigned in December to return to teaching at the University of Chicago but continues to serve as Argonne's director until his successor is appointed.)

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BIOLOGY AND MEDICINE

The goal of the AEC's research program in the biological, medical and environmental sciences is to develop the technical knowledge needed for full comprehension of the possible short- and long-term biological consequences of nuclear energy. Toward this end, the AEC sponsors varied programs of fundamental research in many fields of interest which are summarized in a supplemental report (see footnote, page 279). Described below are studies related to the Nation's civil defense program, and new facilities that will enhance the overall effort in biomedical research.

NUCLEAR ENERGY CIVIL EFFECTS

Scientific knowledge continues to accumulate on the effects of ionizing radiations on man and his environment. The nuclear energy civil effects program discussed in this section includes Operation HENRE which is being carried out at the Nevada Test Site. The Oak Ridge National Laboratory-Department of Defense study on civil defense research, and a joint Office of Civil Defense-AEC study on fallout shelters are also discussed in this section.

Operation HENRE

During the fall of 1966, the High Energy Neutron Reactions Experiment (HENRE) became operational at the Neveda Test Site. About 35 tritium targets have been manufactured by Oak Ridge National Laboratory for the experiment. Each traget, with an area of approximately 155 square inches, was designed to provide trillions of 14-Mev (million electron volts) neutrons per second for exposure periods of up to four hours each.[4] The neutron source is mounted in a hoist car on the 1,527-foot BREN [5] tower and operated at various elevations, the lowest being 27 feet and the highest 1,500 feet.

Monoenergetic neutron source. The fundamental purpose of the experiment is the need to improve the understanding of the propagation of neutrons and gamma rays in the atmosphere near the earth's surface. Within the AEC, the information will be used to refine the equations used to calculate the radiation doses of people who are exposed, as were the Japanese survivors of Hiroshima and Nagasaki.

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[4] A target is mounted so that it is hit by a beam of accelerated deuterium ions, and the 14-Mev neutrons result from the reaction: tritium + deuterium = helium + neutron + energy.
[5] See pp. 318–324, "Annual Report to Congress for 1962."

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Continuing studies by the Atomic Bomb Casualty Commission require better estimates of neutron exposures than have been previously available. Although the neutron source produces few gamma rays directly they appear as a result of collisions between neutrons and the atoms in air—nitrogen atoms in particular. Experimental data obtained through the use of an essentially monoenergetic neutron source, that is, a source from which most of the neutrons have an energy of 14 Mev, can simplify the calculations to be done with computers using data obtained in field measurements. Earlier calculations were done with data obtained from Operation BREN in 1962[6] during which a small reactor was mounted on the tower and produced a mixed spectrum of neutrons similar to a fission spectrum.

Other measurements made. A wide variety of experimental measurements are being made during Operation HENRE which is expected to be completed in March 1967. In addition to those for radiation propagation studies, measurements are being made for shielding, dosimetry, instrumentation, neutron activation, and spectral studies. The data are being analyzed by scientific personnel of the participating laboratories.

Operation HENRE was organized as a joint AEC-Defense Atomic Support Agency (DOD) research effort with Oak Ridge National Laboratory providing the main AEC participation and the Armed Forces Radiobiology Research Institute being the focal point for the DOD program. Other research groups are participating, using the unique experimental array for field programs in keeping with their respective interests.

ORNL Civil Defense Research

During 1966, the civil defense research project at Oak Ridge National Laboratory was expanded to include studies of active-passive defense interactions, weapons effects, and behavioral sciences supported by the Advanced Research Projects Agency of the Department of Defense. The project was originally established in 1964 as an activity jointly funded by the Office of Civil Defense and the AEC.

The civil defense research project continued its studies related to advanced civil defense systems which might be feasible for the protection of U.S. population in the 1970's. The research staff, composed of scientists and engineers from various scientific disciplines, is seeking various approaches to the central problem of saving lives in the event of attack upon the United States. Early efforts have dealt with identifying the feasibility of various components of protective systems and

[6] See pp. 318–324, "Annual Report to Congress for 1962."

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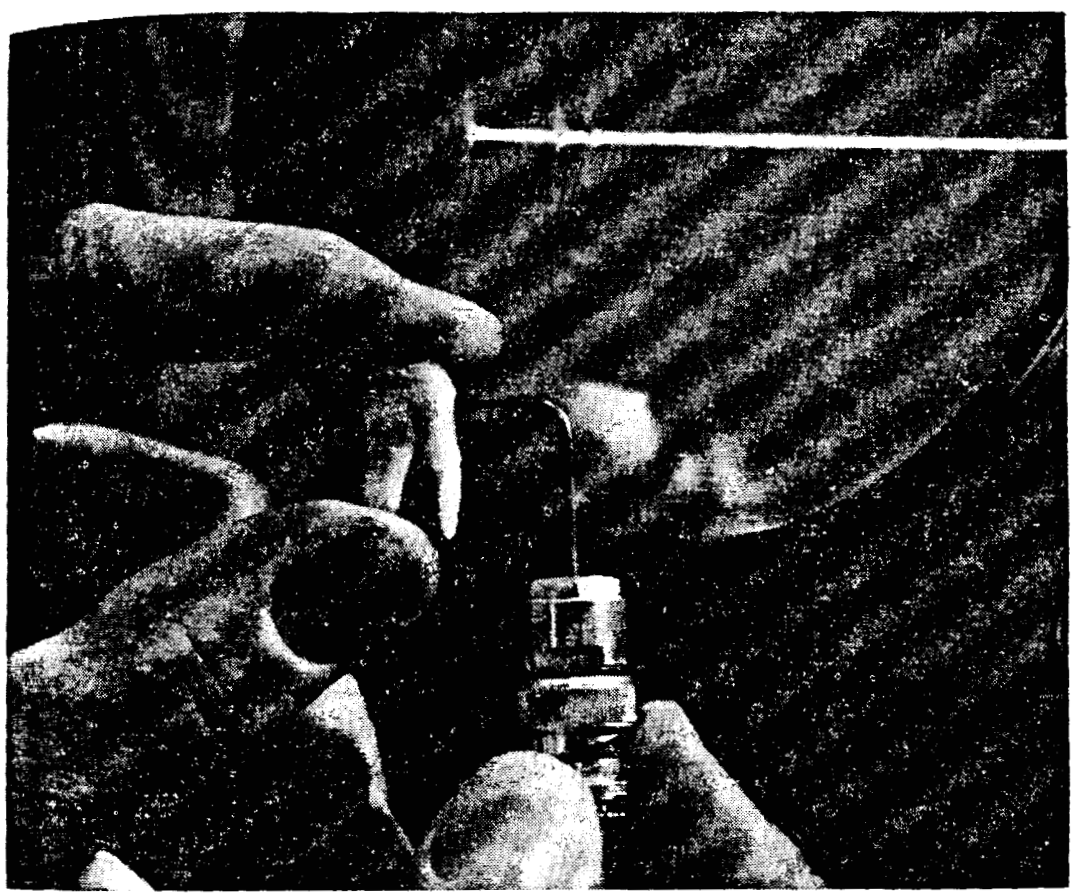
defining areas in which further research is clearly required. Thus biomedical, sociological, engineering, weapons effects, and active defense subjects are being considered.

Non-nuclear weapons included. Important in the continuing work, is the search for methods to protect large concentrations of people against the contingency of attacks on cities. Not only must a working system protect against the initial and residual effects of nuclear explosions, it must also lead effectively into the post-attack recovery stage. The project is also looking into biological and chemical weapons defenses so as to assure that a system for protection of populations against nuclear effects will not be overly vulnerable to non-nuclear weapons. In its totality, protection is conceived of consisting of more than just a shield against weapons effects; passive measures must be



"Spin off". The idea of applying ultrasonics to biomedical uses came out of extensive work done in the field of nondestructive testing techniques in nuclear energy research. Demonstrated here, is how an ultrasonic probe can be used to "see" into a tooth to detect early cavities (note deviations from line on oscilloscope in background) without the use of X-rays. The primary interest in this field of research is to find a means of doing what X-rays do—look inside a solid object—without exposing a person to radiation. This research was initiated at the AEC's Pacific Northwest Laboratory and further studies are currently being carried out under the sponsorship of the U.S. Public Health Service.

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considered as they relate in effectiveness to air defense and antimissile defense.

Important to the study of passive systems are the: (*a*) acceptability of shelters in urban complexes; (*b*) capability of a shelter to resist nuclear and secondary effects while sustaining good health during prolonged occupancy under crowded conditions; and (*c*) adequacy of those items, *e.g.*, food supplies in, and outside, shelters, essential for a vigorous recovery effort in a period following shelter occupancy.

As the program develops, increasing benefits will be obtained through the broad technical and scientific base provided by Oak Ridge National Laboratory and other AEC laboratories.

OCD–AEC Fallout Shelter Study

Field measurements and analyses of data were completed during the year for a separate fallout shelter study project supported jointly by the Office of Civil Defense (OCD) and the AEC. The requirement for the project arose from OCD's desire to have experimental evaluations of proposed fallout shelter designs which will increase the protection against fallout radiation in homes with basements. Although in recent years a substantial advance has been made in the reliability of methods for calculating the protection afforded by a home basement and by a basement augmented by certain types of fallout shelter structure, it was considered that confidence in the designs would be increased by an experimental check.

The fallout shelters were built according to OCD designs in the basement of a wood frame house remaining at the Nevada Test Site from the 1955 Federal Civil Defense Administration tests. Provisions for radiation measurements were made by AEC through its contractor. EG&G, Inc., Las Vegas, Nev.

The radiation field from fallout was simulated by the use of calibrated radioactive sources which were circulated through a hose arranged on the surface around the house and over the roof. Integrating radiation measuring instruments recorded the doses at a number of points inside and outside. The comparison of doses measured with and without shielding, *i.e.*, with and without shelter, makes possible the derivation of values for shielding effectiveness known as protection factors. For the fallout shelter designs studied, the experimental values for protection factors were in the range contemplated by OCD. In addition, information was obtained for the intercomparison of calculational and experimental approaches to radiation shielding.

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NEW BIOMEDICAL RESEARCH FACILITIES

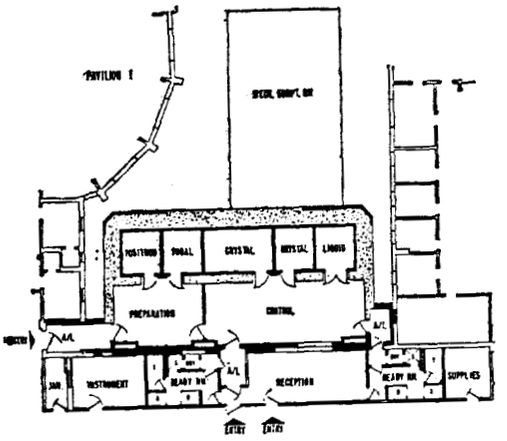
In addition to the four government-owned laboratories described below, the new Plant Research Laboratory constructed by Michigan State University, East Lansing, was completed in June. The research program in plant radiobiology at Michigan State University was described in some detail in the report for 1963.[7] A major addition for the Atomic Energy Project at the University of Rochester, also constructed by the university, is expected to be occupied in December 1966.

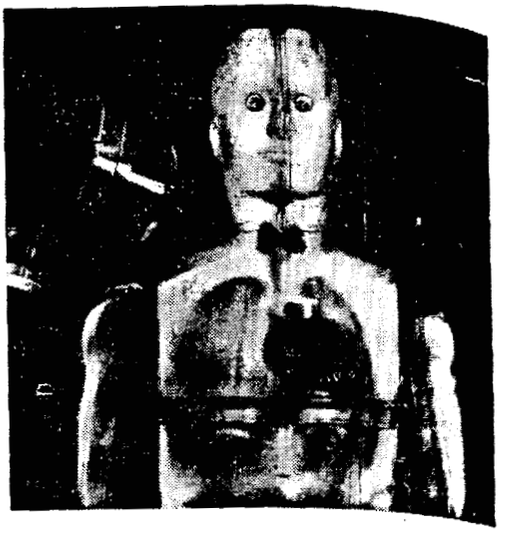
Low-Level Counting Facility at BNL

A new, low background, counting facility will become operational in early 1967 at the Medical Research Center, Brookhaven National Lab-

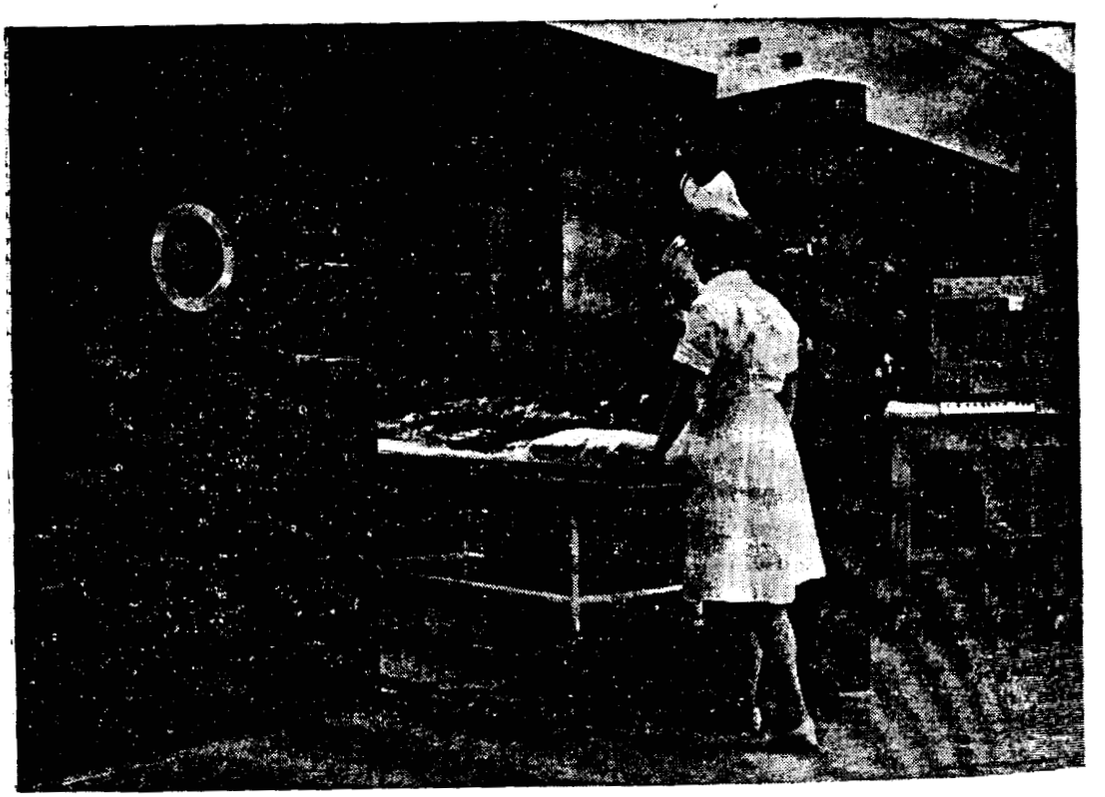
Operation Observer. AEC Commissioner Samuel M. Nabrit (*left*) discusses details of thoracic surgery being carried out on a Hanford miniature swine, with Dr. Harvey A. Ragan, senior research scientist at the Pacific Northwest Laboratory. Dr. Nabrit visited the biology department before attending the November reactor shutdown verification system demonstration for United Nations representatives. The Hanford strain of miniature swine, developed over the past several years for AEC radiation effects studies, are proving invaluable for many forms of medical research since their weight—160–180 pounds—and body structure is similar to man's.

[7] See pp. 256–257, "Annual Report to Congress for 1963."





Low-Level Counting Facility. Drawing *above left* shows the floor plan of the new low-level counting facility at Brookhaven National Laboratory. The heavy lines indicate the steel shielding, which is surrounded by four feet of concrete. The two steel rooms on the left are to be used for localized counting procedure, while the three on the right will be used for various types of whole body counting and for development of new counting methods. The various internal organs of the plastic phantom at *right above*, are filled with known amounts of radioisotopes, and the phantom is then used to calibrate the whole-body counter. In the illustration the gamma spectrum of iodine 131 in the thyroid is being obtained with the sodium iodide scintillation crystal at the left. Photo *below* shows the phantom being taken into one of the steel rooms of the low-level counting facility. The door consists of 8″ thick steel plate with a lead glass window. A lead lining is to be added on the inside of the door and room. The instrument on the table is a pulse height analyzer used in the resolution of the gamma-ray spectra obtained with radiation detection instrumentation located in the steel rooms and not shown in this picture.



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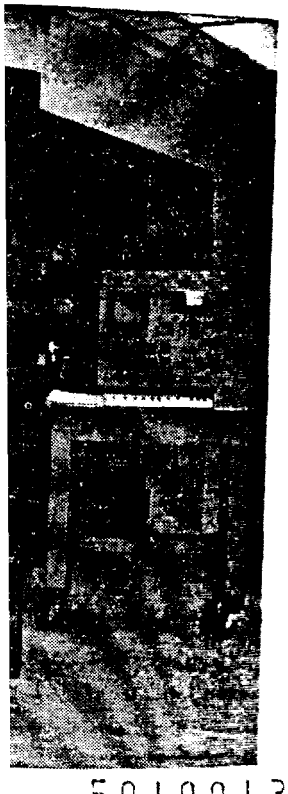

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oratory (BNL). This facility includes five heavily-shielded rooms with a specially controlled air supply to provide for the handling of patients without regard to the unpredictable interferences caused by low-level radioactive argon 41 effluent from the nearby Brookhaven Graphite Research Reactor. It will permit accurate measurement of radioactivity in patients at levels not previously discernible because of inadequate shielding. As a consequence a further reduction in the amount of radioactivity used for clinical diagnostic and metabolic studies can be accomplished.

Among the projected clinical research studies that will use the new facility are: vitamin B_{12} absorption and turnover, using cobalt 60-labeled-cobalamine; thyroid metabolism, using technetium 99^m and radioactive forms of iodine; the turnover of trace metals in *Wilson's* and *Parkinson's* diseases, using radioactive forms of copper and manganese; studies of the long-term turnover of thorium and of cesium, strontium, and other fission products; and the kinetics of skeletal metabolism of calcium. The whole-body counting equipment will also be used in routine physical examinations of employees who work with radioactive materials, and will be available for emergency scanning of employees or others suspected of contamination by radioactive materials. Other rooms in the facility will be used for counting selected organs of the body, for organ scanning, and for the development of new counting methods.

Carcinogenesis Research Laboratory, ORNL

A building formerly used as a part of the Oak Ridge uranium production and separations complex in the Y–12 Plant has been remodeled into laboratories, animal quarters, and related service areas and offices for a joint co-carcinogenesis project sponsored by the National Cancer Institute and the AEC. The structure (Building 9211) is now part of the group of buildings occupied by the Biology Division of the Oak Ridge National Laboratory (ORNL). The building is a four-story structure with steel frame and masonry walls, which has been cleared of processing equipment and decontaminated. Three existing floors will be used for the cocarcinogenesis project. The fourth floor contains special animal quarters and facilities for studying the interaction of viruses, chemicals, and radiation in causing cancer in mice. The chemicals in this case are ozonized gasoline vapor (a substitute for "smog"), and chromium oxide. The third floor contains special animal quarters where "barrier type" animals will be produced and housed for other experiments requiring specific pathogen-free animals. The bottom two floors will be concerned with basic research of many different kinds looking at the various causes of cancer. The

fourth floor, in which experiments have been going on for more than two years, was renovated jointly by the AEC and the National Cancer Institute.

Atmospheric Sciences Building, PNL

A new facility has been completed at the Pacific Northwest Laboratory (PNL) to house the atmospheric sciences operation which had previously been located in several scattered facilities at the Hanford, Wash., complex.

The research and development work in atmospheric sciences at Hanford provides basic experimental data required in the establishment of mathematical models for studies of atmospheric exchange processes. The atmospheric radioactivity and fallout studies are designed to determine the average concentrations of airborne gaseous and small particulate materials at various distances and directions from the source, their subsequent deposition on the ground and vegetation, and the probability of their re-entrainment and translocation by natural forces after initial deposition. This research embraces the life cycle of atmospheric pollutants under a variety of meteorological and terrain conditions and at various times of day and seasons.

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Chapter 14

NUCLEAR EDUCATION AND TRAINING

The AEC conducts a widespread program of cooperative support for nuclear education programs in schools and in institutions of higher education. Major emphasis of the program is graduate education in nuclear science and engineering, and cooperative activities between AEC facilities and the educational community through which staff and facilities of the AEC and its contractors add to the scientific education and research capabilities of colleges and universities. The AEC supports this program to help meet the growing demands of worldwide nuclear activities for specialized manpower not adequately provided by conventional graduate education. The individuals thus educated through AEC support are only a fraction of the total specialized manpower demands.

New Programs Added

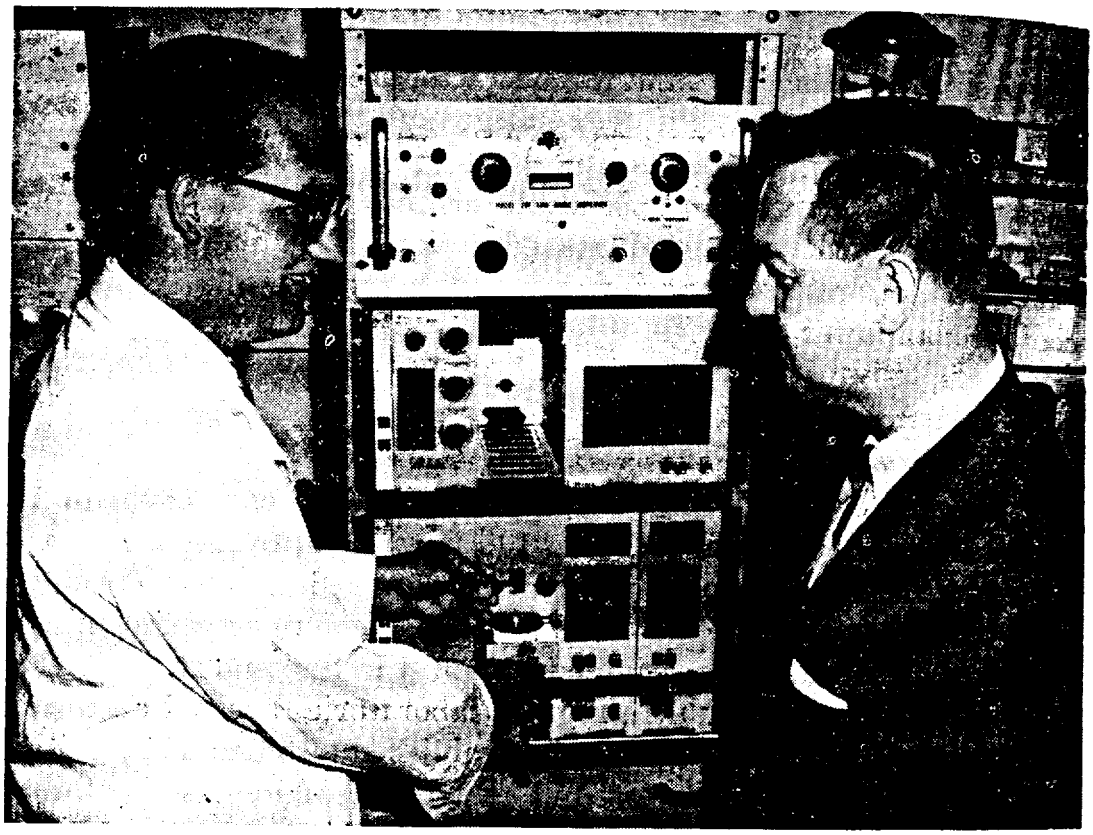
Significant events during the year included the enrollment of 102 trainees in nuclear engineering on 19 campuses in the second year of a graduate student traineeship program designed to help increase the number and geographical distribution of centers of excellence in nuclear science and engineering education. In September, the first 10 students from 5 AEC multi-program laboratories arrived on 8 campuses for full time study in a newly established technician scholarship program. This program, initiated as a result of interest by former Commissioner Dr. Mary Bunting and the Joint Committee on Atomic Energy, recognizes special talents for leadership by providing opportunities for laboratory employees to complete their studies for baccalaureate degrees. The total cooperative efforts between AEC sites and universities continued to expand to more sites and additional institutions.

The AEC's education and training programs involved some 540 fellows, 1,275 institutions, 7,700 faculty, 28,000 participants of various

kinds, and 14 AEC laboratory and research facilities. In addition, approximately 5,300 graduate students received support through employment in research activities at AEC laboratory sites and through university research contracts.

Employee Training

Employees of contractors operating AEC plants and facilities receive educational assistance under various employee development programs. Tuition aid, with most of the cost borne by the employer, is the principal college level assistance provided by contractors. It is estimated that the AEC currently has a major role in assisting employees in receiving some 600,000 hours of formal college educational training annually. In addition, guest appointments to AEC laboratories, part-time employment of students and faculty assisted in the



Job-Related Training. As a part of the overall employee development program, the AEC and its major contractors provide educational assistance leading to advanced degrees. In the photo, Mound Laboratory scientist Richard Wolfe (*left*) explains details of his master's degree research to his graduate advisor, Professor Warren Stubbins of the University of Cincinnati. Wolfe received his master's degree in nuclear engineering following publication of his thesis during 1966. In addition to company financial assistance, both Mound Laboratory (operated for the AEC by Monsanto Research Corp.) and the University of Cincinnati supplied instruments and facilities for his research. During the year, more than 180 AEC-contractor employees were working toward baccalaureate degrees under this program.

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training of some 5,000 persons by AEC contractors. The table reflects the 1965–1966 data comparison for these programs:

AEC Contractor Training Programs	Number of Participants		
	Fiscal Year 1966	Fiscal Year 1965	Percent Change
Temporary and part-time use of students and faculty:			
A. Cooperative education participation (Students taking similar courses alternate between school and work and normally provide continuous position coverage.)	320	283	+13.1
B. Research and engineering participation (Students or teachers combining part-time university attendance or teaching with part-time laboratory assignments or alternate periods of AEC research with university attendance or teaching.)	1,168	1,140	+2.5
C. Guest appointments (Temporary employees appointed to gain experience through performance of research projects which are part of the contractor's mission.)	1,085	699	+55.2
D. Summer technical (Vacation employment of university and secondary school students and faculty.)	2,119	2,008	+5.5
Work experience training (Employees sponsored by other organizations who participate to meet the demonstrated needs of their sponsor where such training is determined to be in the best interest of overall atomic energy development.)	461	329	+40.1
Job related activity (College level training courses and research assignments for regular contractor employees. Only training courses or research assignments of more than 168 hours' duration are reported.)	188	194	−3.1

EDUCATIONAL PROGRAMS AT UNIVERSITIES AND COLLEGES

A variety of specialized programs, such as fellowships, traineeships and faculty training institutes, were provided to update or expand the knowledge and experience of college and university teacher-scientests and to attract capable students into the teaching of nuclear science and engineering. Specialized teaching equipment and nuclear source ma-

terials are provided to participating colleges and universities to improve and expand programs and to develop centers of excellence in nuclear education throughout the nation.

FELLOWSHIPS AND TRAINEESHIPS

The AEC provides assistance for five types of specialized fellowships for graduate students and a traineeship in the area of nuclear engineering.

Specialized Fellowships

During the year, the AEC sponsored fellowships and traineeships in the following areas:

Nuclear science and engineering. A total of 209 graduate students received fellowships to pursue their studies at the first, intermediate, or terminal year levels of graduate work at 36 universities. The fellowships are limited to support of highly qualified applicants who express intent to remain within the field of the fellowship after completion of their studies.

Health physics. To meet the growing demand for qualified persons in research and applied health physics activities, 67 graduate students were awarded fellowships for study at 11 universities. The graduate studies are at three levels (first, intermediate, and final year), with the first academic year of study followed by a three-month period of on-the-job summer training in an AEC national laboratory.

Industrial medicine. Licensed physicians were encouraged to attain specialization for medical practice in nuclear industries through fellowships administered by the University of Rochester (N.Y.) for the AEC. Fellowships were awarded to 16 physicians to complete an academic year of study at an approved university and participate in a year of in-plant training in the medical department at an AEC operating plant or industrial laboratory.

Predoctoral thesis research. AEC laboratory research, when mutually approved by the laboratory and the student's university, provides a unique source of doctoral thesis material. Predoctoral students, totaling 116, received fellowships for pre-arranged thesis research in the physical and biological sciences and engineering at AEC laboratories.

Postdoctoral fellows. A group of 37 postdoctoral fellows worked at AEC laboratories or at universities during some part of the year.

Traineeships in Nuclear Engineering

To assist good universities to become centers of excellence in nuclear engineering throughout a broad geographical area, 19 participating institutions of higher learning were authorized to select 102 trainees to pursue graduate work.

FACULTY TRAINING INSTITUTES

During the year, the AEC conducted four types of training sessions for college and high school-level faculty members.

Nuclear Science Institutes

Summer sessions. During the summer of 1966, there were 33 faculty training institutes conducted on the graduate level at 29 colleges and universities, and at the Argonne National Laboratory and the Oak Ridge Associated Universities.[1] Lasting from 6 to 10 weeks, 15 of these institutes were for college science faculty, and 18 were for high school faculty. A total of 735 college and high school faculty members were selected to participate in summer institute programs appropriate to their needs and their regular teaching assignments. Typical of the subjects covered in these concentrated summer institute programs were radiation biology, nuclear spectroscopy, isotope technology, nuclear physics, and basic nuclear engineering. In all summer institutes science teachers are encouraged to incorporate their summer training into the science curriculum at their home institution.

In-service sessions. Five colleges and universities and two educational associations (Oak Ridge Associated Universities, and Associated Universities, Inc.), conducted eight in-service institutes evenings and Saturdays for high school science faculty, enrolling over 200 practicing science teachers for specialized graduate-level training in nuclear sciences. Particularly effective in populous areas, these institutes enable the science teachers to incorporate and test newly-learned information in atomic energy in their classrooms by including it in their current lesson plans.

Academic-year sessions. For 26 college and secondary school faculty who were able to take leave from their school year teaching duties, an academic year institute was offered at both Oak Ridge Associated Universities and at Cornell University. Graduate study in some depth is made possible by this full year devoted to the study of some

[1] On January 1, 1966, the corporate name of the former Oak Ridge Institute of Nuclear Studies (ORINS) was changed to Oak Ridge Associated Universities.

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are free loans of enriched uranium for fuel elements and fission plates, plutonium or polonium for neutron sources and heavy water. The AEC provided $530,259 to assist reactor programs at six major universities.

EDUCATIONAL PROGRAMS THROUGH AEC LABORATORIES

The University-AEC laboratory cooperative programs continued to expand with 12 AEC laboratories [2] participating. Designed to make the unique research facilities of AEC laboratories available to university and college students and faculty primarily at the graduate level, the program increase the interchange of scientific and technical information among students, faculty and laboratory personnel. Activities in this area vary from general orientation in broad areas to sophisticated research training in specific aspects of nuclear science and engineering. Insofar as possible, these activities are tailored for the individaul and his specific educational needs.

COOPERATIVE PROGRAMS

Many of the cooperative uses of the facilities at AEC laboratories are developed by associations of universities and colleges as a part of their overall programs. In most instances, the association program is based on a particular AEC laboratory within its geographic area. The use of AEC laboratories, however, is open to faculty and students without regard to regional limits.

Active Associations

Among the more active associations so invloved are the Oak Ridge Associated Universities (ORAU), Associated Midwest Universities (AMU), Associated Rocky Mountain Universities (ARMU), Central States Universities, Inc. (CSUI), Associated Colleges of the Chicago Area (ACCA), and Associated Colleges of the Midwest (ACM). Within the ORAU, two new committees were established to strengthen the cooperative activities in engineering education and to coordinate university use of the new transuranium facilities at Oak Ridge National

[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, Sandia Laboratory, Savannah River Laboratory and University of Rochester Atomic Energy Research Project.

Laboratory. Within the AMU, two new committees also were established to strengthen the cooperative activities in biology and to coordinate university use of the new advanced research reactor to be built at the Argonne National Laboratory. About 450 faculty members and 1,100 students from 550 different institutions throughout the United States participated in cooperative arrangements at AEC laboratories.

AEC Plant Used as Training Site. Facilities at the AEC's Oak Ridge Y-12 Plant, were used to update the training of vocational and technical teachers attending a training and technology summer institute. In photo *above*, participants attend a class in electronics; photo *below* shows a welding class. Courses are being conducted in mechanical technology and drafting, industrial electronics technology, and maintenance and machine shop fabrication. The training, supported by the U.S. Office of Education, is administered through the Oak Ridge Associated Universities. Other participating agencies include the U.S. Department of Labor, the Tennessee State Department of Education, the University of Tennessee, and the Oak Ridge Atomic Trades and Labor Council.

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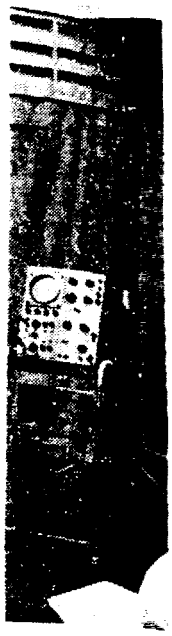

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Faculty Participation

Activities directed toward the training of faculty of colleges and universities take a variety of forms. All are designed to provide faculty members with research training experience which will enable them to translate the acquired technology into the development or improvement of curricula in their institutions or into the initiation of new research programs. There are three major activities in this area.

Faculty research training appointments. Selected faculty members are assigned to various AEC laboratories for research experience. About 150 faculty members from 124 institutions received research training appointments in the summer of 1966.

PACE programs. Faculty are provided the opportunity to become acquainted with new developments and research techniques in their scientific area under the PACE (Professional Activities for Continuing Education) program. The PACE program was carried out at Argonne National Laboratory in the areas of chemistry and biology with five faculty members from five institutions participating.

Weekend workshops. Faculty from nearby colleges are encouraged to use facilities at the Argonne National Laboratory for research and training in areas such as neutron activation analysis, nuclear magnetic resonance, gamma scintillation spectroscopy, and several others. These facilities, now known as the "Common Laboratory", were formerly used for the training of foreign nationals under the "Atoms for Peace" program and contain much scientific equipment not normally available in college laboratories. Two hundred and eleven faculty from 104 institutions attended weekend workshops at ANL during fiscal year 1966.

Graduate Student Training and Research

Programs are being carried out at all AEC laboratories to enable graduate students to use the unique facilities and to associate with mature scientists in the field of their study. In general, the activities in this area involve thesis research, temporary employment, and engineering practice school.

Temporary employment. Graduate students gain valuable laboratory experience through actual participation in nuclear science research programs by working with specialists at AEC laboratories. About 1,100 graduate students were thus employed during fiscal year 1966. In addition, there were 4,200 graduate students in university laboratories working on AEC research projects in the physical and life sciences.

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Engineering practice schools. Graduate students can gain practical engineering experience at AEC laboratories. In the summer, the annual ANL–AMP Engineering Practice School was held with 32 students from 19 institutions attending the 12-week school. In the fall, the Massachusetts Institute of Technology re-established an engineering practice school at Oak Ridge National Laboratory. Ten students formed the first class in this 10-week program. It is planned to have 4 groups, of about 10 students each, participating each year. An MIT faculty member in residence at ORNL supervises the program.

Undergraduate Instruction and Research

While a majority of the AEC-sponsored educational activities are directed toward faculty and graduate students, the following important activities provide the undergraduate student valuable scientific experience.

Argonne semester. Science students from institutions represented by the Associated Colleges of the Midwest (ACM) engage in half-time study and half-time research at Argonne National Laboratory. Three professors from ACM member institutions are assigned to ANL for a year to assist the laboratory staff in supervising these students. During fiscal year 1966, the eighth year in which the program operated, 10 science students participated.

Honors programs. Science students of outstanding ability are selected to study and do research at ANL. In February, a CSUI–ANL Honors Program for 12 science students was initiated and the program was continued in the fall semester with 14 students participating. These 26 students were from 20 institutions. The National Science Foundation provided full stipends for the students. A similar activity was conducted at Argonne National Laboratory during the summer for 11 science students from 18 predominantly Negro colleges.

Summer student trainees. Selected junior-year students in science and engineering can participate during the summer months with senior laboratory staff on important research and development projects. During the summer, 282 students from 207 institutions took part in this program at seven AEC laboratories.

Student experiments. College science classes, under the guidance of their own faculty, conduct experiments in the facilities of the Argonne "Common Laboratory." During 1966, approximately 650 students from 76 institutions visited ANL to participate in these experiments.

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Training of Radiation Protection Technicians

The need for radiation protection of health physics technicians has resulted in a new pilot training program. The AEC in cooperation with Idaho State University has instituted a two-year program at the University and the National Reactor Testing Station (NRTS). The training consists of two years of collegiate level course work and two summers of health physics training at NRTS. The first class of 10 people completed its work in September 1966.

SPECIAL PROGRAMS

A variety of activities, not directed specifically at faculty and student participation in AEC laboratory programs, are also sponsored. These programs offer specialized training to diversified groups of participants.

Summer Student Trainees. Technical-minded students are provided an opportunity to advance their education by practical experience during summer employment at AEC laboratories. Insofar as possible, the summer jobs are oriented to the students's field of interest without regard to regional locations. *Left* photo shows Fred Lewis, a summer trainee with Pacific Northwest Laboratory, making a final correction on a schematic design for a facility to test an axial flow separator. Lewis is in his senior year at Southern University, Baton Rouge, La., and working toward his B.S. in mechanical engineering. Eleven college students from throughout the U.S. participated in Pacific Northwest Laboratory's summer training program. On *right*, an Argonne National Laboratory staff member shows John Flowers, a University of North Carolina student, some of the sophisticated hardware to be used in his nuclear research work.

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Specialized Training Courses

During the year, specialized training courses were sponsored on the following basis:

Radioisotopes techniques courses. The ORAU, under contract with AEC, conducts a variety of special courses in radioisotope research and analytical techniques. During 1966, 133 scientists, engineers, physicians, faculty members, and others attended these courses.

Medical qualifications courses. ORAU also conducts basic training courses in the handling of radioactive materials and provides clinical experience in the use of radioisotopes for diagnosis. Seventy physicians attended these courses.

Mobile radioisotope laboratory courses. Intensive 2-week on-campus training courses in basic radioisotope techniques were provided for faculty and students by means of 3 mobile laboratories which visited 43 college campuses. In all, 199 faculty and 420 students received instruction during the year.

Technical scholarship program. A pilot program was started in 1966 wherein 10 outstanding technicians, employed by AEC contractors, were provided an opportunity to complete their education at the baccalaureate level. Eligible employees must be able to complete their academic requirements in two years or less. Two employees, each, from Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos Scientific Laboratory, Lawrence Radiation Laboratory, Livermore and Oak Ridge National Laboratory were enrolled in eight universities across the country in this pilot program.

Mobile Training Laboratory. Three mobile radioisotope training laboratories were operated during the year by the Special Training Division of Oak Ridge Associated Universities in the AEC's program to provide short radioisotope techniques courses to small colleges throughout the country. These laboratories provide instruction and training in basic radioisotope techniques for both faculty members and students at small colleges which have limited staff and essentially no appropriate facilities. They also provide additional training support to some faculty institutes at universities conducted during the summer. During the year, a total of 43 colleges were visited for two weeks' special training at each site.

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Puerto Rico Nuclear Center

The Puerto Rico Nuclear Center (PRNC), with facilities located at Rio Pedras and Mayaguez, provides graduate and undergraduate education and research opportunities primarily for Puerto Rican and Latin American students in nuclear science and engineering and in the application of nuclear techniques in agriculture and medicine. The center is operated by the University of Puerto Rico under contract with the AEC.

More than one-third of the staff-effort at the PRNC involving research programs in marine biology, tropical ecology, food irradiation, radiation effects, and neutron diffraction continued to be supported by the AEC. In July, PRNC was selected by Battelle Memorial Institute, Columbus, Ohio—an AEC contractor for the interoceanic sea-level canal study—to perform terrestrial and marine ecology studies in connection with the canal study (see Chapter 13—The Plowshare Program).

PRNC entered into a laboratory-to-laboratory arrangement with the Institute of Nuclear Affairs in Bogota, Colombia. Under this arrangement, which is financed by the Agency for International Development (AID), PRNC will provide advice and guidance to the Institute in developing the latter's nuclear research program. A similar program, financed by Venezuela, was established with the Institute of Scientific Investigation at Caracas, Venezuela.

In the area of training and education, 52 students were enrolled in advanced degree course work on research at PRNC and 230 students were enrolled in various individual courses given at PRNC during the 1965–1966 academic year. Of these, 32 were non-U.S. citizens representing 17 countries.

OTHER EDUCATIONAL ASSISTANCE

Universities, colleges, high schools, AEC laboratories and contractor sites were assisted in a variety of ways through relatively small but highly specialized programs ranging from the visiting lecturer-consultant to the more formalized conference or symposia. In addition, educational publications are funded ranging from brochures to laboratory manuals.

Lecture and Consultation Programs

The AEC makes available, through contracts with the American Society for Engineering Education (ASEE) and the American Institute of Biological Sciences (AIBS), a broad program of lecture and consultation services. Nuclear engineering consultations were

arranged by the ASEE; such consultations included lectures, participation in seminars, laboratory and curriculum development, and the exchange of information through faculty and student discussions. This program was further expended and formalized, to make possible a National Nuclear Lectureship series to cover 15 presentations by distinguished engineering educators.

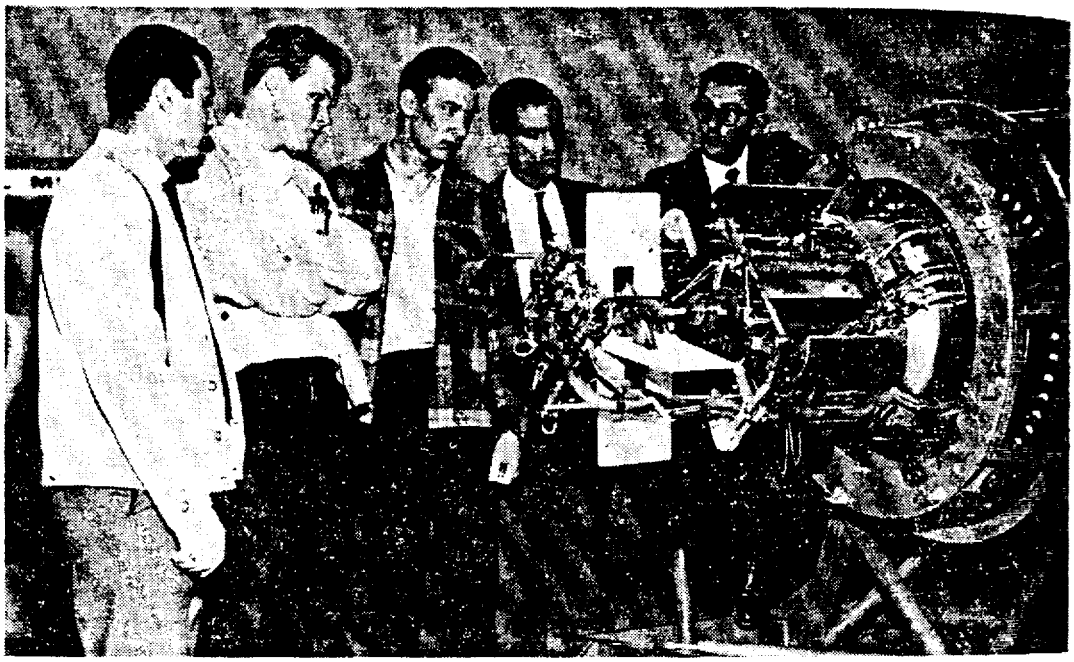
The AIBS also administered a visiting radiation biologist program under which 39 biological scientists spent 86 days consulting and lecturing at 58 educational institutions in 38 states.

Scientific and engineering staff members of AEC laboratories also schedule visits upon request to colleges and universities to deliver lectures in their areas of professional interest to students and faculty.

During the year 436 lecture and consultation visits were made to 214 institutions. These were attended by 14,690 undergraduate students; 8,786 graduate students; 5,264 faculty; and 2,057 others.

Conferences, Seminars, and Symposia

The AEC supported 17 conferences at six universities and five AEC facilities involving 1,640 participants on nuclear subjects. The scope of topics included:



Future Engineers. In addition to providing the more formal education and training opportunities for students, the AEC encourages its contractors to participate in special observances. As a feature of National Engineers Week, engineering students from San Fernando Valley State College (Los Angeles, Calif.) toured Atomics International's Nuclear Field Laboratory in the nearby Santa Susana mountains. Photo shows a group being briefed about the SNAP-10A—the only reactor yet to be launched into space. The SNAP-10A was developed for the AEC by Atomics International.

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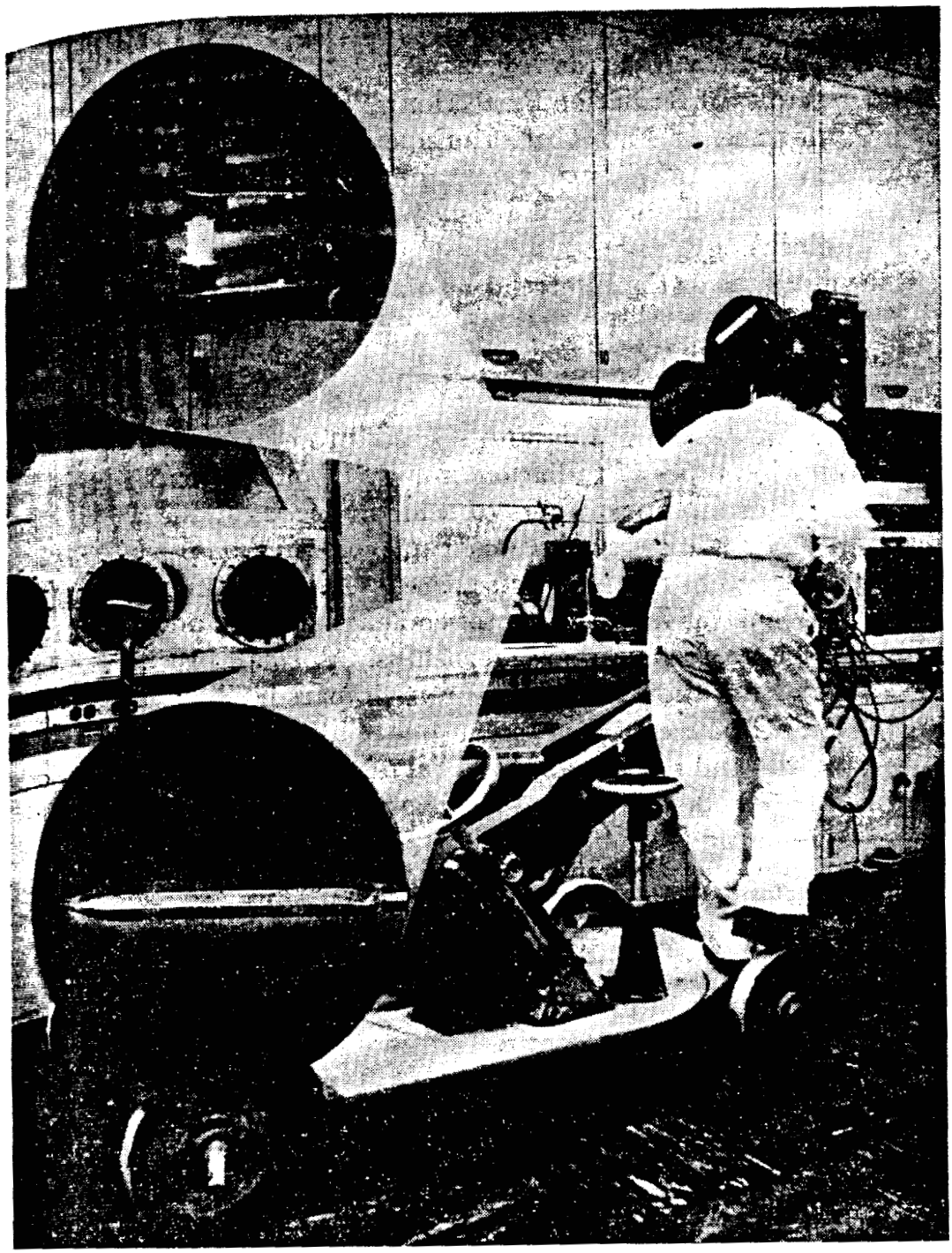

Production of Educational Film. The two insets show scenes from an educational movie recently filmed at the AEC's Mound Laboratory. The film, entitled "Mass of Atoms", will be used in high school and college physical science classes. It explains how helium and polonium can be studied in a basic experiment. The *top* inset shows radioactive polonium 210 in a tube mounted between heating electrodes during spectral analysis to confirm the presence of polonium and its radioactive decay product, helium. The *bottom* inset shows the polonium sample, self-lighted, in a capillary tube used in the experiment.

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(1) Plasmas and Controlled Fusion;
(2) Symposium on Neutron Noises;
(3) Principles of Radiation Protection;
(4) Conference on Fast Critical Experiments and Their Analysis;
(5) Impact of Bioengineering on Engineering Education;
(6) Biological Effects of Radiation and Techniques of Measurements;
(7) Radioecology; and
(8) Symposium on the Interrelation of Proteins and Nucleic Acids.

Teaching Aids and Special Projects

Among the teaching aids and special projects developed in 1966 were television tapes of radiation biology laboratory experiments for classroom use; tape recordings of seminar lectures; the writing and field testing of a laboratory manual; and color motion picture films for career guidance in the nuclear sciences. A new Faculty Internship Pilot Program was inaugurated to send engineering and faculty members to industry for one-year internships. A small brochure, "Guide to Nuclear Education Activities," was prepared. The brochure,[3] intended for public use, presents an outline of all AEC educational assistance activities and provides a keyed list of addressees where additional details may be obtained on any specific program.

[3] Copies may be obtained, without charge, from the Director, Divisions of Nuclear Education and Training, U.S. Atomic Energy Commission, Washington, D.C., 20545.

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Chapter 1

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Chapter 15

INFORMATIONAL ACTIVITIES

As a part of its stewardship of the Nation's nuclear energy program, the AEC has the responsibility to enlarge the fund of technical information available to the scientific community, and to foster public understanding of nuclear matters. These activities take a number of forms and are conducted on an international, as well as domestic, bases.

TECHNICAL INFORMATION

Principal developments during 1966 included the significant progress made towards an international system for mechanized handling of nuclear scientific and technical information; the initiation of a joint AEC–NASA series of "Tech-Briefs"—summaries of non-nuclear, AEC-developed technical innovations potentially useful to industry; and a quickened tempo in AEC's demonstrations and exhibits programs, particularly in presentations abroad.

INFORMATION SYSTEMS AND SERVICES

In the face of continued increases in the world-wide volume of nuclear research and development, the AEC further developed and refined its methods for communicating the resulting scientific and technical information.

International Nuclear Information System

Important progress was made during the year in the development of plans for a cooperative International Nuclear Information System (INIS). Representatives of the AEC, the International Atomic Energy Agency (IAEA), and the Soviet Union met in June and

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September to draft a proposed plan for IAEA coordination of the new system. This plan was considered in detail by the Member States at a meeting in Vienna during December. Under INIS, individual nations or regional groupings of nations will assume the responsibility for preparing English-language abstracts and indexes of the significant literature on the peaceful uses of nuclear energy produced within their respective geographical areas. All participants will then share in the services and products of a common computer-processed store of information. Until now, the AEC has assumed responsibility for abstracting and indexing both United States and foreign nuclear energy literature and for disseminating these and other information services and products on a world-wide basis.

A major step in the further development of international cooperation in the handling of nuclear information occurred in July when the United Kingdom Atomic Energy Authority formally agreed to take responsibility for abstracting and indexing nuclear literature originating in the United Kingdom. Similar undertakings were made in September by Denmark, Finland, Norway, and Sweden.

Cooperation also continued between the AEC and the European Atomic Energy Community (Euratom) in the further development of a mechanized nuclear information system originally developed by Euratom.[1] Possible ways of employing this system as an integral part of the INIS were under study at the year's end.

Rapid Communication Experiment

A novel experiment for rapid communication of scientific and technical information is being planned by the American Institute of Physics (AIP) with support from the AEC. Under the proposed system, a formally constituted group of worldwide high-energy physicists would be established. Each of the members would send his unpublished communications, both formal and informal, to a central point, where they would be reproduced and distributed to the other members without delay. The AIP is studying existing communications practices among high energy physicists to determine the feasibility of introducing the new system.

Specialized Information Centers

In recognition of the increasing difficulty which scientists and engineers experience in assimilating the mass of valuable information

[1] See p. 282, "Annual Report to Congress for 1965."

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being generated in their fields of interest, the AEC has established and supports a number of specialized information and data centers. These centers provide critically evaluated compilations and a variety of other needed information services.

Three new centers were established by the AEC during 1966, and three others, started in prior years by AEC contractor organizations for the use of their own staffs, began providing information services

Merit Badge Winners. As a part of its technical information programs, the AEC sponsors the awarding of the Atomic Energy Merit Badge to members of the Boy Scouts of America. Photo shows three Los Angeles area Boy Scouts who qualified for the Merit Badge by enrollment in a 4-week course which is given at intervals through the year under AEC auspices at Atomics International (AI) at Canoga Park, Calif. The first seven such courses over 1½ years have graduated 142 Scouts. Subjects studied include nuclear fission, chain reaction, structure of the atom, radiation detectors, health physics responsibilities, radiological physics, operation of a training reactor and cobalt 60 gamma facility, history of atomic energy, and biographies of its major contributors. Displaying reactor models they made as a part of the course are: (*left* to *right*) Scout Mike Ludlow and his father Mark, Scout Andy Jordan, Scout Preston Burrow, and Bud Loba (coordinator of the AEC-Boy Scout program at AI). The AEC assisted the Boy Scouts of America in establishing the Atomic Energy Merit Badge in 1963. During 1966, the AEC established a Liquid Metals Information Center at Canoga Park.

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to the general scientific community. The subject areas covered by these six centers and their locations are as follows:

Subject	*Location*
New Centers:	
Liquid Metals	Atomics International, Canoga Park, Calif.
Nuclear Desalinization	Oak Ridge National Laboratory, Tenn.
Criticality	Oak Ridge National Laboratory, Tenn.
Centers which expanded service:	
Accelerators	Oak Ridge National Laboratory, Tenn.
Fused Salts	Sandia Corp., Albuquerque, N. Mex.
Gamma Ray Spectrum Catalogue	National Reactor Testing Station, Idaho

Table 1, Appendix 8, lists the 25 centers currently supported in whole or in part by AEC. 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." [2]

Depository Libraries

A new AEC depository library was established at the National Reference Library, London. The closing of four others in the United Kingdom reduced the number of AEC depositories outside the United States to 78, located in 55 countries and 5 international organizations. A new depository was established at Idaho State University, Pocatello, bringing the number of AEC depositories within the United States to 97, located in 46 states and Puerto Rico. The size of a typical domestic document collection increased to about 90,000 titles (AEC reports plus those foreign reports abstracted in Nuclear Science Abstracts).

A list of AEC Depository Libraries is given in Table 2, Appendix 8.

Facility Libraries Presented to Universities

During the year, the AEC presented two collections of technical material no longer necessary to AEC operations to universities. Arrangements for the transfers were made through the General Services Administration and the Department of Health, Education, and Welfare.

U. of Missouri. In connection with the shutdown of the Weldon Spring Plant, Mo. (see Chapter 4—Source and Special Nuclear Materials), the extensive technical library at the facility was donated to the University of Missouri's Normandy campus. The library consists

[2] Available free from the USAEC, Division of Technical Information Extension, P.O. Box 62, Oak Ridge, Tenn. 37830.

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of approximately 3,000 volumes of textbooks, handbooks, monographs, periodicals, encyclopedias, and international conference reports on the peaceful uses of atomic energy. The donation to the university also included approximately 20,000 unclassified microcards and microfiche reports with the necessary reading equipment.

U. of New Mexico. Some 2,400 research volumes—which had an acquisition value of $36,000—stored at the AEC's Los Alamos Scientific Laboratory, N. Mex., were presented to the University of New Mexico in October. The reference publications will be placed in the University's Medical Library in Albuquerque. The Los Alamos staff will continue to have research access to the material.

Conferences

Conferences give workers in various fields the opportunity to meet with their colleagues to present and receive fresh information about current work, and to discuss this work critically on the basis of common experience and knowledge. The AEC continued its support of selected conferences related to its programs. Eleven such conferences organized by U.S. professional groups were supported during the year. The AEC also organized United States participation in 12 conferences conducted by the International Atomic Energy Agency. The conferences are listed in Tables 3 and 4, of Appendix 8.

TECHNOLOGY UTILIZATION

Experimentation continued on ways to facilitate the transfer to the nonnuclear industry of innovations resulting from AEC-sponsored research and development.

"AEC–NASA Tech Briefs"

The AEC and the National Aeronautics and Space Administration (NASA) began, in August, the joint issuance of a series of business-oriented summaries of selected non-nuclear devices, processes, and techniques developed at Argonne National Laboratory. Known as "AEC–NASA Tech Briefs," they are distributed by both AEC and NASA and are sold, for 15 cents each, by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 37831. If the program appears successful, it may later be expanded to include innovations developed at other AEC-supported research facilities. NASA has for several years been issuing a similar series called "NASA Tech Briefs," based on innovations developed in its own programs.

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Offices of Industrial Cooperation

AEC's technology transfer work has centered at Offices in Industrial Cooperation (OIC's) at Argonne National Laboratory and Oak Ridge National Laboratory. These offices operate principally to promote and maintain the types of individual laboratory-industry contacts that can result in actual "spinoff" of AEC-developed technology into commercial use. Occasionally the Argonne and Oak Ridge National Laboratories also use the offices for contacting industrial groups. Thus, the Argonne OIC, in addition to acting as focal point for AEC participation in the joint "Tech Brief" activity with NASA, described above, hosted three briefings for industry by members of the laboratory staff to explain the Federal Government's technology transfer programs. These briefings were conducted in cooperation with the Small Business Administration and with participation by NASA, the Department of Defense, the Department of Commerce, the State of Illinois, and the Chicago Association of Commerce and Industry. The Argonne Office also conducted a special tour of the laboratory in June for members of the Tool and Die Institute.

The Oak Ridge OIC arranged four industrial briefings by laboratory personnel during the year in conjunction with the Southern Interstate Nuclear Board to present information on AEC developments in instrumentation, equipment, and materials technology.

PUBLISHING ACTIVITIES

The AEC sponsors publication of text and reference material on nuclear subjects to help meet the informational needs of engineers, scientists, and students.

Nuclear Science Abstracts

AEC's semi-monthly journal "Nuclear Science Abstracts" (NSA), the principal source of information on the world's literature in the nuclear field, abstracted and indexed approximately 50,000 items (reports, articles, books, conference papers, etc.).

Foreshadowing the development of an international nuclear information system, discussed above, NSA was sent to recipients in 66 foreign countries. These included AEC depository libraries, foreign governments, and other organizations having publication exchange agreements with the AEC. The AEC received in return regular issues of 551 foreign journals, approximately 3,800 research and development reports, and a variety of other publications.

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Scientific Books

The volume of information reflecting advances in nuclear science and technology continues to grow dramatically both in size and complexity. Recognizing the need of scientists, engineers, teachers, and students to have some of the larger segments of this information compressed into readily usable form, the AEC has for 20 years sponsored the preparation of manuscripts for specialized text and reference books and published the proceedings of outstanding conferences and symposia. A list of the more important volumes published in 1966 appears in Table 5, of Appendix 8. Of special interest among the year's publications was a bibliography, "Biological Effects of Ionizing Radiation," TID–3097, which contains nearly 13,000 references to the world's radiation biology literature for the 60-year period 1898–1957.

Technical Progress Reviews

The quarterly review journal "Reactor Fuel Processing" was merged after its fall issue into the journal "Power Reactor Technology." The journal "Nuclear Safety" was expanded to include two new features—abstracts of all articles, and summaries of results of nuclear safety research and development. These Technical Progress Reviews are prepared for the AEC by the staffs of prominent laboratories. They condense, review, and evaluate the most recent technical literature for the information of scienists, technologists, and managers in the respective subject fields.[3]

Educational Literature

Eleven new titles, five in the life sciences, were added to AEC's popular "Understanding the Atom" series of educational booklets. Revised editions were published of seven older booklets. One of these, "Nuclear Terms—A Brief Glossary," was greatly enlarged following extensive technical review. Written in non-technical language, the 38 titles now available [4] include some coverage of virtually all AEC programs for peaceful uses of the atom.

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[3] Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, at the following prices: Nuclear Safety, $3.00; Reactor Materials, $2.50; Power Reactor Technology, $2.50; and Isotopes & Radiation Technology, $2.50.

[4] See Table 6, Appendix 8 for complete listing.

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DEMONSTRATIONS AND EXHIBITS

Through its demonstrations and exhibits program in the United States and abroad, the AEC fosters the growth of nuclear knowledge for working scientists and engineers, managers, students, and the general public. Its international exhibits have created widespread public interest and stimulated increased local efforts devoted to peaceful uses of nuclear energy.

"ATOMS IN ACTION" SCIENCE CENTERS

More than 300,000 visitors and participants were attracted to 4 AEC "Atoms in Action" Science Centers presented in San Jose, Costa Rica (March 8–April 4), Utrecht, The Netherlands (March 1–28), Dublin, Ireland (September 28–October 23), and Managua, Nicaragua (October 17–November 13) at the invitation of the host countries.

Besides exhibits and demonstrations for the public, the presentations at these centers included: scientific investigations conducted cooperatively by U.S. scientists and those of the host country; training of host-country professional personnel in nuclear techniques; scientific lectures and seminars; technical information reference rooms equipped with technical literature and films on nuclear subjects; and specialized instruction for secondary school science students and their teachers.

Attendance and participation at the four presentations was as follows:

	Utrecht	*Dublin*	*San Jose*	*Managua*
General public	62, 000	65, 000	78, 000	62, 000
Secondary school science classes	4, 400	7, 600	5, 600	4, 800
Technical information reference room	6, 000	10, 000	5, 600	4, 800

European Presentations

The original "Atoms in Action" pavilion, first used at Tokyo in 1959, was used for the last time at Utrecht. To replace it, a larger pavilion, used previously in Latin America, was renovated and refurnished. This double-domed, air-supported, vinyl structure, which has an area of 22,000 square feet, had its European premiere at Dublin.

Utrecht showing. A unique feature of the European centers is a 10-kilowatt (thermal) pool-type research and training reactor. At Utrecht, the reactor was used for 238 hours to conduct classes and a variety of experiments. The latter included the neutron activation

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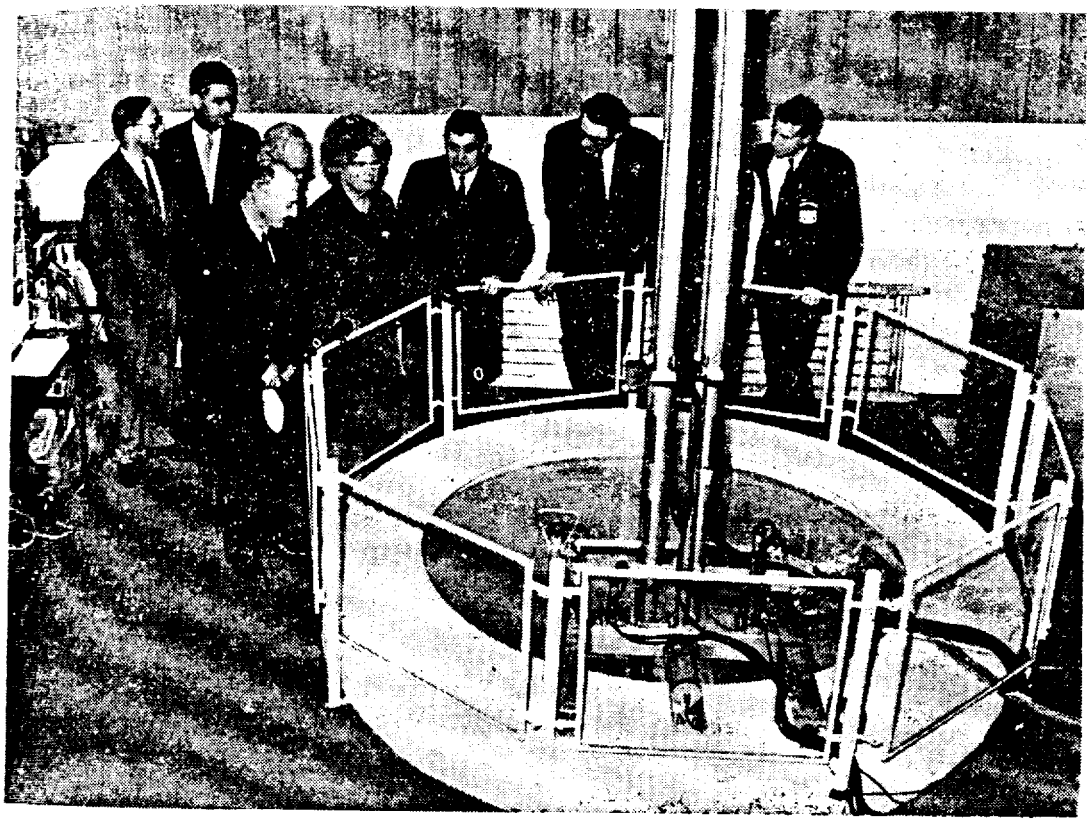
analysis of special aluminum pellets, work which required a neutron flux not available in two Dutch research reactors at Petten, The Netherlands' nuclear experimental facility.

In conjunction with "Atoms in Action," The Netherlands Atoomforum and the AEC jointly held a month-long series of scientific and technical lectures and seminars at Bunnik, near Utrecht. The participants included 20 U. S. and 60 Dutch scientists; 3,800 professional personnel attended.

Dublin showing extended. At Dublin, "Atoms in Action" was co-sponsored by the Royal Dublin Society, a national cultural and scientific organization. The center's research and training reactor was the first reactor to be operated on Irish soil. It was used primarily in training experiments for Irish university students. The gamma facility was used principally for experiments dealing with the improvement and preservation of agricultural products. There were 247 irradiation experiments, involving 324 specimens.

At the request of Ireland's Ministry of Education, evening sessions of classroom instruction for secondary school science students were



Royal Visitor. At her own request, Queen Wilhelmina of The Netherlands was given a special tour of AEC's "Atoms in Action" Science Center at Utrecht. She is shown here inspecting the center's 10 thermal kilowatt pool-type research and training reactor which was operated for 238 hours for class work and a variety of experiments during the March 1–28 showing. During the year, "Atoms in Action" showings were also held in Dublin, Ireland; San Jose, Costa Rica; and Managua, Nicaragua, as a part of the AEC's international effort to foster the growth of nuclear knowledge.

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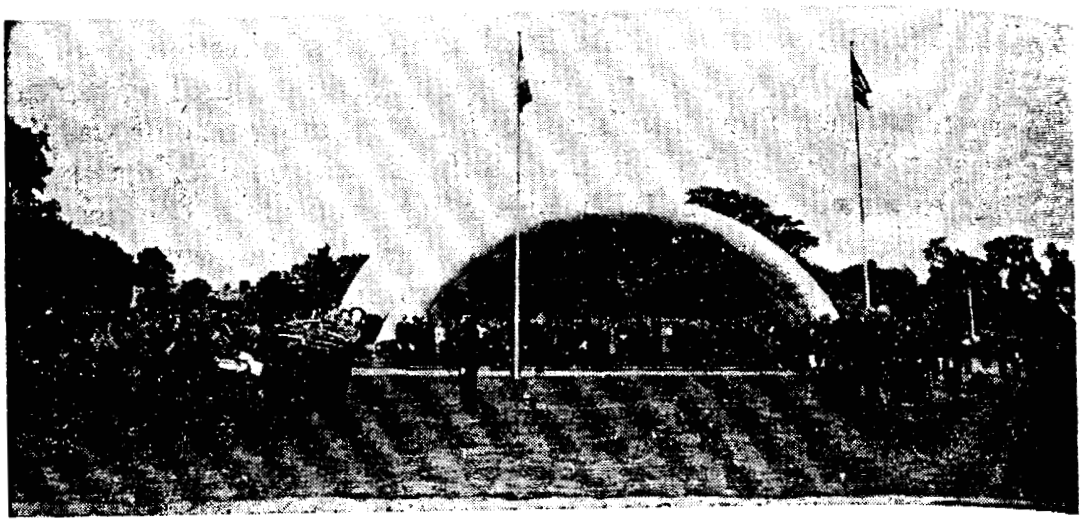
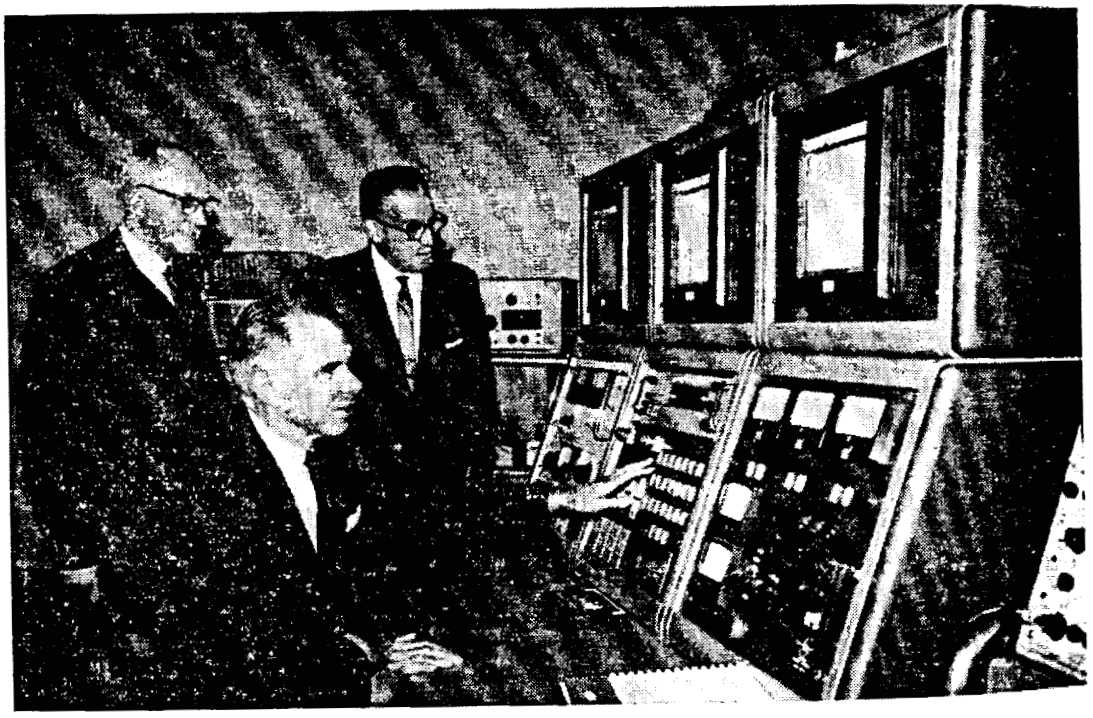
added to the usual morning and afternoon sessions. Even with the 50 percent expansion, it proved impossible to accommodate all the classes for whom instruction was requested. Accordingly, the Irish Government transmitted through the American Ambassador a request for an extension of the center's stay in Dublin which led to the center remaining open five days longer than originally scheduled.



Dublin Opening. The AEC's "Atoms in Action" Science Center, housed in a double-domed, air-supported plastic pavilion opened at Dublin, Ireland, on September 29. Photo *above* shows part of the opening day ceremonies as the Irish and American flags were raised. In photo *below*, AEC Chairman Glenn T. Seaborg demonstrates the operation of the reactor control console to Dr. Ernest Walton, Nobel Prize winner for chemistry (*left*) and Prime Minister Sean Lemass (*right*) after Dr. Seaborg and President Eamon DeValera of Ireland had officially opened the exhibit.



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Presentations in Latin America

The Latin American "Atoms in Action" Center includes one program not found in its European counterpart: month-long training courses on radioisotopes in medicine, radioisotopes in research, and maintenance and repair of nuclear instruments. These three courses, designed to prepare host-country professional personnel for immediate participation in peaceful nuclear energy programs, were filled to capacity in both San Jose and Managua.

San Jose center. In conjunction with the "Atoms in Action" showing in San Jose, Costa Rica conducted its first national science fair for secondary school students. Three winning entries were displayed at the center.

The research program at San Jose centered around the pool-type 5,300-curie cobalt 60 gamma irradiation facility where 1,214 irradiations were performed. Most of the work involved participation by the University of Costa Rica and/or the National Council of Production. Seventeen research projects were begun, of which 15 are continuing for a year or more. Most of these are directed towards improving the quality, storage life, or other characteristics of various foodstuffs important to the well-being of the area.

Managua showing. In Nicaragua, beans are important to both the national diet and the economy. Consequently, the gamma facility at "Atoms in Action" in Managua was used to study the potential effects of radiation on bean genetics and on the palatability of stored beans. Also studied were the possible uses of radiation for insect control, for preservation of various fruits, and for viability studies on corn, rice, bean, cotton, and avocado seeds. Conducted in close cooperation with Nicaraguan universities and government agencies, some of these studies will continue for as long as two years.

1967 Schedule

In 1967, "Atoms in Action" Centers are scheduled for the spring in Ankara, Turkey, and Panama City, Panama, and for the fall in Tehran, Iran, and Quito, Ecuador.

OTHER INTERNATIONAL EXHIBITS

The AEC and the Department of Interior cooperated in a nuclear desalting exhibit for the United States Pavilion at the Levant Fair in Bari, Italy, September 7-20. The exhibit highlighted rapidly increasing demands for freshwater, explained the various methods for changing saline water to fresh, and described the advantages of large, dual-purpose reactor plants for heavily populated areas requiring both

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"Atoms in Action" in Nicaragua. Combining demonstrations, practical experiments, month-long training courses, and general information exhibits, the AEC's "Atoms in Action" Science Centers are fostering the growth of nuclear knowledge among scientists, students, and the general public in Latin America. In photo, *left above*, AEC Commissioner Samuel M. Nabrit (*center*) is shown with U.S. Ambassador to Nicaragua, Aaron S. Brown (*left*) and the President of Nicaragua, Lorenzo Guererro Gutierrez (*right*) as the President cuts the ribbon opening the "Atoms in Action" Science Center in Managua, Nicaragua, on October 17. Photo, *right above*, shows a *Fricke* dosimeter being placed in a melon to measure the internal radiation dose given in the cobalt 60 food irradiator. Research at the centers has been concentrated on agricultural problems of local interest which may best be approached utilizing the scientific resources of the exhibit. Of the four "Atoms in Action" showings in foreign countries during the year, the one at San Jose, Costa Rica, drew the largest general public attendance. In photo *below*, the use of a multichannel analyzer is demonstrated to Costa Rican science teachers.

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large amounts of electrical power and additional supplies of potable water. Three limited-capacity, non-nuclear desalting plants manufactured by U. S. firms were displayed. Two of the plants were sold to Italy.

The AEC displayed information on nuclear desalting, peaceful nuclear explosives, toll enrichment of uranium, and the AEC civilian power reactor development program at NUCLEX-66, an exposition devoted to the nuclear industry held at Basel, Switzerland, September 8–14 (see also Chapter 17—Industrial Participation).

In cooperation with the U.S. Information Agency, a special exhibit titled "A Better Life From the Atom's Rays" was displayed in Thailand at the Bangkok Trade Fair, November 16–December 16. The exhibit explained the benefits of gamma irradiation in food preservation, creation of new plant varieties, disinfestation of grains, insect sterilization, package sterilization, and polymerization improvement of plasticized wood.

PRESENTATIONS IN THE UNITED STATES

The AEC, through traveling exhibits and demonstrations, fosters the understanding of nuclear energy among students and the general public.

Secondary School Demonstrations

Traveling "This Atomic World" lecture-demonstrations were presented before more than 1½ million students and their teachers in some 1,800 secondary schools in 27 States during the year. In this program, trained teacher-demonstrators first make a 45-minute presentation to the entire student body, then consult with science teachers and deliver more specialized lecture-demonstrations to selected science classes.

With its 11 traveling lecture-demonstration units, AEC can service only about 7 percent of the nation's 29,000 secondary schools each year. In 1966–67, therefore, the AEC and Texas A & M University are exploring means whereby this coverage may be expanded. The AEC is supplying the demonstration equipment and the van for transporting it. The AEC also provided training for a teacher-demonstrator selected by the University. The university is paying the demonstrator's salary and expenses and is scheduling the presentation to Texas schools during the academic year. If this arrangement is successful, it may be expanded into other areas where universities or other State-supported educational organizations are willing to undertake similar co-sponsorship.

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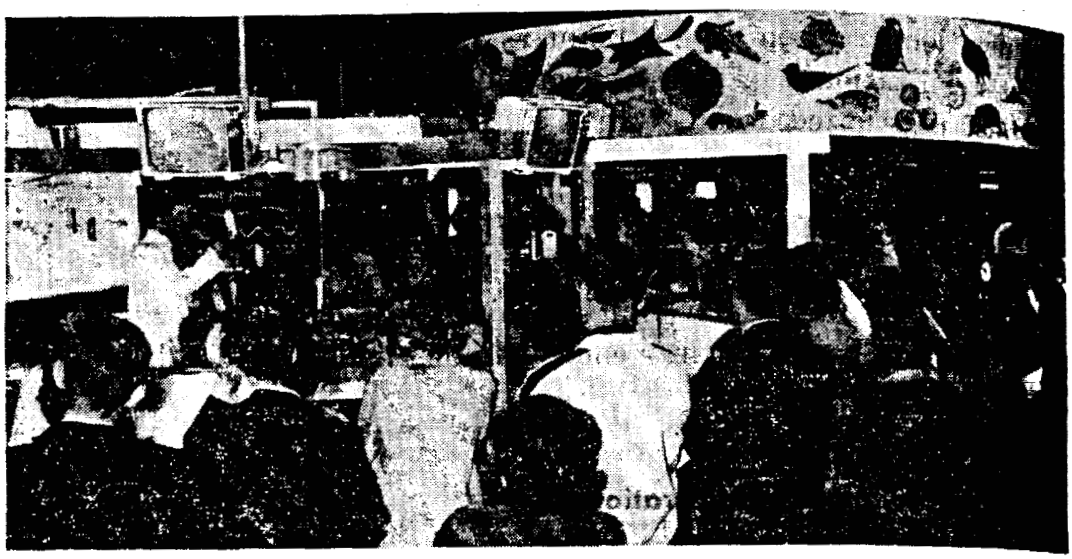
Circulating Exhibits for Museums

Completion of the "Life Science Radiation Laboratory" added a fourth major exhibit to the AEC's circulating exhibits that tour museums. It features a biology laboratory where actual experiments are carried out with plants, animals, and fish which have been irradiated or "tagged" with radioisotope tracers. There is also a lecture-demonstration area where some of the newest innovations in science teaching are employed. The exhibit premiered at the Smithsonian Institution in Washington, D.C., from mid-April through Labor Day. It then moved to New York City's newly reopened Hall of Science.



Museum Exhibits. One of the newest traveling exhibits prepared by Oak Ridge Associated Universities for the AEC is a large "Life Science Radiation Laboratory," designed for extended showings in museums throughout the country. Shown *above* is a part of the demonstration area during the showing at the Smithsonian Institution, Washington, D.C. The AEC's traveling "Atomsville, U.S.A." exhibit, designed especially for children in the 7–14 age bracket, had its one-millionth visitor (shown *at left*) in August, during a showing at the Chicago Museum of Science and Industry. The youngster was presented with a commemorative plaque, a complete series of the AEC's "Understanding the Atom" booklets, and a non-hazardous radioactive dime from the American Museum of Atomic Energy in Oak Ridge, Tenn.

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"Atomsville, U.S.A.", the highly animated and colorful children's exhibit which was one of the most popular features of the New York World's Fair, played host to its millionth young visitor during its 8-month engagement at Chicago's Museum of Science and Industry. In September, it was moved to the Hall of Science in New York.

"Radiation and Man", which explains some of the basic principles of nuclear science with special emphasis on the causes and effects of radiation, was exhibited for nine months at the California Museum of Science and Industry in Los Angeles.

Other Domestic Exhibits

"Your Stake in the Atom", featuring animated audience-participation devices and a lecture-demonstration, appeared at nine State and regional fairs during the summer and early fall, before nearly 250,000 persons.

During the summer, the American Museum of Atomic Energy at Oak Ridge, Tenn., remained open an additional five hours each day (until 10 p.m.) to accommodate the area's increased tourist flow. With these additional hours, summer attendance increased 27 percent over the previous year. The highest one-day attendance in the Museum's 17-year history, 1,902 persons, was recorded on August 3.

Hall of Science Opening. Commissioner Wilfrid E. Johnson was the principal AEC representative at the opening of the Hall of Science of the City of New York at the September 21 opening day dedication ceremonies. The AEC is participating with a large exhibit on nuclear energy, including "Atomsville, U.S.A.," which is for children 14 years of age and under and drew considerable attention during the New York World's Fair. To *right* of Commissioner Johnson is Mayor John B. Lindsay of New York City.

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The Oak Ridge Museum and AEC traveling exhibits in the United States are operated for the AEC by Oak Ridge Associated Universities, which also designed and fabricated the public demonstration area for the "Atoms in Action" Science Center used for the first time at Dublin.

PUBLIC INFORMATION AND FILMS

The AEC has placed increased emphasis on informational services to the public in line with the President's request to all Government agencies to improve their service and communications with the public. The AEC's activities have included the holding of courses on telephone courtesy and techniques; courses in plain letter writing; attendance at Civil Service Commission seminars on courteous and efficient service to the public; increased emphasis on AEC exhibits and on visits and tours of AEC facilities; free public exhibition of atomic energy films on a regularly scheduled basis; organization of speakers' bureaus for civic groups and other organizations; emphasis on community service activities; and general improvements in directional signs and facilities in reception areas of AEC buildings.

Aid To Local News Media

The AEC's public information staff has responded to the surge in utility interest in building nuclear powerplants with assistance to utilities in connection with their programs to improve public understanding of nuclear power. This includes providing informational materials for informing customers, employees, and for use of local news media to explain the operational and safety aspects of nuclear plants in non-technical language. Members of the staff have participated in regional workshops for utility executives on public informational aspects of nuclear power and have held meetings with utility executives on the same subject.

ATOMIC ENERGY FILMS

Use by the public of atomic energy films continues at a high level. The AEC's 10 domestic film libraries loaned prints of films on atomic energy for 91,940 showings and 15 new motion pictures were added to the film libraries during the year (see Appendix 9 for summaries of new films and the locations of film libraries). AEC films were also used widely on television, in international exhibits, and

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National Science Youth Day. Despite their remote locations and heavy snow at both sites, the AEC's National Reactor Testing Station (NRTS) in Idaho and Los Alamos Scientific Laboratory (LASL) in New Mexico, drew large crowds of high school students for the annual National Science Day Observance. In photo *above*, high school senior science students from Montana and northern Utah hear an explanation of the Zero Power Reactor (ZPR–III) at the National Reactor Testing Station. More than 1,300 students from Idaho and adjoining States made 500–900 mile round trips for the commemoration of the 119th birthday (February 11) anniversary of Thomas A. Edison. Photo *below* shows a few of the some 800 students from New Mexico, Arizona, Colorado, Texas, and California who visited LASL and heard an explanation of the Vela satellite program.

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through the AEC's and U.S. Information Agency (USIA) libraries abroad. Thirteen films were entered in five foreign and one U.S. film festival.

Film Showings

Stocked with 9,362 prints of 313 popular and professional-level films, the AEC's 10 domestic film libraries loaned prints for 92,000 showings which were viewed by more than 3,320,000 persons in high schools, institutions of higher learning, industrial organizations, scientific and engineering groups, service clubs, etc. There were 328 educational and commercial channel television showings with audiences estimated at about 36 million.

International Aspects

AEC motion pictures were integral parts of three exhibits: NUCLEX–66 in Basel, Switzerland, and "Atoms in Action" in Dublin, Ireland, and in Managua, Nicaragua.

Loans of approximately 200 motion pictures, largely on a professional level, were made from AEC's 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 and Holland leading the list. Production services were provided to make Spanish, Dutch, and Japanese language versions of selected films, and also 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.

The AEC continued to supply films to: the American Film Library in The Hague; the film library of the IAEA in Vienna; the U.S. Information Service Office in Stockholm for use throughout Scandinavia; the Agency for International Development (AID) for use in Brazil, Bolivia, and Mexico; USIA for use in Turkey and Formosa; and prints of "First Reactor in Space: SNAP–10A" to USIA for worldwide distribution.

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Film Festivals and Awards

Thirteen films were entered in five foreign and one U.S. film festival. Included were "Nuclear Witness," "Plowshare," and "The Fresher, the Better" at the 10th International Exhibition of the Scientific-Didactic Film, Padua, Italy; "Diagnosis and Therapy with Radiation," "Fabrication of the Accelerator Structure" and "Transcurium Elements" in the Australian and New Zealand Association for the Advancement of Sciences (ANZAAS) Fourth International Scientific Film Exhibition; and "Nuclear Witness" in the 1966 Columbus Film Festival, Ohio.

CLASSIFICATION AND DECLASSIFICATION

A primary objective of the AEC classification program is to make available to industry, science, and the public, as much project-developed information as possible without endangering the common defense and security. The AEC has been accomplishing that purpose through continuous review of its classification rules and guides and through the vigorous pursuit of a program of document review to insure that all possible AEC program-developed information is made generally available.

Classification Policy

In a further effort to meet the primary objective mentioned above, the Commission requested in March that its classification staff and the Committee of Senior Reviewers (see Appendix 2) conduct a comprehensive and detailed study of the AEC's classification policy. The study was to be made in light of the current "state of the art" of atomic energy information, both at home and abroad, to determine how current classification policies could be altered to provide an even greater flow of atomic energy information to industry and the general public without endangering the common defense and security. This study is expected to be completed by early 1967.

Interagency Coordination

In the space power and propulsion area, the Department of Defense (DOD) and National Aeronautics and Space Administration (NASA) as well as the AEC are generating information and making much

of it publicly available. To avoid release by one agency of information which another believes important to hold for the common defense and security, the AEC suggested in late 1965 that the three work together to develop security classification principles and rules on which all could agree and adopt. There has been a series of joint discussions during 1966 with the DOD and NASA on a common policy for declassifying information in these fields. As a result of these discussions, as concerned with space electric power systems, a greater and more consistent release of useful information for potential commercial application would be possible. For example, it has been possible for the AEC to declassify most of the technical information concerning isotopic systems being developed for use on land, and in or on the sea.

Documents Declassified

A continuous review of AEC classified documents is conducted so as many as possible can be released as their subject areas become declassified. About 14,000 documents were thus found declassifiable during the year and made available for public use.

ACCESS PERMITS AND PATENT INFORMATION

As more and more areas of nuclear information have been declassified, the AEC's Access Permit program has declined over the past 11 years; at the same time, the portfolio of nuclear energy-related patents available for domestic and foreign licensing has continued to grow.

ACCESS PERMITS

The AEC's Access Permit Program was established in 1955 to permit industrial organizations to obtain access to Restricted Data pertinent to civilian applications of atomic energy. The program provides for controlled dissemination of that portion of atomic energy information which is required by private industry in peaceful atomic energy applications, and which cannot be declassified without undue risk to the common defense and security.

Access Categories

The following categories of information are available under this program:

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C-44—Nu
C-65—Plu
C-90—Nu
C-91—Nu
C-92a—Sy
C-92b—Sy
C-93a—Ac
C-93b—Ac
C-94—Mil

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C-44—Nuclear Technology;
C-65—Plutonium Production;
C-90—Nuclear Reactors for Ramjet Propulsion;
C-91—Nuclear Reactors for Rocket Propulsion;
C-92a—Systems for Nuclear Auxiliary Power (SNAP)—Isotopic;
C-92b—Systems for Nuclear Auxiliary Power (SNAP)—Reactor;
C-93a—Advanced Concepts for Future Application—Reactor Experiments;
C-93b—Advanced Concepts for Future Applications—Conversion Devices; and
C-94—Military Compact Reactor (MCR).

Number of Permittees

As of the end of November 1966, there were 427 Access Permits in effect (332 for access to Secret Restricted Data, and 95 for Confidential), as compared with 493 a year earlier (376 for Secret and 117 for Confidential). Continuing declassification of research and development work and related reports has caused the number of Access Permits to decline from a maximum of 1,432 in effect in 1958, three years after the start of the program.

PATENT INFORMATION

The AEC, in implementing its program of dissemination of technical information and data to the public, has also taken steps to make inventions and patents available to the public. The AEC has requested the issuance of U.S. and foreign patents and has prepared abstracts thereof for publication in press releases [5] and technical journals, such as "Nuclear Science Abstracts." Listings of patents are also furnished to interested parties and copies of U.S. patents are available from the U.S. Patent Office.

1966 Issuances

During the period November 23, 1965, to November 22, 1966, the U.S. Patent Office issued 251 U.S. patents to the AEC. As a result, the portfolio of AEC-owned U.S. patents administered by the AEC

[5] Listings published as AEC press releases during 1966: No. IN-657 (Belgian Patents), January 12; No. IN-663 (Japanese Patents), February 1; No. IN-669 (British Patents), March 10; No. IN-684 (Italian Patents), May 12; No. IN-694 (U.S. Patents), June 8; No. IN-702 (Canadian Patents), July 18; No. IN-706 (U.S. Patents), August 10; IN-712 (German Patents), September 1; IN-735 (U.S. Patents), November 25; and IN-743 (Belgian Patents), December 8.

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and available for licensing, now numbers 3,912 domestic patents. The AEC portfolio of foreign patents increased during this period by 382. This included 51 British patents, 50 Belgian patents, 74 Canadian patents, 51 French patents, 32 German patents, 31 Italian patents, and 20 Swedish patents. The balance of AEC-owned foreign patents issued during this period were by eight other foreign countries. The total portfolio of AEC-owned foreign patents numbers 3,086.

The AEC granted 65 non-exclusive licenses on Government-owned patents. At present, 1,158 non-exclusive licenses have been issued on 620 of the 3,912 Government-owned patents administered by the AEC. In addition, 623 non-exclusive licenses have been retained by contractors. Contractors have retained exclusive licenses in fields other than atomic energy in 503 patents. In 453 instances, the title and rights in the patents are vested in the contractor, subject to a non-exclusive license in AEC for governmental purposes.

Private Atomic Energy Applications

The Commissioner of Patents referred to the AEC 699 privately owned U.S. patent applications in the atomic energy field under Section 152 of the Atomic Energy Act of 1954, as amended. This indicates a continuing interest in the atomic energy field by the industrial community. The AEC filed 15 directives with the Commissioner of Patents with respect to the question of rights during the year, bringing the total number of directives filed under Section 152 of the Atomic Energy Act of 1954, as amended, to 169. The AEC has acquired rights in 98 applications, and in 62 cases after completion of investigations, the directives were withdrawn without acquisition of rights. Seven applications are pending, two having been abandoned.

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Chapter 16

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Chapter 16

OPERATIONAL SAFETY

The 1966 record shows no unusual experience in either industrial or radiation safety at AEC installations. Not a single radiation accident in Government facilities caused any known injury to contractors' employees or to the public.

SAFETY ACTIVITIES

Despite the fact that of all routine industrial and scientific activities, those surrounding the atomic energy program pose the most constant hazard potential (radioactivity) the AEC and its contractors have been near-consistent recipients of the National Safety Council's "Award of Honor". The AEC also pursues an active pollution control program in all of its wide spread activities to assure that radioactive contamination of the environment is eliminated, or at least held to such a minimal level that it poses no health hazard if complete elimination is not possible.

POLLUTION CONTROL

During 1966, existing AEC facilities were reviewed and it was determined that, with very few minor exceptions, water pollution control measures at AEC sites met the standards prescribed in the 1965 Executive Order 11288, "Prevention, Control, and Abatement of Water Pollution by Federal Activities."

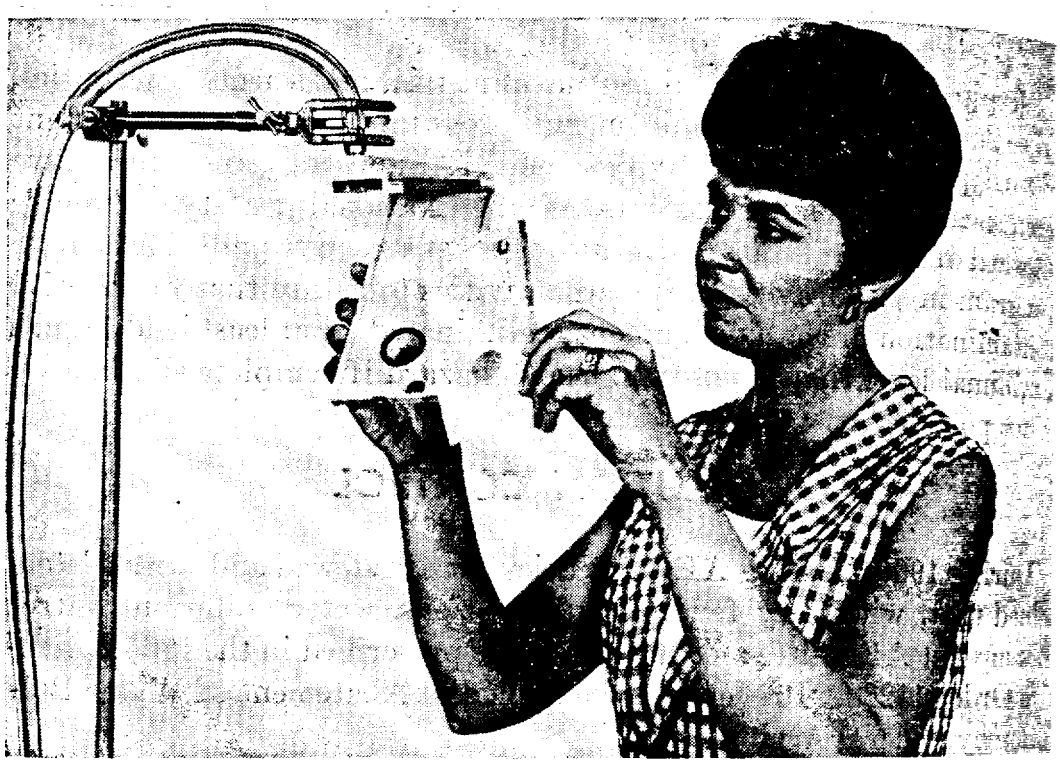
Implementation of Presidential Orders

The few exceptions to the Executive Order on water pollution required modifications to provide improved sewage treatment, better confinement of possible leakage from oil and toxic chemical storage tanks and, in one instance, improved treatment of chemical wastes to assure meeting the standards in the Executive Order. The last instance involved treatment of water for cooling towers at Argonne Na-

tional Laboratory, and accounts for three-quarters of the estimated total of $826,000 to be spent on modifications in the 1966–1968 period. At year-end, a similar review of air pollution was underway in response to Executive Order 11282, but the findings are not expected to reveal any major discrepancies.

Pollution Control Studies

The growing concern with pollution evident in the Executive Orders was shown in other inquiries and studies, for which considerable effort was required to coordinate AEC's contributions. This effort included providing information to numerous evaluative groups within and outside of the Federal Government on new AEC developments in environmental water and air pollution control and waste management. Some examples of the need for added effort during 1966 included:



Air Analyzer. The Oak Ridge Y–12 Plant has developed a simple and inexpensive air sampling system to determine radiation content of the air throughout the plant. The system combines a filter medium, through which air is continually drawn (by hose on left), with a computer card. Each card, with a built-in filter (circular black area on card), replaced a plastic holder at a sampling station. When removed, every 24 hours, the card is taken directly to a key punch machine equipped with a scintillation counter for automated analysis and data recording on the original card. When the counting process is completed, a computer is used to tabulate, calculate, and print out the area location where the samples were obtained. Some 300–400 samples can be processed in about five minutes. The system has reduced air analysis costs by 85 percent.

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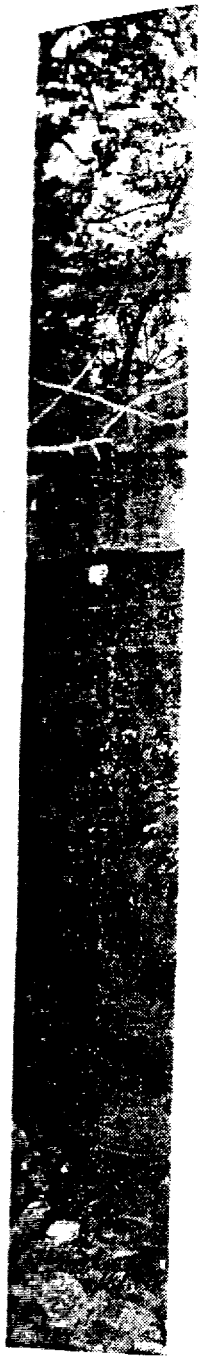

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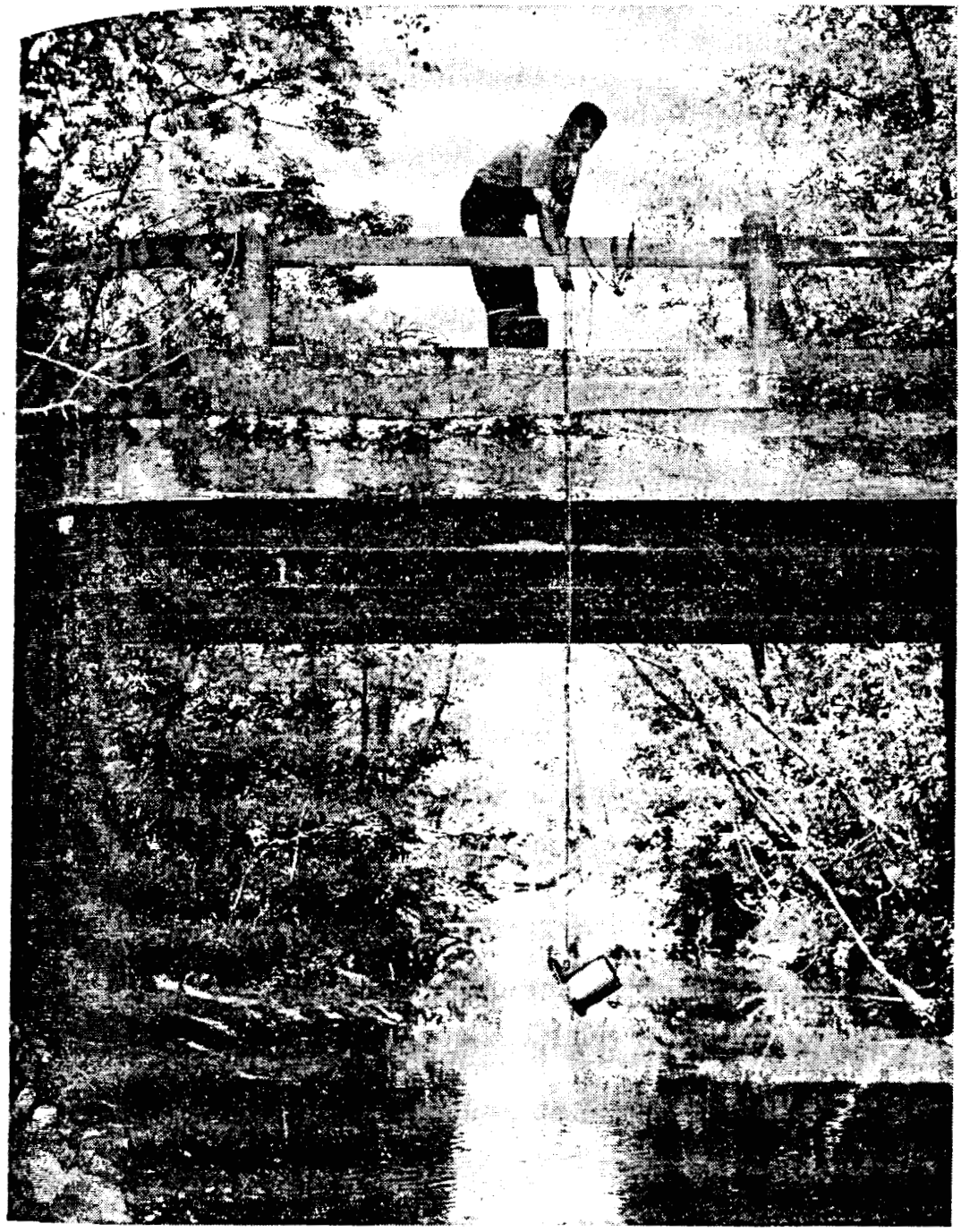
(1) A study by the Science Policy Research Division, Library of Congress, on the evolution and evaluation of Federal in-house capability for research and development in environmental pollution to meet the changing needs of the Federal Government and the public.



Pollution Samples. Pollution control starts with small tributaries. The need for stream samples at remote locations, where electricity may not be available to power instruments, led to the development of this simple, gravity-powered sampler by Union Carbide Corp. at the AEC's Paducah, Ky., Gaseous Diffusion Plant. This device has been helpful in the plant program for elimination or reduction of discharge of waste chemicals.

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(2) A report by the Natural Resources and Power Subcommittee, House Committee on Government Operations, updating and supplementing its previous report on the status of waste disposal practices at Federal installations, including AEC sites.

(3) The completion of a review by the Federal Committee on Pest Control (FCPC) activities. This is an annual review of the AEC's programs for use in its own operations of pest control agents, such as, pecticides, herbicides, fungicides—chemical as well as natural. These programs cover several thousand acres involving 36 sites in 20 states.

Uranium Mill Tailings

During the year, the question of possible water pollution from uranium mill tailings came under examination by the Subcommittee on Air and Water Pollution of the U.S. Senate Committee on Public Works. AEC witnesses testified in May that pollution of air or water by radioactivity in the effluents is not a present problem at any of the operating uranium mills. The AEC witnesses also stated that concentrations of radioactivity in rivers and streams resulting from tailings accumulations left at the sites of former mill operations were well below the limits listed in 10 CFR Part 20.[1]

Federal Water Pollution Control Administration witnesses expressed concern over potential long-range hazards and recommended that uranium mill tailings should be stabilized. Some communities near tailings piles have complained of dusting and other problems.

Since the hearings, the AEC, the Federal Water Pollution Control Administraiton, and the Public Health Service have issued the following joint statement:

> "The Federal Water Pollution Control Administration, the Public Health Service, and the Atomic Energy Commission agree that inactive tailings piles resulting from uranium milling operations should be structurally stabilized and contained to prevent water and wind erosion. Active tailings piles should be managed to minimize such erosion during use.
>
> "Planning, management, stabilization, and containment of tailings piles are viewed as being the responsibility of the individual mill owners. Mill owners should develop, without undue delay, specific plans for accomplishing such management, stabilization and containment, and submit such plans through the appropriate state regulatory agencies for approval. The staffs of the Fed-

[1] Title 10, Code of Federal Regulations, Part 20—Standards for Radiation Protection.

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eral Water Pollution Control Administration, the Public Health Service, and the Atomic Energy Commission will be available to the state regulatory agencies, upon request, to provide advice and assistance regarding the development of pile stabilization and containment objectives and measures for achieving them.

"Compliance by mill owners with approved plans for stabilization and containment should be recognized as constituting fulfillment of mill owner responsibility with regard to such tailings piles. Obtaining and enforcement of tailings piles stabilization and containment plans should rest initially with the states concerned."

The AEC is continuing its study of the uranium mill tailings and is cooperating with Federal and state authorities.

OFF-SITE MONITORING ACTIVITIES

The safety program for each major AEC installation includes environmental monitoring around the facility. The collected data are summarized for publication in Radiological Health Data and Reports,[2] a monthly report by the U.S. Public Health Service. Though data are published for many AEC facilities, the summary data for the Nevada Test Site (NTS) are included here because of the special interest in any radioactivity released to the off-site environment by nuclear tests.

Nevada Test Site

The AEC has recognized both the need for operational safety programs to cope with day-to-day radiological problems and the need for long-term safety programs which are essential to the development of basic data and a better understanding of fallout and other effects. Before any nuclear test is conducted, detailed evaluations are made of any potential hazards. For these studies, the AEC solicits the advice of other Federal agencies and its contractors who are knowledgeable on these hazards.[3] As necessary, the specialized services of various laboratories and scientific and technical consultants are obtained.

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

[3] These agencies and contractors are as follows: the U.S. Public Health Service; the 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 Environmental Research Corp., Alexandria, Va.; Reynolds Electrical and Engineering Co., Inc., Las Vegas, Nev.; Hazelton-Nuclear Science Corp., Palo Alto, Calif.; John A. Blume and Associates, Los Angeles, Calif.; Holmes & Narver, Inc., Los Angeles, Calif.; and EG&G, Inc., Las Vegas, Nev.

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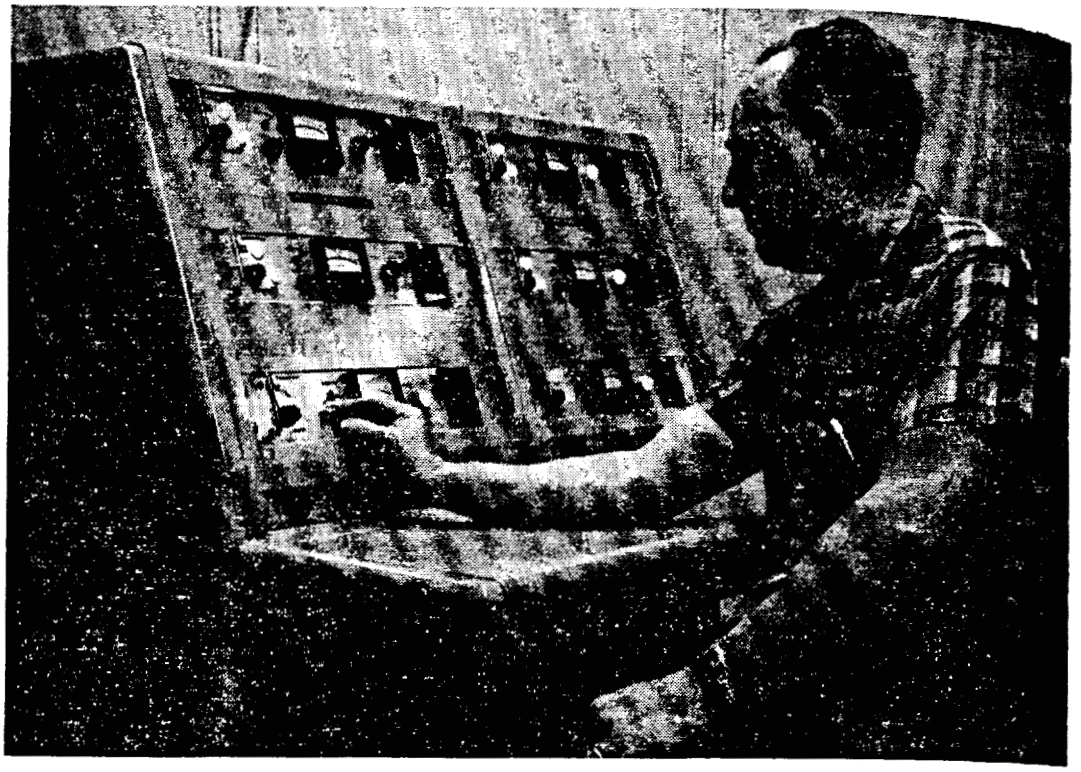
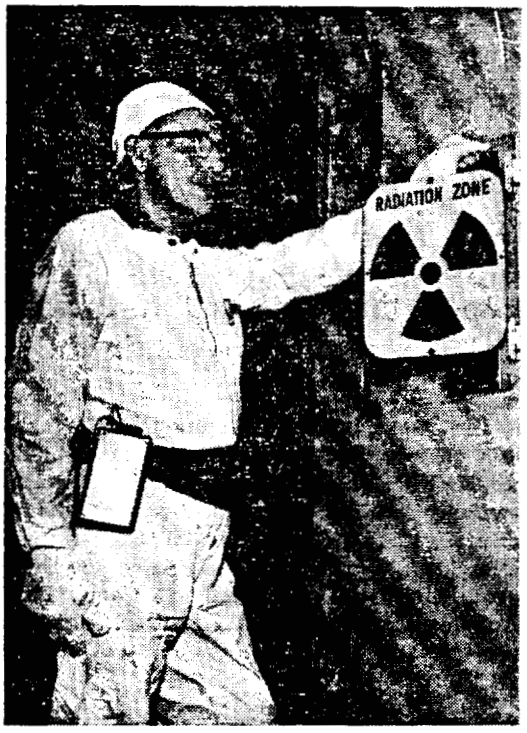
Off-Site Monitoring

During 1966, there were 36 announced underground weapons development or Department of Defense tests, 4 underground Plowshare experiments (see Table 1 in Chapter 5 for list of detonations) at the Nevada Test Site (NTS), and 5 Nuclear Rocket Development Station tests. The off-site radiological monitoring near NTS, and at other test sites, is conducted for the AEC by the U.S. Public Health Service.[4]





Telemetered for Protection. Improved personnel radiation protection in the areas of the AEC's production reactors at the Hanford Plant results from use of radiation dose-rate telemetering equipment being developed by Douglas United Nuclear, Inc. Radiation dose information is radioed from small unit worn on belt by radiation worker (photo at *left*) to a central control console elsewhere in the building (photo *above*). There the integrated radiation eposure for up to six workers can be monitored of on a continual basis.

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Detectable levels of radioactivity were measured off-site by ground monitoring from three of the 1966 underground nuclear detonations: Red Hot, March 5; Pin Stripe, April 25; and Derringer, September 12. Only from the Pin Stripe event could external gamma dose-rate levels above background be positively documented at a populated off-site location. The highest dose-rate measured in a populated area for this event was at Hiko, Nev., a town about 23 miles north of the control area. On April 25, the peak dose rate was 1.5 milliroentgens per hour at Hiko. It dropped to 0.4 milliroentgen per hour within two hours, and on April 26 (24 hrs. later) was down to 0.08 milliroentgen. The total estimated integrated infinity dose delivered was about 15 milliroentgens (if a person remained out of doors for this period of time).

Film badges. Approximately 1,456 film badges were issued to the off-site population surrounding the NTS during the year and each was worn for approximately one month. Of all these film badges, which were used to relate off-site exposures associated with NTS events, none showed exposures above 20 milliroentgens—the lowest detectable limit for these films.

Milk monitoring. About 236 routine milk samples were collected at approximately 30 different routine milk sampling stations during 1966. In addition to the routine milk samples, 167 special samples were collected for the Nuclear Rocket Development Station activities, and 670 special samples for weapons events.

The highest radiodine content found in milk where children were living was at Schofield Dairy near Hiko, where a peak level of 4.8 nanocuries [5] of iodine 131 per liter of milk was recorded on April 27, 1966. This is less than one-tenth [6] of the Protective Action Guide of the Federal Radiation Council (FRC). As a precautionary measure to avoid any necessary exposures, milk cows at Schofield Dairy were put on dry feed for about three weeks.

Even though the levels of radioiodine in human thyroids were expected to be low, the U.S. Public Health Service moved its mobile thyroid scanning equipment into the area and invited residents to undergo measurements. Low levels of radioiodine were detected in the thyroids of 11 children and 2 adults on April 27, 1966.

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

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

[6] It was reported in the 1965 Annual Report (pg. 64) that the value of 5.5 nanocuries of iodine 131 per liter of milk was one-fortieth of the FRC guide. The applicable FRC guide in that case was for individuals since the milk was from only two cows. The peak value of 4.8 nanocuries of iodine 131 per liter in 1966 occurred in milk from a sizable dairy herd. Thus, the applicable FRC guide is for a suitable sample of the population which is one-third the guide for individuals.

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The projected doses to the thyroids of those measured ranged from below detectability up to 300 milliroentgens. The projected dose means the total radiation exposure to the thyroid expected from radioiodine present in the thyroid at the time of measurement. This compares with normal background radiation in the Hiko-Alamo area of about 150 to 200 milliroentgens per year to the whole-body, and is a small fraction of the usual medical dose used for diagnostic purposes.

Water monitoring. Water supplies are routinely monitored for gross beta contamination in the off-site area around the NTS. During the year, samples were collected at 117 different locations. Of the more than 942 samples collected, 96 demonstrated positive results for fresh fission products (27 sampling points in 7 locations). All 96 of these positive results were attributable to the Pin Stripe event on April 25. The highest level of radioactivity found was 3.9 nanocuries of iodine 131 per liter in a sample collected at a ranch near Hiko, on April 26. This water, used for human consumption flowed for about 1½ miles through an open, spring-fed irrigation ditch into an open holding tank near the house.

Gross beta radioactivity in air. There were 106 air sampling stations operating continuously in the area surrounding the NTS. In addition, up to 20 supplementary sampling units were employed during specific events. The highest gross beta activity in air in a populated area was measured at Ash Springs, Nev., on April 25, with a value of 25 nanocuries per cubic meter averaged over the 3-hour time period during which the high concentration occurred.

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

New facilities. The Southwestern Radiological Health Laboratory (SWRHL), a unit of the U.S. Public Health Service, dedicated a new $6 million complex in Las Vegas, Nev., in the spring of 1966, thereby adding greatly to its capabilities for radiation surveillance around the NTS and for research projects in conjunction with the AEC's test site activities.

OTHER SAFETY ASPECTS

In addition to setting up special safety programs for its specific activities, the AEC cooperates with other agencies to provide assistance in case of a radiological hazard occurring offsite.

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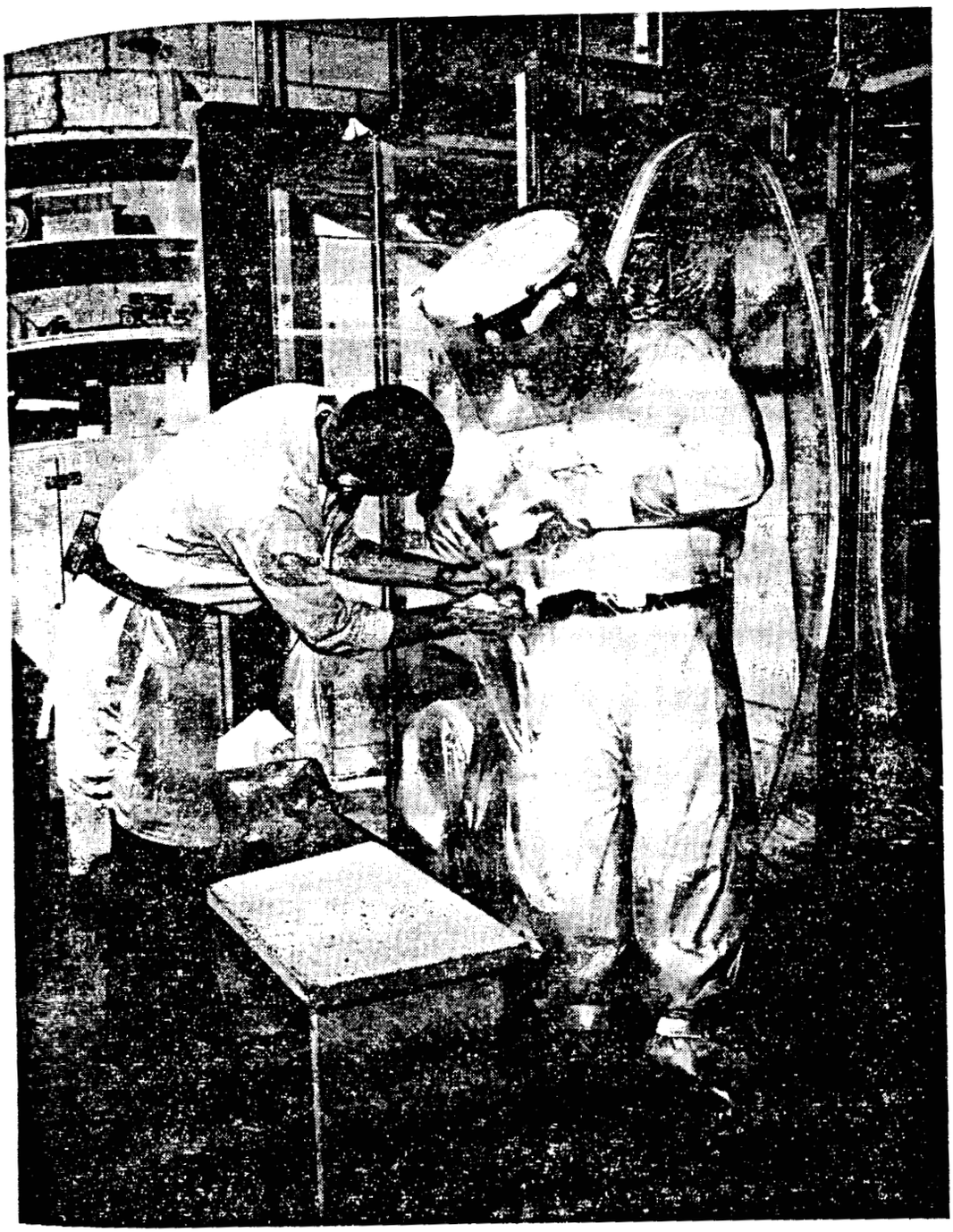
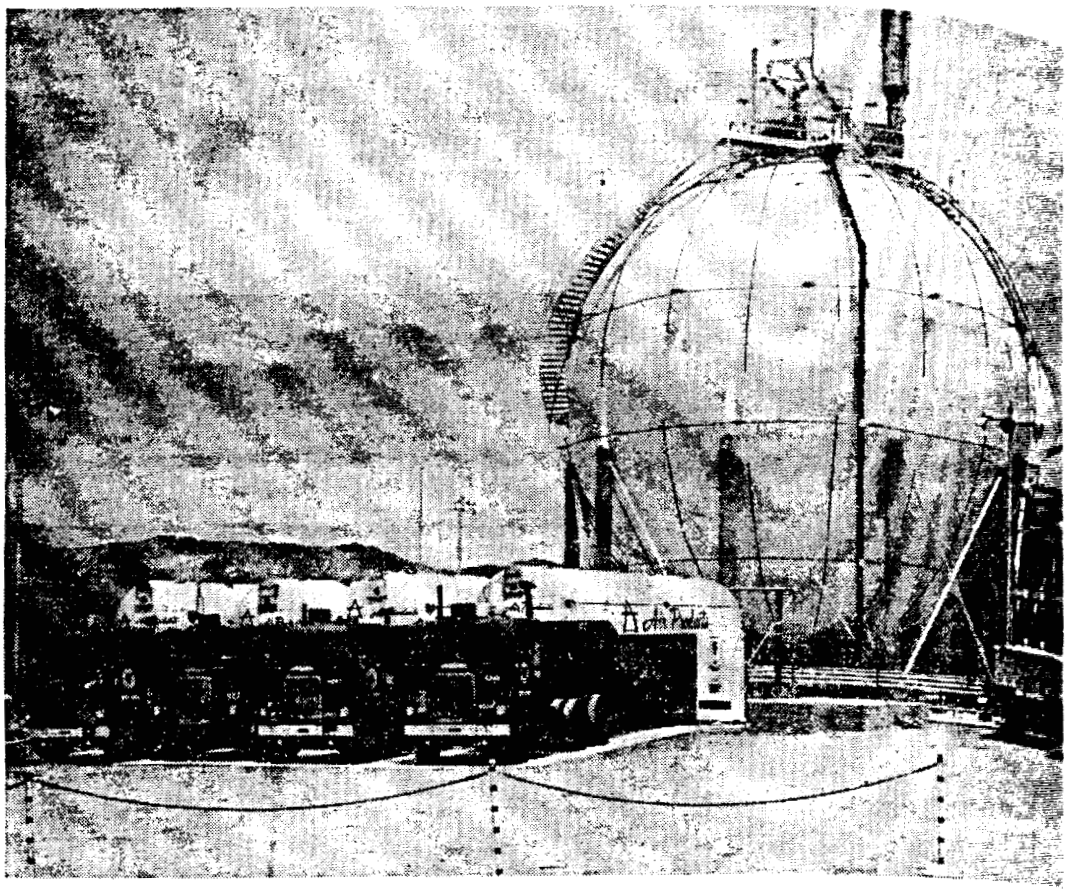
Cryogenic Safety

The development of nuclear rocket propulsion technology at the AEC-NASA Nuclear Rocket Development Station (NRDS)—located within the Nevada Test Site reservation—involves the storage and use of large quantities of cryogenic (super-cold) fluids. During



Plastic Protection. This suit is the latest creation of Isochem Inc., engineers at the AEC's Hanford Plant where the development of plastic clothing to protect people working in radioactive contaminated environments has been pioneered. The suit is air-conditioned, wired for sound, and its disposable outer covering provides a unique approach to control the spread of radioactive contamination.



Liquid Hydrogen Storage. The storage capacity for liquid hydrogen (LH_2) has been increased by a million gallons at the Nuclear Rocket Development Station (NRDS) in Nevada. The LH_2 is used—often at the rate of 10,000 gallons per minute—in the AEC–NASA development of a reactor engine for propulsion of space vehicles. Storage and handling of the liquified gas poses a number of cryogenic (super-cold) safety problems. In photo *above*, four transports, with capacities of approximately 12,000 gallons each, unload LH_2 into the two 500,000 gallon capacity dewars (double-walled tanks) at NRDS. Prior to its use in a test run of the experimental propulsion reactors, the LH_2 is transferred to a 250,000 gallon dewar storage tank at the Engine Test Stand. Photo at *left* shows how the tank is cooled by a water deluge system. Total flow capacity of the deluge system is an estimated 21,000 gallons per minute.

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1966, the storage capacity for liquid hydrogen alone tripled to more than 1.5 million gallons with the rate of use during some operations often approaching 10,000 gallons per minute.

Along with the application of radiation and reactor safety disciplines, cryogenic safety plays an important role in the ground testing of nuclear rocket engines. The cryogenic fluids are extremely hazardous. To be kept in a liquid state they must be maintained under extreme pressure and the resulting extremely low temperature (−432° F. for liquid hydrogen) reduces the ductility and impact resistance of most materials on contact. Severe damage results when human tissue is contacted by the liquid, its immediate container, or the resultant extremely cold gas formed when the liquid vaporizes. Fundamental factors involved in the NRDS program for the safe handling of cryogens include:

(1) Proper respect for the associated hazards;
(2) Attention to safe design and operating features of systems;
(3) Training and orientation of operating personnel;
(4) Pre-planning and check-listing of the sequence of operations;
(5) Adherence to operating procedures; and
(6) Documentation and reporting on operating errors and anomalies for subsequent corrective actions.

These factors—combined with engineering safeguards, fail-safe systems and components, or personnel control and area exclusion concepts—make routine the handling and use of large quantities of cryogenic fluids at the NRDS.

Emergency Decontamination Facility

A special facility has been designed at the National Reactor Testing Station, Idaho, to handle injured persons who have also been contaminated with radioactive material. The emergency center consists of a special decontamination room, a surgery room, a personnel shower room, and a changeroom. The equipment in the facility includes a filtered ventilation system, a holdup tank for radioactive liquid wastes, a shielded storage bin, and movable radiation shields to protect medical personnel working on the injured person.

New Developments in Occupational Medical Program

The first AEC-operated Occupational Medical Program to receive American Board of Preventive Medicine approval for in-plant resident training of physicians in occupational health was that of the Idaho Operations Office. This 1-year program of training is to be

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conducted in affiliation with the University of California at Los Angeles, School of Public Health. The training will include experience with all aspects of the comprehensive occupational health program at the National Reactor Testing Station. The program will accommodate one resident physician in training each year.

Radiological Assistance Program

On May 9, the Department of Defense and the AEC revised their agreement of February 27, 1958, on responding to nuclear weapons accidents. The agreement sets forth the general areas of responsibility of each agency in responding to accidents involving radioactive material; the general procedures to follow; and defines the mission and

Mobile Counter. A new rotational scanning-type whole-body counter has been designed and put into use at the National Reactor Testing Station. The counter is incorporated into a 30-foot medical van (shown *above*), which also includes facilities for diagnostic X-ray and clinical laboratory studies. The unit has the advantage of increased accuracy with good detection efficiency despite the use of only 1,500 pounds of shielding material. Scheduling the van to all major plants on the 894-square-mile testing station reduces the amount of productive worktime previously required for workmen to travel to central facilities for whole-body radioactivity measurements and periodic medical examinations. Photo at *left*, shows the inside of the medical van with the rotational scanning system being demonstrated. In the *upper left* corner, partially seen, is the X-ray unit.

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principal task and functions of the DOD–AEC Joint Nuclear Accident Coordinating Center (JNACC) at Albuquerque, N. Mex.

The AEC and DOD radiological emergency assistance capabilities are a major part of the total Federal agency capabilities being coordinated through implementation of the Interagency Radiological Assistance Plan. Under AEC leadership, the 13 Federal Agencies presently participating in the interagency plan are developing plans and procedures for coordinating their operations at the regional level in the event of serious offsite or onsite accidents resulting in radiological hazards. The main purpose of the interagency plan is to make available as soon as possible the appropriate advice and emergency assistance needed to protect public health and safety, to save life, to minimize injury and to limit the restriction of property from the accidental loss of control of radioactive materials.

SAFETY AWARDS AND EXPERIENCE

Five AEC contractors and one AEC field office earned the AEC's Award of Honor for outstanding safety performances in their respective categories for periods terminating in 1966. They were: Dow Chemical Co. (production), Golden, Colo., with 6,750,000 injury-free man-hours; Phillips Petroleum Co. (research), Idaho Falls, Idaho, with 12,921,162 injury-free man-hours; South Carolina Office of the United States Forest Service (services), with 754,942 injury-free man-hours; E. I. du Pont de Nemours & Co. (construction), Aiken, S. C., with 1,893,617 injury-free man-hours;[7] Las Vegas-Tonopah-Reno Stage Line (special award) for operating 12.8 million injury-free miles; and Idaho Operations Office (Government) with 4,861,273 injury-free man-hours.

The AEC and its contractors received the National Safety Council's Award of Honor for the sixth time since 1955 at a formal presentation held at Headquarters in July.

ACCIDENTS AND PROPERTY DAMAGE

Ten deaths occurred in AEC operations during the year, none from radiation. Seven resulted from industrial-type accidents and three from motor vehicle accidents—as compared with six industrial-type

[7] On December 31, 1966, the Savannah River facilities became the first in AEC's history to complete one calendar year (1966) without a lost-time injury. The record involves more than 6,500 individuals, including all persons at the Savannah River Plant employed by du Pont Operations, du Pont Construction, the Savannah River Laboratory, the AEC's Savannah River Operations Office, the Automatic Canteen Corp., Miller-Dunn Electric Co., Pittsburgh Testing Laboratory, Inc., B. F. Shaw Co., North Brothers, Inc., the U.S. Forest Service, and the University of Georgia.

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accidents in 1965. The AEC property damage ratio of 1.76 cents was well below the AEC 19-year average of 2.02-cent loss per $100 of AEC property evaluation and compares with a 2.46 figure for 1965. Of the total property damage of $980,000, two operating incidents each resulted in a loss of $200,000 or more.

Radiation Exposures

Among the 11 Type A and B incidents[8] involving radiation exposure through November 30, 1966, as are required to be reported in plants operated by AEC, there was only one Type A incident. It involved a whole body of exposure of 50 *rem* to an employee who worked in a restricted area. This incident was reported by the University of Minnesota research laboratory, but upon investigation, the circumstances were found to be questionable and the exposure doubtful.

The 10 Type B reportable exposures occurred as follows: a 58 *rem* exposure to the hands of a laboratory worker engaged in experimental work; another 29.2 *rem* to the hands of an analyst; 22.6 *rem* to the fingers of a third research operator; an estimated 300 *rem* of X-ray to one foot of a technician in an accelerator incident; two employees who received estimated 4.6 and 2.0 *rem* in a laboratory experiment and another received 3.2 *rem* in another laboratory incident; to a worker who received 3.1 *rem* of internal beta exposure while loosening bolts on a vacuum hood; to an employee, in processing plutonium who received an estimated 5.1 *rem* whole body exposure; to an employee who received 70 *rem* to his thigh when he inadvertently carried a source in his pocket; and to a technician who received 3.4 *rem* to his hand.

Releases of Radioactive Material

Releases of radioactive or other material at AEC-owned facilities were involved in the following incidents: an estimated 420 pounds of uranium solution was lost in a waste tank through the failure of a valve; 3,844 pounds of uranium-hexafluoride were lost due to an error in opening a cylinder; a quantity of mercury (50,000 lbs., nonradioactive) was spilled to the ground in an operational error; some tritium gas escaped to the atmosphere through a glove port to the stack and diluted in the atmosphere; 10 gallons of waste solution were spilled on the floor during the repair of a valve; approximately one-half pint of

[8] Reportable Type A and Type B incidents are defined in TID 5360 (pg. 13), supplement 5, "A Summary of Industrial Accidents in USAEC Facilities, 1963–1964," available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va. 22151, price $3.00.

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plutonium solution was spilled in an elevator and tracked to adjacent rooms; and 100,000 pounds of sodium dichromate (nonradioactive) was spilled from a storage tank and lost into a sewer.

Safety Training Programs

The AEC has designated a public safety liaison officer to maintain a liaison service for public safety organizations and for Government and private agencies interested in the public safety area. At the present time, fire departments are responding in large numbers to a request to name officers to act as liaison with the AEC. A bi-monthly "Public Safety Newsletter"[9] is provided these public safety representatives. As soon as the fire department program is underway, the service will be offered to other public agencies, such as police departments and interested federal agencies. This service provides a channel for close cooperation with appropriate officials in the event of a major accident involving radioactive materials.

AEC Fire Protection and Prevention School

Since 1950, the facilities of the U.S. Navy Structural Fire Protection School, Norfolk, Va., have been made available to the AEC annually for conducting courses. One of the courses covers fire loss management for AEC facilities. Over the years, several hundred AEC and contractor employees have attended this course. One function is the development of simple practical demonstrations which can be used at the students' own facilities.

[9] Available without charge from the Director, Division of Operational Safety, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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Chapter 17

INDUSTRIAL PARTICIPATION ASPECTS

Ever since the inception of the Government's atomic energy program—during World War II—great reliance has been placed on the initiative and ingenuity of American industry to achieve Government goals. This initiative and ingenuity have likewise been primarily responsible for the development of the private competitive nuclear industry which continued to grow during 1966.

AEC ACTIONS IN COOPERATION WITH INDUSTRY

The development of a viable private industry has been a major objective of the AEC since passage of the Atomic Energy Act of 1954 permitted private ownership of facilities such as nuclear reactors. Subsequently, passage by the Congress (1964) of legislation permitting private ownership of the special nuclear materials which fuel reactors, removed a major legal obstacle to competition by the atom on the commercial energy market on a similar economic basis with older energy sources. The nuclear industry dramatically reached a more mature status as a basic energy supplier during 1966 as privately- and publicly-owned utilities announced plans for construction of 26 power reactors—dual-units at some sites—having a total output of more than 31,000 net megawatts of electricity (see Appendix 4). Other segments of the nuclear industry also showed signs of continued growth.

COOPERATIVE ASPECTS

In working toward a position of industrial maturity, close cooperation and good communications between the AEC and the nuclear industry have been essential.

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Industry Associations

One means of maintaining good channels of communication with industry has been through frequent meetings of the Commissioners and/or the AEC staff with leaders of industry associations having active interests in the nuclear field. For this purpose, meetings are regularly scheduled between the Commissioners and the Board of the Atomic Industrial Forum. Other, less frequent, meetings are held with the Atomic Energy Committee of the Edison Electric Institute, the Science and Technology Committee of the U.S. Chamber of Commerce, and the Executive Committee of the American Public Power Association. In addition, less formal meetings are held between the AEC staff and groups following nuclear activities within the National Association of Manufacturers, the American Public Power Association, the National Rural Electric Cooperative Association, the National Security Industrial Association, the Aerospace Industries Association, and the Manufacturing Chemists' Association. The meetings provide for a free exchange of ideas and a means of discussing common problems.

NUCLEX '66

The AEC worked with the Department of Commerce in cooperation with representatives of American industry in planning United States participation in NUCLEX '66, an international commercial exhibit and technical symposium in Basel, Switzerland, in September, 1966. Sixteen countries, including the United States, exhibited nuclear products and services and commercially-oriented technical papers from 13 countries were presented at 14 general sessions. AEC activities in connection with this exhibit were directed toward assuring international sales opportunities for United States producers of nuclear equipment and services and included presentation of papers on the new policy of enrichment of foreign-owned uranium concentrate (see Chapter 4—Source and Special Nuclear Materials and Chapter 12—International Cooperation Activities) and U.S. nuclear power and raw materials resources and requirements. Sixty-one U.S. firms presented exhibits including an operating desalting facility, and some 50 technical papers were presented by U.S. participants. It has been estimated that $62 million in sales of U.S. products abroad will result from this exhibit over the next five years. (This estimate excludes potential reactor sales and sales of engineering services.)

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[1] See pp. 29

Improved Regulatory Procedures

A panel of qualified industrialists, lawyers, and scientists, appointed by the Commission in 1965,[1] identified major problem areas in the AEC's licensing procedures and recommended steps for improvement. Implementation of the recommendations represented significant procedural advances not only from the standpoint of the AEC but also from the standpoint of license applicants (see Chapter 1—Licensing and Regulating the Atom).

Radioisotope Production

In March, the AEC withdrew from the production of 19 radioisotopes bringing to 36 the number no longer produced for public sale by the AEC. These withdrawals are consistent with the AEC's established policy of transferring routine production and distribution of radioisotopes to industry as industry demonstrates an ability to perform these activities (see Chapter 4—Source and Special Nuclear Materials).

Commercial Production of Cobalt 60

During April, the AEC approved the request of Consumers Power Co. of Michigan to produce cobalt 60 in the company's Big Rock Point Nuclear Power Plant located in Charlevoix County, Mich. Production of the radioactive cobalt, which has wide uses in industry, medicine, and research, will be incidental to continued operation of the 72 Mwe Big Rock Point plant as a power-producing reactor.

This is the first use of a central station nuclear powerplant for the large-scale commercial production of cobalt 60. Cobalt targets are being inserted into the Big Rock Point reactor and irradiated to the extent necessary to produce useful radioactive sources. The first cobalt was inserted into the reactor during the May refueling and production is expected to reach 2 million curies annually by late 1967. The venture is a joint effort by Consumers and Neutron Products, Inc., an affiliate of NUS Corp., Washington, D.C. (see also Chapter 4—Source and Special Nuclear Materials).

The only other commercial cobalt 60 producer is General Electric which announced in March that it planned to step up the cobalt 60 output of its GETR (General Electric Test Reactor) near Pleasanton, Calif.

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[1] See pp. 298–299, "Annual Report to Congress for 1965."

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Plutonium Utilization

Actions directed toward the commercial use of plutonium as a reactor fuel offer a particularly good example of cooperation between AEC and industry. The Edison Electric Institute, through its Committee on Fuels, is sponsoring development work on plutonium fuel for both thermal and fast reactors. This work is carefully meshed with the AEC's own plutonium fuel development program (see Chapter 7—Reactor Development and Technology). In March, a conference on commercial plutonium fuels was jointly sponsored by the Atomic Industrial Forum, the Edison Electric Institute, and the American Nuclear Society in cooperation with the AEC.[2]

Nuclear Safety

Another outstanding example of cooperation between Government and industry has been in the nuclear safety program (see Chapter 7—Reactor Development and Technology). The Atomic Industrial Forum (AIF) Nuclear Safety Committee has worked closely with the AEC's Steering Committee on Reactor Safety Research to make sure that the safety research and development program is keyed to the needs of the commercial nuclear industry as well as one that meets the first criterion of the AEC—the health and safety of the public. Included in this working relationship is the continuing assignment, through the AIF, of industrial representatives as participants in a number of major AEC safety research and development projects.

INDUSTRIAL GROWTH

For the past few years the private nuclear industry has had the capability to provide almost all the materials, equipment and services needed in the generation of nuclear-electric power.[3] Two important exceptions have been the enrichment of uranium in the uranium 235 isotope and the processing of spent reactor fuels to recover unconsumed fissionable materials.

The latter exception was removed in April with initial operation of Nuclear Fuel Services, Inc., fuel processing facility at West

[2] The proceedings of the Conference, including a talk by Dr. Seaborg, "Plutonium—Past, Present, Future", are available as CONF-660308, "Commercial Plutonium Fuels Conference", March 1–2, 1966 available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va. 22151, for $3.00.

[3] For a complete report on the private atomic energy industry prepared by the AEC's Division of Industrial Participation, see "The Nuclear Industry—1966", available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $1.00.

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Valley, N.Y. With respect to the other exception, it now appears possible that eventually commercially owned or operated enriching facilities will become available. In the meantime, an approach to commercial production of enriched uranium will be provided through "toll enrichment." AEC contacts with the private nuclear industry assisted in the development of criteria for this service, which criteria were established in 1966 (see "Criteria and Policies" summary in Chapter 4—Source and Special Nuclear Materials).

Gaseous Diffusion Plants Studies

The AEC announced at year's end that it is giving serious consideration to the possible desirability of selling or leasing to the private sector one or more of its three gaseous diffusion plants which produce enriched uranium 235. The Commission is discussing with the Atomic Industrial Forum the scope and ground rules for a proposed study of the feasibility of such an arrangement. In addition to its discussion with the AIF, the AEC is conducting its own internal study on the feasibility and desirability of transfer of the gaseous diffusion plants to private operation. The plants are located at Oak Ridge, Tenn.; Portsmouth, Ohio; and Paducah, Ky., and are operated for the AEC by private contractors.

Interest in transfer of the gaseous diffusion plants to industry has intensified as a result of the rapidly accelerating civilian nuclear power industry and passage of the Private Ownership Act of 1964. The Act permits, and eventually will require, private ownership of special nuclear materials (SNM) used as power reactor fuel. Previously the Atomic Energy Act required all SNM to be Government-owned.

Uranium enrichment is expected to constitute an enterprise of large economic significance over the next decades. The value of enrichment services is expected to reach approximately $500 million per year by the late 1970's. Under the Atomic Energy Act, the AEC has a responsibility for encouraging private enterprise; in fact, private industry is now participating in every phase of the nuclear fuel cycle except uranium enrichment.

The Commission's discussion with the Atomic Industrial Forum is directed toward obtaining the considered views of the industry on the many factors involved in any transfer of ownership and operation of the gaseous diffusion plants to private hands. While no definite decision on the matter has yet been reached, the AEC believes that a study at this time might most appropriately be conducted by a representative group such as the AIF which encompasses mining, manufacturing, the utilities, and related segments of the nuclear industry.

GROWTH INDICATORS

Some indications of a maturing nuclear industry are given in the following paragraphs.

Increasing Competition

The trend of power reactor contracts going to only the two largest manufacturers which had prevailed through 1965 was changed in 1966. Consumers Power Co. of Michigan, and the Omaha Public Power District placed orders with Combustion Engineering, Inc., Windsor, Conn., for the nuclear components of 700 and 450 Mwe plants, respectively. Duke Power Co. and Metropolitan Edison Co. placed orders with the Babcock and Wilcox Co., Lynchburg, Va., for nuclear components for two 839-Mwe units and one 839-Mwe unit, respectively.

Nuclear Fuel Market

The first utility order for reactor fuel was placed with a supplier other than a reactor builder when Commonwealth Edison Co. ordered a complete core for its Dresden Unit 1 Nuclear Power Station from United Nuclear Corp., New Haven, Conn. Both Westinghouse and General Electric placed orders for uranium concentrate (U_3O_8) for delivery in the 1967–1975 period. Commonwealth Edison, and Philadelphia Electric (for itself and three associates), also placed orders for uranium concentrate for delivery in the 1968–1973 period. These were the first orders placed by industry for U_3O_8 and reflect preparations for the time when private ownership of uranium will become mandatory for power reactor fuels with reactor operators—July 1973. It is estimated that these orders for concentrate in 1966 totaled in excess of $200 million.

Reactor Vessels

A second plant capable of producing large pressure vessels of the type used as primary containment for very large light water reactors began operation in early 1966. This was the Babcock & Wilcox Co. plant at Mt. Vernon, Ind. The only other U.S. facility with a comparable capability is the Combustion Engineering, Inc., plant at Chattanooga, Tenn.

A further development in pressure vessel construction was the proposal by Chicago Bridge and Iron Works to fabricate large vessels of this type at the reactor site. The first such order for a field fabri-

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cated vessel was received for the Northern States Power Co.'s Monticello plant. At year's end the public safety aspects of this type of construction were under study by the AEC.

Specialization

A trend toward "turnkey" arrangements in the construction of nuclear powerplants was reversed during the year. Under the turnkey concept, plants are offered as complete, ready-to-operate units. The June announcement by General Electric that it would no longer offer nuclear powerplants on a turnkey basis helped to bring nuclear plants under the more normal utility-supplier relationship which has prevailed in the past in the construction of fossil-fueled plants. GE also announced that in order to concentrate its efforts in the power reactor field it would no longer sell test, research, or training reactors.

In December, both General Electric and Westinghouse announced they were standardizing the sizes of nuclear plants that they would offer. General Electric will sell three sizes—515, 762, and 1,075 net Mwe; Westinghouse is offering six power levels—480, 530, 700, 785, 930, and 1,040 net Mwe.

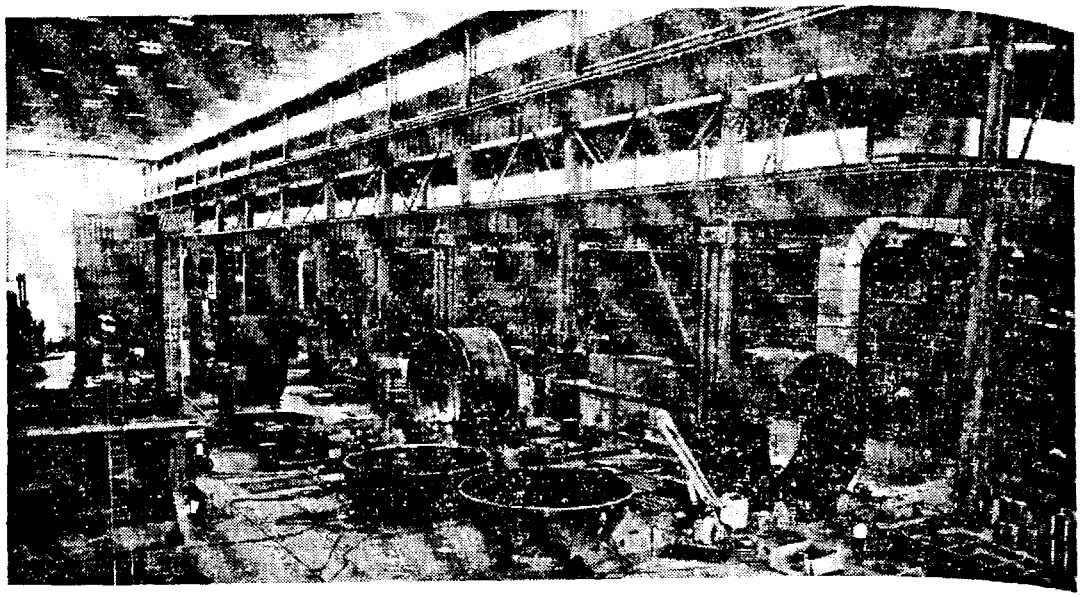
Fuel Processing Plants

Nuclear Fuel Services, Inc. (NFS). The NFS plant at the Western New York Service Center in West Valley, N.Y., began full scale processing of irradiated reactor fuel in April. Fuel processed during the period consisted of 96 tons of fuel from the AEC's Hanford "N" reactor and 50 tons of power reactor fuel from the Commonwealth Edison Co.'s Dresden reactor.

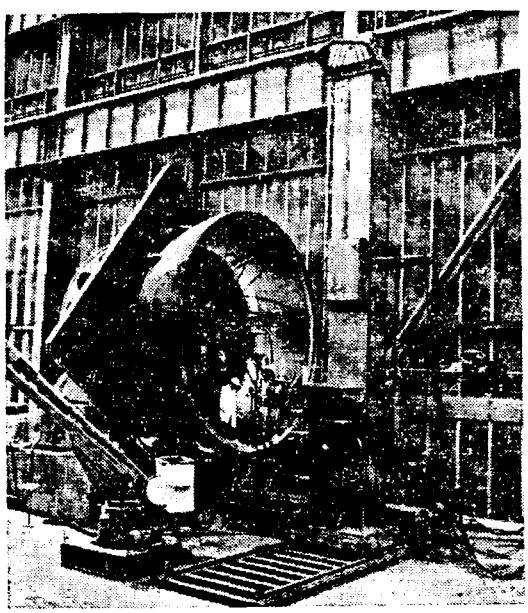
The New York State Atomic and Space Development Authority announced on July 11, that it is investigating the installation of a neptunium recovery facility at West Valley. The new facility would be used initially to extract neptunium from the residues from NFS' fuel processing operations. It would be capable of being expanded later for extraction of other isotopes.

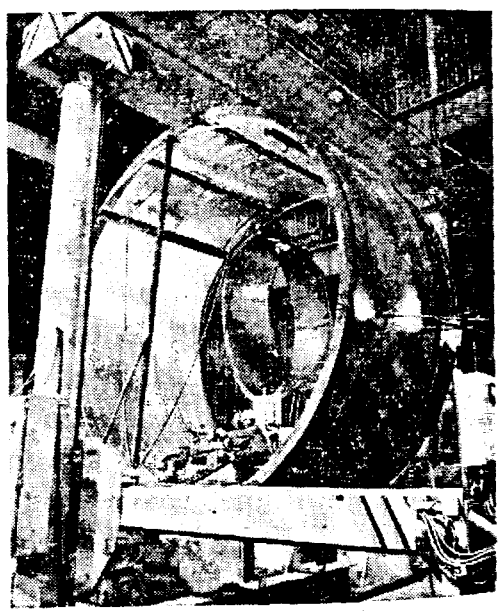
General Electric Co. On September 15, General Electric announced it would build an aqueous-fluoride processing plant near Morris, Ill. The plant is expected to be in operation by the early 1970's. The planned process will leach re-usable fuel materials out of segmented cladding and will separate uranium, plutonium, and neptunium from gross fission products by solvent extraction. The uranium will be purified by a fluoride volatility process. Plutonium and neptunium purification is to be by ion exchange. High level wastes will be calcined, canned, and stored in waste storage vaults. There will be no liquid radioactive wastes discharged from the plant.

REACTOR VESSEL FABRICATION



New Fabrication Plant. Indicative of private industry's growing participation in the atomic energy field is the new $20 million Babcock & Wilcox Co. plant at Mt. Vernon, Ind.—the world's most advanced facility for fabrication of nuclear reactor pressure vessels. The first job for the plant is the fabrication of the 800-ton vessel for the Dresden Unit No. 2 reactor as shown on these two pages. Photo *above* shows a portion of the main pressure vessel shop. A unique feature of the plant is the use of portable machine tools (*shown below*) which can be moved from place-to-place by an overhead crane having a 1,200-ton capacity. The big machines can roll, rotate, and tilt parts simultaneously to maneuver the segments of the reactor vessel for boring or machining, cladding the stainless steel, or welding. The plant, which was built primarily for reactor vessel work can handle pressure vessels for nuclear power reactors of 1,500 Mwe capacity.





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Dresden No. 2 Takes Shape. A giant plate roll—one of the world's largest—is shown *above* forming a section of the Dresden Unit 2 reactor pressure vessel at the new Babcock & Wilcox Co. fabrication facility at Mt. Vernon, Ind. The roll can form 6-inch cold plate or 14-inch hot plate in widths up to 12 feet with accuracy and speed. An "orange peel" section of the reactor vessel is shown at *left below* being assembled. The submerged-arc welding is facilitated by rotating weld positioners having a 500-ton capacity. Photo at *right below* shows the bottom section of the reactor vessel and the holes through which the control rods will pass. When completed in late 1967, the boiling water reactor housed in the vessel will provide heat for 715 megawatts of electrical output for the Commonwealth Edison system. A twin vessel for the Dresden Unit No. 3 is also being fabricated at the Mt. Vernon plant.

Allied Chemical. During 1966, Allied Chemical Corp. affirmed its interest in eventually building a commercial processing plant, but stated it had abandoned the initial plans for the use of a combination aqueous-fluoride volatility process which the firm had been studying since January 1963. Following this decision, Allied curtailed construction of the full scale cold pilot plant it was building at Metropolis, Ill., and is presently concentrating its research and engineering efforts on several processes within the firm's advanced fluorine research group. A process selection is expected to be made in 1967 for use in its commercial plant. Although Allied Chemical has made no decision as to site location, present indications favor the eastern United States.

Commercial Isotope Power Units

The first commercial offering of compact, electric power systems powered by radioisotopes was made by the Martin-Marietta Corp., Baltimore, Md. The units provide 25 watts of power over warranted periods of up to five years. The first commercial sale was to the Department of the Navy (see also Chapter 3—The Regulation of Radioactive Materials, and Chapter 9—Isotopic Heat and Power Applications).

CHANGES IN THE INDUSTRY

As the nuclear industry approached a period of substantial and steady growth, the economic future of its individual segments began to clarify and generate a number of changes and realignments in the industry. Among these were the following:

- Nuclear Utility Services, Inc., Washington, D.C., originally formed as a consulting firm for utilities interested in nuclear power, changed its name to NUS Corp. as it diversified into marine-oriented activities and expanded its operations to include the manufacture of measuring devices for oceanographic applications.
- The increasing importance of radiopharmaceuticals and radiochemicals was reflected in consolidations of firms in these activities with major medical supply or chemical concerns. The Upjohn Co., Kalamazoo, Mich., acquired an interest in Isomet Corp., Palisades Park, N.J.; Becton Dickinson and Co., East Rutherford, N.J., purchased Schwartz Bio-Research, Inc., Orangeburg, N.Y.; Mallinckrodt Chemical Works, St. Louis, Mo., purchased Nuclear Consultants Corp. also of St. Louis.
- In other changes in the radioisotope field, Isotopes, Inc., Westwood, N.J., broadened its operations through acquisition of Hazelton Nuclear Science Corp., Palo Alto, Calif., and the U.S. Nuclear Corp.,

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Burbank, Calif. U.S. Nuclear had previously acquired Volk Radiochemical. In a somewhat different merger, Union Carbide, Tuxedo, N.J., acquired Neisler Laboratories, Inc., Decatur, Ill., a small drug concern, to market radiopharmaceuticals which Union Carbide produces.

- Related medical uses of isotopes and instruments were reflected in: the merger of Nuclear-Chicago, a leading nuclear instrument manufacturer, into G. D. Searl, Skokie, Ill., a large drug concern; and the establishment of a jointly owned company, Nen-Picker Radiopharmaceuticals, Inc., by New England Nuclear, Boston, Mass., a leading processor of radiochemicals, and Picker X-Ray, White Plains, N.Y., one of the larger nuclear instrument makers.
- The rapid increase in utility orders for nuclear powerplants led to expansion of fuel fabrication facilities. For example, Combustion Engineering expanded its Windsor, Conn., plant, and National Lead acquired the fuel fabrication facilities of Sylvania Electric Products at Hicksville on Long Island, and moved them to its expanded fuel fabricating plant at Albany, N.Y.
- Allis-Chalmers withdrew from the nuclear power reactor business, but will complete its current commitments in this field. This move followed its earlier decision to withdraw from production of steam turbines for electric utility generating stations.

REGIONAL SUPPORT ACTIVITIES

The interstate compact offers a unique means for cooperation between the States and the Federal Government, especially in a field such as atomic energy where comparable action by individual States could be beyond the means of most—both technically and economically. Regional efforts toward meeting common needs in the nuclear field during 1966 are discussed below.

Southern Interstate Nuclear Board

The Southern Interstate Nuclear Board (SINB),[4] established 5 years ago, has served as a means of pooling the energies and resources of the 17 southern States in applying nuclear and aerospace technology to the economic advantage of the region.

In cooperation with the AEC, the SINB has assessed the economic impact of food irradiation and wood-plastic alloys on the southern States. During 1966, the SINB completed a study on transportation of radioactive materials in international trade for the AEC. The

[4] 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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report itself[5] provides an excellent review of the field, its history, and its problems. Perhaps more importantly, under the SINB auspices the study provided a forum at a propitious time for experts and executives in all forms of transportation. A continuation of the discussions initiated during the study should prove of exceptional value in later years to the country as a whole.

Among SINB's other activities have been the holding of seminars at Oak Ridge, Tenn., in cooperation with the AEC's Oak Ridge Operations Office, for the purpose of informing southern leaders on various aspects of atomic energy. Three of these were held during 1966: a nuclear power briefing for utility executives in January, one on "The Working Man and the Atom" in June, and one in September in cooperation with the National Coal Association for executives in the coal and coal transportation industries.

Midwest Compact

The Midwest Governers' Conference,[6] at its 1964 annual meeting, appointed an *ad hoc* committee to study a nuclear compact for the midwest. The committee subsequently recommended such a compact, and the Midwest Governors at a special meeting in Lexington, Ky., in February 1966, endorsed a formal Midwest Nuclear Compact. The compact seeks to foster the industrial progress of the midwest through the proper employment of scientific and technological advances in nuclear and related fields. Enabling legislation in each of the States in the Midwest Governors' Conference is expected to follow.

Western Compact

At the Western Governors' Conference[7] in April 1966 a resolution was adopted authorizing a special committee for the purpose of formulating the details of a western interstate nuclear agreement. The committee's report will be considered at a forthcoming meeting.

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[5] "International Traffic of Radioactive Materials," expected to be available in early 1967 from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va. 22151.

[6] Representing: Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

[7] Representing: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming, Guam, and American Samoa.

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Chapter 7

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Chapter 18

ADMINISTRATIVE AND MANAGEMENT MATTERS

During the year, the AEC continued its diversification efforts to strengthen the economic base of communities dependent upon local AEC operations and to attract new industries into the nuclear energy program. Three facilities no longer needed, were disposed of, and transfer of a satellite community to local government was advancing toward completion. The annual survey of atomic energy manpower shows employment has declined in both Government-owned and privately owned establishments. Strikes at Government-owned facilities accounted for a loss of 0.7 percent of scheduled man-hours of work—up 0.4 percent from 1965. Almost half of the AEC's subcontracts continued, for the fifth year, to go to small business.

DIVERSIFICATION AND DISPOSAL ACTIVITIES

During the year, the transition of the Hanford Plant's single contractor-operation to seven contractual segments was completed; a new firm took over part of the operations at the National Reactor Testing Station; and the management of Argonne National Laboratory came under a tripartite arrangement. One no-longer-needed facility was sold, another was transferred to the Air Force, and another was offered to industry for possible commercial use. Developments toward terminating the AEC's ownership and management of the Los Alamos community continued.

COMPLETION OF HANFORD SEGMENTATION

Transfers of operating responsibility at the AEC's Hanford Works near Richland, Wash., from the General Electric Co. to the last two of seven new contractors, under the plan for segmented operation

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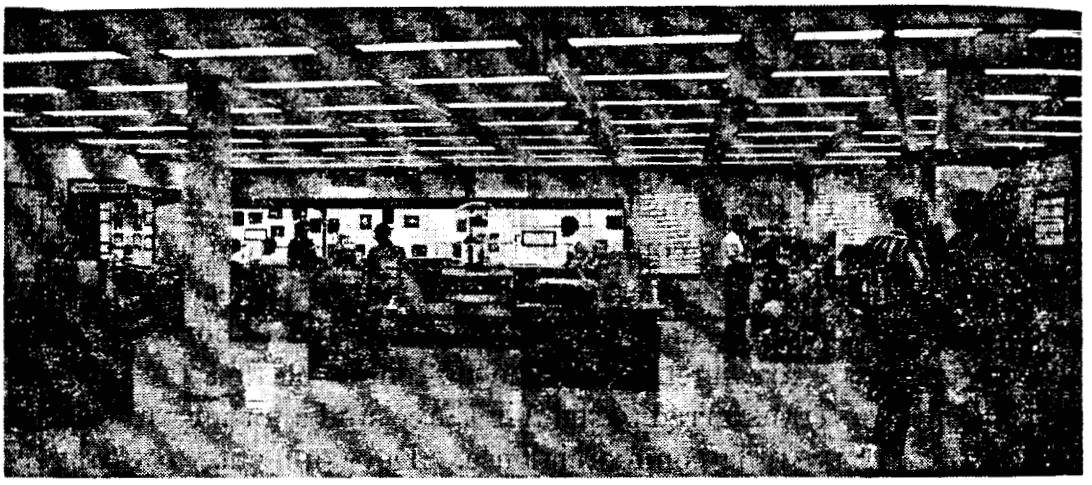
previously initiated,[1] were accomplished on January 1, and March 1. Isochem Inc., formed by U.S. Rubber Co. and Martin Marietta Corp., took over operation of the chemical-separations facilities at the beginning of the year. Two months later, ITT Federal Support Services, Inc., a Richland subsidiary of International Telephone and Telegraph Corp., assumed operation of the Hanford support facilities and services, including operation of plant utilities, performance of purchasing and warehousing, and providing transportation, maintenance, and administrative services.

Economic Base Strengthened

The new contractors and their affiliates brought to 11 the number of firms involved in widely diversified private ventures in the Richland-Kennewick-Pasco area stemming from the AEC's solicitation of proposals for bringing in private business activity in connection with the new operation contracts for the Hanford facilities. With commitments for the investment of approximately $38-million over a period of 10 years, the private ventures will provide a strong economic base for the three communities. Heretofore, the local economy was geared primarily to the AEC's operations at the Hanford complex.

The other contractors with "diversification" projects in progress are Battelle-Northwest division of Battelle Memorial Institute, Columbus, Ohio; Douglas United Nuclear, Inc., and its joint-venture parent



Tourist Attraction. Relocated in the new Richland Federal Building, the Hanford Science Center has become a popular tourist attraction of Southeastern Washington state. The center features 40 animated exhibits, graphic displays and models which depict production, research, and development activities at the Hanford plant. ITT Federal Support Services, Inc., operates the Hanford Science Center for the AEC and other Hanford contractors. The above photo shows a small portion of the exhibits in the new facility.

[1] See pp. 25–31, "Annual Report to Congress for 1965"; pp. 19–23 "Annual Report to Congress for 1964."

companies—Douglas Aircraft Co., Santa Monica, Calif., and United Nuclear Corp., Centerville, Md.; United States Testing Co., Inc.,[2] Hoboken, N.J.; Computer Sciences Corp., El Segundo, Calif.; and Federal Electric Corp., Paramus, N.J., another ITT subsidiary.

Some of the nearby land previously leased by the AEC to the State of Washington for use in developing nuclear industry, was subleased by the State to the California Nuclear, Inc., Pleasanton, Calif., and Lafayette, Ind., early in 1966. The firm will, as a private business, use the land for burial of low-level solid waste materials generated in nuclear installations.

Healthy Economy

During the contractor transition, the economy of the "Tri-Cities Area" has remained healthy and vigorous, notwithstanding the earlier cutback in the level of AEC operations there. As of November 30, 1966, AEC contractor employment totaled 5,877, including the manpower equivalent of about 500 persons applied to "diversification" projects and other private work of the contractors. The AEC will continue to cooperate with community leaders in seeking to stimulate private business activities as a means of broadening the economic base of the area.

The AEC is exploring possibilities for in-place use of support facilities near the shut-down reactors, by governmental agencies (both Federal and State) or industrial firms.

DIVERSIFICATION

A new company, Idaho Nuclear Corp., took over part of the operations at the National Reactor Testing Station and a new university group—Argonne Universities Association—joined with the University of Chicago in the administration of Argonne National Laboratory. The AEC continued to find new uses for other facilities where the normal workload has been reduced.

New Contractor at NRTS

On July 1, Idaho Nuclear Corp. (a joint venture of Aerojet-General Corp. and Allied Chemical Corp.), under a 5-year contractual arrangement, took over as operator of the AEC's test reactors, chemical processing plant and associated research and development, and support services work at the National Reactor Testing Station (NRTS)

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

near Idaho Falls, Idaho. Idaho Nuclear replaced Phillips Petroleum Co. in performing this work. Phillips continues to conduct the AEC's extensive nuclear safety program at NRTS under a recently negotiated five-year extension to its current contract. The present arrangements for performance of work at NRTS reflect the Commission's decision to afford additional qualified industrial concerns an opportunity to participate in the operation of one of its major facilities.

New Contract Arrangement for ANL

A new contract for the operation and management of Argonne National Laboratory (ANL) was signed on November 1, 1966. The contract is a tripartite agreement between the AEC, the University of Chicago, and Argonne Universities Association (AUA), an association of 26 midwestern universities incorporated in July, 1965. Under the agreement, Argonne Universities Association will formulate, approve, and review laboratory programs and policies. The University of Chicago, which has operated the laboratory since its establishment in 1946, will be responsible for its operation and management in accordance with policies established by AUA. The University and AUA, will collaborate in the development of long-range objectives and programs.

Work for Others at Oak Ridge and Paducah

Unique plant facilities and technology at Oak Ridge, Tenn., and Paducah, Ky., available as a consequence of earlier cutbacks in the rate of uranium production, were used to an even greater extent in 1966 than in the previous year for meeting special needs of other AEC installations and performing specialized work for other Federal agencies, including the National Aeronautics and Space Administration, the National Institutes of Health, the Department of the Interior, and Defense agencies. Such "work for others" besides providing economies for the Federal Government and assisting in the retention of skills required for gaseous diffusion and other critical operations should they be needed, contributes materially to maintaining the economic health of the Oak Ridge and Paducah areas.

Oak Ridge Vocational-Training Program

A model cooperative vocational-training program was started at the Oak Ridge Y-12 Plant in June. Both shops and classrooms were utilized for training. The entire program was under the coordination

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and administration of the Oak Ridge Associated Universities, with participation by the Union Carbide Corp.-Nuclear Division, the University of Tennessee, the local Atomic Trades and Labor Council and constituent unions, the Tennessee Employment Security Department, the AEC, the U.S. Office of Education, and the U.S. Department of Labor. The latter two agencies provide funds for the program. Included in the activity are a 9-week summer session to update the training of vocational-technical teachers, quarterly sessions to supplement the training of university students who plan to enter programs in industrial education, and year-long training for unemployed and underemployed workers in certain skills that are urgently needed by modern industry.

Contribution in the Portsmouth Area

Establishment of a new private plant for the manufacture of automobile parts at Waverly, Ohio, was completed during 1966 when the manufacturer moved into a newly built facility of its own. While the new plant was under construction, the firm had leased interim quarters in excess warehouse space at the AEC's Portsmouth plant. The space had been previously made available as part of the AEC's cooperation in local business-development efforts.

DISPOSAL OF FACILITIES

Following a radical program change in mid-1965 which caused closing-out of development work carried on at the AEC's Connecticut Advanced Nuclear Engineering Laboratory, Middletown, Conn., sale of the plant facilities was effected by the General Services Administration in 1966, under competitive-bidding procedure. For a total price of approximately $16 million, United Aircraft Corp. (whose Pratt & Whitney subsidiary had been the AEC contract operator) acquired the real property and most of the equipment, exclusive of the sewer and water systems, which were donated to the City of Middletown through the Department of Health, Education, and Welfare. More than 1,200 Pratt & Whitney workers had been employed in the contract work; all had been placed elsewhere, or provided an opportunity for such placement, by early 1966.

Medina Facility

Phasing-out of weapons-modification work which had been done at the Medina Facility, San Antonio, Tex., was completed in April, fol-

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lowing a two-year period of gradual employment reduction accompanied by highly successful employee placement activities conducted in collaboration with Federal, State, and local agencies. The physical plant then was transferred to the Air Force, which has placed it back in use with a consequent increase in area employment.

Weldon Spring Plant

In April, the AEC announced plans to consolidate at its Fernald, Ohio, plant—the uranium feed materials production operations being conducted there and at Weldon Spring, Mo., with shutdown of the Weldon Spring plant to take place within a year. In July, expressions of interest in possible commercial use of the Weldon Spring facilities were solicited from 93 industrial firms. Sixty-two negative replies were received and 13 companies accepted the invitation to inspect the plant and discuss the possibilities for private operation. The visits were made in the fall.

LOS ALAMOS COMMUNITY DISPOSAL

Steps leading to the termination of AEC ownership and management of the community of Los Alamos, N Mex., continued in 1966. The termination was authorized by legislation approved September 28, 1962, which required that the utilities and municipal installations be transferred within five years. No date was set for the final disposal of all real estate. During 1966, some major results materialized from the intensive efforts begun in 1962.

Sale of Real Property

A total of 1,545 dwelling units in single family or duplex houses have been classified and appraised. The first home was sold on November 18, 1965, with the sale of 1,543 of these homes being completed by December 31, 1966. The remainder of the dwelling units to be sold, all in apartment houses, will be offered to priority holders. Any remaining apartment houses will be sold to the highest bidder.

Forty-one scattered lots were offered for sale to Los Alamos-connected persons; 32 large parcels of unimproved property have been offered for sale to the highest bidder.

Commercial, church, and non-profit properties have been appraised. Some have been offered for sale, and the remainder will be in the near future.

Appraisal and sale of properties at Los Alamos are being conducted by the Department of Housing and Urban Development.

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Private Housing Construction

Sale of unimproved land for private housing construction was discontinued by the AEC in 1965 in view of the imminent sale of Government-owned housing and other unimproved real estate. A total of 1,067 houses have been completed or are under construction in three housing development areas known as Barranca Mesa, White Rock, and Pajarito Acres. In addition, there are 507 developed lots on which private homes can be constructed.

Utility Systems

AEC has entered into a contract with Los Alamos County for the operation of the natural gas and electric distribution systems in the community to provide operating experience to the county prior to their actual transfer in 1967.

The Los Alamos Area Office has been authorized to proceed with negotiations with The Mountain States Telephone and Telegraph Co.

Community Relations. During October a fact-finding session was held at Los Alamos, N. Mex., to discuss some of the aspects associated with the AEC's termination of ownership and management of the community. Photo shows, *left to right:* AEC Commissioner Wilfrid E. Johnson; Herman Roser, Deputy Manager of the AEC's Los Alamos Area Office; Glenn W. Wiltrout, Assistant Director for Administration, Division of Military Application, AEC Headquarters; and Mrs. Joann Allen, Administrative Assistant to Congressman Thomas G. Morris of New Mexico who is a member of the Joint Committee on Atomic Energy.

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for sale of the Government's interest in the community telephone system.

Municipal Functions

On July 1, the school facilities at Los Alamos were transferred to the Los Alamos County Board of Educational Trustees. Most of the other municipal functions are being operated and maintained by the County under contract with the AEC. All municipal facilities and functions are scheduled for tranfser to the County in 1967.

Predisposal Construction Projects

The rehabilitation of all utilities systems in the community was completed, additional school facilities, water distribution systems and sewage disposal plants were built, and street improvements were made. A courthouse and administrative facility for the county is under construction, with completion expected in the spring of 1967.

Community Operations

AEC will continue to be responsible for community operations until the utilities and municipal functions and facilities are tranferred to the county in 1967. After the transfer, the AEC is authorized to make annual assistance payments to the County for a 10-year period. The AEC will also be responsible for the operation and maintenance of unsold Government-owned property remaining in the community and of utilities and municipal-type facilities in the technical areas and in the other two-thirds of Los Alamos County that are not subject to disposal.

LABOR RELATIONS

The Bureau of Labor Statistics (BLS) conducts an annual survey of manpower in the atomic energy field for the AEC. Data are collected from industrial establishments each year and are compiled separately for Government-owned and privately-owned establishments. As of March 1966, total employment in the atomic energy field was 132,630 compared to 141,093 in March 1965. Of this total, 101,377 or 76.4 percent were employed in Government-owned establishments and 31,253 or 23.6 percent were employees of privately-owned establishments (see Appendix 10). Table 1 gives a 2-year comparison of atomic energy employment by occupational categories at industrial establishments.

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AEC CONTRACTOR EMPLOYMENT

Facilities owned by the Government and operated by 40 AEC prime cost-type contractors employed a total of 103,903 persons in November 1966. These contractors are engaged in production, research, development, maintenance, and testing activities. Included are production and related workers which represented 41.1 percent of the total; 23.6 percent were clerical and related; 19.0 percent were non-supervisory scientists and engineers; and 16.3 percent were executives, administrators and other professional personnel including supervisory scientists and engineers.

Earnings

An analysis of average earnings of 40 AEC cost-type contractor employees over a 5-year period shows that average hourly rates for production and related workers have increased at a rate of 2.4 percent per year, and for clerical and related workers at a rate of 2.5 percent per year. Data on salaried employees who are exempt from the over-

TABLE 1.—COMPARISON OF EMPLOYMENT BY OCCUPATION

	March 1965	March 1966	Actual change	Percent change
Government-Owned Establishments:				
Engineers	13, 528	12, 933	−595	−4. 4
Scientists	9, 755	9, 514	−241	−2. 5
Technicians	16, 543	16, 141	−402	−2. 4
All Other	68, 769	62, 789	−5, 980	−8. 7
Total	108, 595	101, 377	−7, 218	−6. 6
Privately Owned Establishments:				
Engineers	6, 764	6, 522	−242	−3. 6
Scientists	1, 977	1, 972	−5	−0. 3
Technicians	6, 405	6, 428	+23	+0. 4
All Other	17, 352	16, 331	−1, 021	−5. 9
Total	32, 498	31, 253	−1, 245	−3. 8
Total All Establishments	141, 093	132, 630	−8, 463	−6. 0
Scientists & Engineers In Research & Development Work At Government-Owned Establishments	16, 760	16, 457	−303	−1. 8
Scientists & Engineers In Research & Development Work At Privately Owned Establishments	4, 626	4, 765	+139	+3. 0

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time provisions of the Fair Labor Standards Act are available only for a three-year period. Base earnings for scientists and engineers have increased an average of 4.0 percent per year and all other professional employees 4.9 percent per year over the three years.

Fringe Benefits

During the year, the AEC expanded its study of contractor expenditures for suplementary compensation to include contractor payments for "white collar" employees. A modified BLS form was used to collect the data of the total employees covered in the survey—40 percent were production and related (blue collar) employees, and 60 percent were office clerical, executives, administrators, scientists, engineers, and other non-manual (white collar) personnel. The survey shows that:

(*1*) Fringe benefit expenditures for blue collar and white collar employees combined amounted to 24.4 percent of total gross payroll or 97.1 cents per payroll hour.

(*2*) Expenditures for blue collar workers averaged 27.2 percent of gross payroll or 84.2 cents per payroll hour and for white collar employees, the costs averaged 23.1 percent of gross pay or 106.3 cents per hour.

(*3*) Included in these expenditures are payments made directly to employees such as paid leave for vacations, holidays, sick leave, etc., overtime work or shift differentials, and nonproduction bonuses and severance pay. Such payments represented 16.8 percent of gross pay for blue collar workers and 13.4 percent for white collar workers.

(*4*) Payments in addition to the payroll include life and health benefit insurance, pension and retirement plans and insurance payments required by law (*i.e.*, unemployment compensation, social security, and workmen's compensation). These payments averaged 10.4 percent of total gross payroll for blue collar and 9.7 percent for white collar.

Survey of Scientific Salaries

In November 1966, Battelle Memorial Institute (BMI) of Columbus, Ohio, was awarded a contract for the design of a new survey of compensation paid to scientific and engineering personnel engaged in research and development in the United States. The survey will utilize the maturity or "age-wage" approach under which salary data are related to years since receipt of degree, chronological age, etc. It is planned that the survey will replace the National Survey of Profes-

sional Scientific Salaries conducted by the Los Alamos Scientific Laboratory.

In the design phase, which is estimated to take about 12 months, BMI will place particular emphasis on assuring that the survey sample accurately represents the universe to be measured. The actual conduct of the survey will be dependent upon AEC acceptance of the design. Assuming such acceptance and Bureau of the Budget (BOB) approval under the Federal Reports Act, earliest the new survey could be conducted would be during calendar year 1968. Currently being considered, is the need for achieving an orderly transition from the LASL survey to the new one.

Because of direct interest in this project, the Department of Defense, National Aeronautics and Space Administration, and AEC will share equally the cost of this design and the conduct of the first survey.

COLLECTIVE BARGAINING

The 40 cost-type AEC contractors employed 67,000 non-exempt employees (excluding construction) in November 1966. About 43 percent of these employees are represented by labor unions as follows:

Union organization	Approximate representation	Percent
Metal Trades Council (AFL–CIO)	9, 740	33. 8
International Association of Machinists (AFL–CIO)	5, 985	20. 8
Oil, Chemical & Atomic Workers International Union (AFL–CIO)	3, 345	11. 6
Office Employees International Union (AFL–CIO)	1, 735	6. 0
Misc. Unions (excluding Guards)	6, 475	22. 5
Misc. Guards Unions (IND)	1, 505	5. 2
	28, 785	99. 9

Contract Renewals and Work Stoppages

As of November 1, 1966, 39 organized units had completed negotiations involving labor contract renewals or reopening provisions. Twenty-five of these contracts were negotiated without work stoppage. The work stoppages resulting in the major portion of the 1,448,637 man-hours lost were:

(1) A strike at the Nevada Test Site over renewal terms for construction labor contracts between the Electricians and Pipefitters unions and Reynolds Electrical and Engineering Co. and Catalytic Construction Co. resulted in 324,159 man-hours of lost time.

(*2*) A dispute over daily travel allowance on construction work at the National Reactor Testing Station, Idaho, caused a strike which affected several projects and resulted in a loss of 264,332 man-hours.

(*3*) In June, the Hanford (Wash.) Atomic Metal Trades Council (HAMTC) called a strike against Battelle Memorial Institute — contract-operator of the Pacific Northwest Laboratory — in which some 152,000 man-hours were lost over an issue of union security under a reopening provision of the contract.

(*4*) In July, the HAMTC began a strike against ITT Federal Support Services, Inc., following the contractor's takeover of a portion of General Electric's operations. Employees of Douglas United Nuclear, Isochem, and General Electric also participated in the strike which arose over wage rate inequities. Total time lost amounted to 491,440 man-hours.

(*5*) The Fernald Atomic Trades and Labor Council went on strike September 30, after the union membership failed to ratify the agreement previously worked out by their bargaining committee on contract renewal terms. The renegotiated contract was ratified on October 21 and work resumed on October 24.

EMPLOYMENT OPPORTUNITY

The AEC and its major contractors continued to broaden the employment opportunities in the nuclear energy field. AEC instituted a strengthened equal employment opportunity effort, within the framework of the AEC merit system, which calls for imaginative affirmative planning and continuing appraisal of results. During FY 1966 the percentage of Negro employees within AEC increased from 4.3 to 6.3 percent.

Youth Opportunity Program

During the summer, 1,000 young people worked for cost-type contractors at AEC-owned facilities in response to President Johnson's Youth Opportunity Campaign. In the summer of 1965, when the program was introduced, participants totaled 655. Every effort was made to expose the participants in the program to stimulating work and to lift their employment horizons. They worked as trainees in laboratories, hospitals, libraries, computer units, shops, offices and on construction projects in a wide variety of technical, clerical, administrative, and manual occupations.

About one-fourth of the 1,000 were members of minority groups. High school dropouts accounted for 5 percent; high school students, 8

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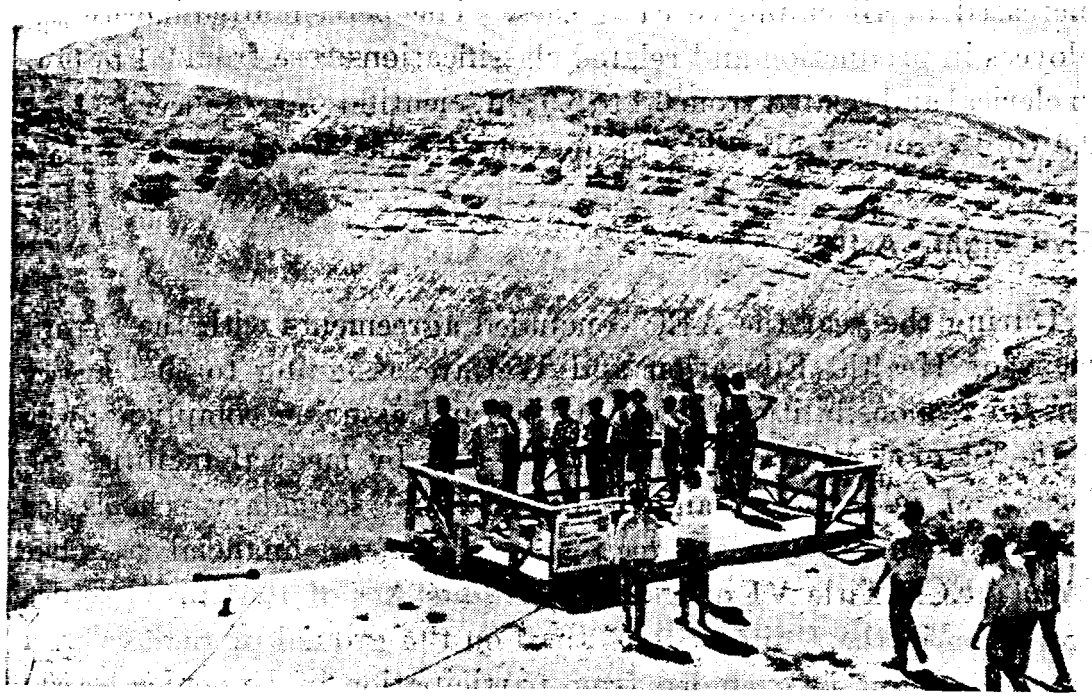
percent; high school graduates, 36 percent; and college students, 51 percent. Many of these would have been unable to continue their education without the employment offered through this program.

During the summer, the AEC employed at its Headquarters and Field Offices, 190 youths in accordance with President Johnson's Youth Opportunity Program. Over 50 percent (108 of the 190) of these employees were members of minority groups.

Summer Intern Program

As a part of its continuing effort to obtain well-qualified candidates for direct employment, the AEC instituted a "summer intern program" during 1966 for students who have completed 3 years of college; one purpose was to attract and encourage competition for the AEC regular intern and trainee programs. Although the first year's effort was modest in number (64), it brought forth a gratifying response from minority group students.



Historic Plowshare Site. During 1966, a viewing stand was constructed on the edge of the Project Sedan crater at the Nevada Test Site. Among the first to use it were student summer employees of the AEC's Nevada Operations Office. The youths, ranging in age from 16 to 21, were hired as a part of President Johnson's Youth Opportunity Program. The 1,280-foot wide, 320-foot deep crater was formed on July 6, 1962, by the Plowshare program's first nuclear cratering experiment—a 100-kiloton nuclear detonation fired 635 feet deep in a 36-inch diameter hole in the alluvium soil. The detonation removed 8.42 million tons (6.6 million cubic yards) of dirt in a matter of seconds, showing the feasibility of using nuclear experiments for large-scale earth-moving projects that would take months, or even years, to do by conventional means.

Contractor Equal Employment Opportunity

During the year ending September 30, 1966, the AEC conducted 582 on-site compliance reviews of Government contractor establishments to assure affirmative action compliance with Executive Order 11246, which calls for equal employment opportunity for all employees and applicants for employment. Increased emphasis was given to corporate reviews of multiplant companies, and to stressing the need for top management support and communication to all levels of supervision. A significant advance was the adoption of pre-award equal employment opportunity compliance reviews of prospective recipients of large supply contracts, and their subcontracts. Pre-award equal employment opportunity reviews and compliance reviews of major construction contractors were conducted in selected cases.

In cost-type contractor facilities the percent of Negroes to total employment increased from 2.6 percent to 3.1 percent and all other minority groups from 3.3 percent to 4.3 percent. Minority employment increased in all employee categories. The percent of minority employees in production and related classifications rose from 9.1 to 12.2; in clerical and related from 6.1 to 6.9; in scientific and engineering from 2.3 to 2.5; and in all other professional from 1.3 to 1.6.

Civil Rights Act

During the year the AEC concluded agreements with the Department of Health, Education and Welfare assigning to that agency certain responsibilities for evaluating and assuring compliance with Title VI of the Civil Rights Act of 1964 by medical facilities, colleges and universities, and elementary and secondary schools and school systems, which are recipients of Federal financial assistance from AEC. 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. The assignments are provided for by AEC regulations and follow a plan of coordinated procedures developed by the Department of Justice. At year's end, approximately 6,000 assurances of compliance with Title VI and the AEC Regulation had been received from current and prospective recipients of Federal financial assistance from the AEC.

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RECORDS AND REPORTS SYSTEM FOR RADIATION WORKERS

During 1966, the AEC continued to stress the importance of an adequate record keeping system for radiation workers. The need for adequate records for radiation workers has been well recognized for a number of years and has been an important part of the AEC's health and safety program since the inception of the Manhattan Engineer District. In 1959, the Joint Committee on Atomic Energy (JCAE) of Congress had held hearings on "Employee Radiation Hazards and Workmen's Compensation," looking to the problem of protecting the health and safety of workers employed in the radiation industry, the complex problem of compensation when a worker receives a radiation injury and the causal relationship between the two. One of the important conclusions reached by the JCAE, as stated in its Summary Analysis of the hearings, was that practically universal agreement existed on the need for centralized records of individual exposures in order to know the amount of radiation which an individual had absorbed and also to prevent unnecessary exposure to excessive radiation.

On August 9 and 12, 1966, identical bills were introduced by Congressman Melvin Price of Illinois (H.R. 16920) and Senator John O. Pastore of Rhode Island (S. 3722) to amend the Atomic Energy Act of 1954 to authorize the AEC to provide financial assistance to States participating in a uniform record-keeping system for radiation workers. Hearings were held on August 30 and 31, and September 20–22, before the Joint Committee on Atomic Energy to receive testimony from the AEC, industry, organized labor, U.S. Department of Labor, the medical profession, the insurance industry, the States, and others. The record of the proceedings will be available early in 1967.

PROPOSED SYSTEM

The proposed records and reports system, as initially drafted, contemplated an employer-State-Federal arrangement for the collection and maintenance of four basic categories of personnel data on monitored employees: (*a*) identification of the individual, his work location and duties; (*b*) occupational exposure experience; (*c*) certain administrative data; and (*d*) medical information, if maintained by the employer.

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Central Information Repository Proposed

Under the proposed system, the monitoring requirements would be the same as those specified in AEC regulations for employees of AEC licensees. For exposure to external radiation, these would include primarily those individuals whose exposure is likely to exceed 25 percent of permissible levels under the AEC's criteria (e.g. 1¼ *rems* per quarter or 5 *rems* per year for whole body exposure). In apportioning responsibilities, employers would be required to collect and maintain individual employee data; and the State would audit employer record keeping practices and retain certain individual employee records—for example, in the event an employer goes out of business. The Federal Government would maintain a central repository of accumulated exposure information. In addition, a registry would be kept on individuals otherwise not included in the system who had received high radiation exposure. Announcement of the proposed system was made by news release and in letters disseminated to more than 300 individuals and organizations in April.

As a result of public comment, the proposed system was modified on September 2, 1966, and limited to: (*a*) the recording and reporting of certain identification data, and (*b*) occupational radiation exposure information. Under the modified system, there will be no change in the nature of the State and Federal responsibility. Announcement of the modified system was also made by news release and in letters disseminated to more than 300 individuals and organizations. It is expected that further public comment on the modified system will contribute to the ultimate development of a uniform records and reports system for radiation workers.

RELATED ACTIVITIES

When the Federal-State cooperative program was first announced on December 6, 1965,[3] it identified 11 standards which, if adopted by the States, would materially strengthen workmen's compensation laws for radiation workers. The standards suggested the need for compulsory workmen's compensation laws for the radiation worker, elimination of numerical exemptions for such workers, extra-territoriality, prohibition against waivers, second injury funds, adequate time limits for filing claims, coverage for radiation injury, full coverage of medical expenses and physical rehabilitation, vocational rehabilitation, authority to review medical care and lump sum settlements.

[3] See pp. 49–51, "Annual Report to Congress for 1965."

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Status of State Participation

As of the end of the year, participation by the States in strengthening their workmen's compensation laws was:

(1) Forty-six States have agreed to analyze their workmen's compensation laws to determine their consistency with the 11 suggested standards;

(2) Nineteen States have completed and furnished the AEC with an analysis of their workmen's compensation law; and

(3) Eighteen States are presently conducting the analysis of their workmen's compensation laws.

(4) Eleven States have indicated that they will participate in the study.

In another phase of the program, some 19 States, meeting certain minimum criteria established by the AEC, have been asked to furnish the AEC with copies of reports filed by employers concerning medical expenses or lost time occasioned by occupational radiation exposure, copies of claims filed by employees alleging injury arising from occupational exposure to radiation, and analyses by the States of settled or adjudicated claims involving radiation injury. Of these 19 States,[4] 17 have agreed to participate.

Council of State Governments Action

In August 1966, the Council of State Governments adopted proposed uniform workmen's compensation legislation for radiation injury, incorporating the 11 standards recommended by AEC. The Council urged the State adoption of the standards as vital if radiation workers are to receive adequate workmen's compensation coverage.

Meetings and Symposia

During the year, the AEC staff discussed the proposed records and reports system with a number of groups and organizations. Among others, these included the U.S. Chamber of Commerce, the American Medical Association's Council on Occupational Health, the International Association of Industrial Accident Boards and Commission, the Health Physics Society, and the Atomic Industrial Forum. In addition, regional seminars were sponsored at Oak Ridge, Tenn. ("The Working Man and the Atom") and at San Francisco, Calif. ("Atomic Energy in the West") for the purpose of discussing the Federal-State cooperative program.

[4] Alaska, California, Hawaii, Idaho, Illinois, Indiana, Iowa, Louisiana, Maryland, Michigan, Minnesota, Montana, Nebraska, New Jersey, New York, Puerto Rico, South Dakota, Utah and Washington.

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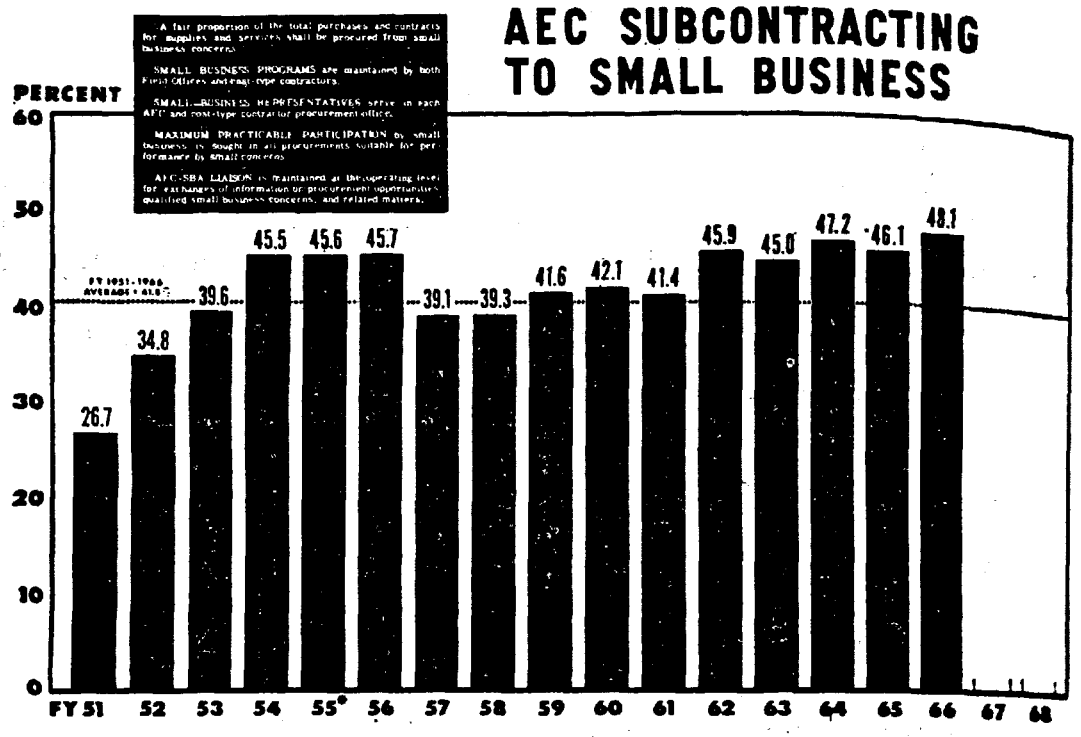
CONTRACTING POLICY

The AEC continues to promote and assist small business participation in its prime contracts and subcontracts. During 1966, for the fifth consecutive year, AEC prime contractors awarded over 45 percent of subcontracts to small business concerns: $312.9 million out of $650.9 or 48.1 percent. The average percentage of subcontract awards to small business during the period 1951–1966 was 41.8 percent. The chart shows, on a percentage basis, the share of AEC subcontracts that has gone to small business during the past 16 years.



BOARD OF CONTRACT APPEALS

During 1966, the Commission made its last two decisions on contract disputes appeals in the *Matter of Metals & Controls Inc.* and the *Matter of Rutherford Construction Co.* These decisions concerned matters still pending before hearing examiners at the time the Commission created the Board of Contract Appeals in November 1964.

During the year, the membership of the Board of Contract Appeals (BCA) was increased to 20, including the Chairman and Vice Chairman (see Appendix 2 for list of members). In addition, the position of Vice Chairman was made a full-time job.

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1966 Appeals Decrease

The Board of Contract Appeals in the past year, received 19 appeals. This represents a modest decrease of one appeal received by the board in 1966 as compared with those received in 1965. Of the 1966 appeals, two were transferred from the Office of the Hearing Examiners to the board, and one was referred to the board by the Commission. Six appeals which were docketed by the board in 1965 remained for disposition at the beginning of 1966; five of these appeals have now been disposed of.

As in 1965, the board has been successful in bringing the parties together for the purpose of resolving their disputes by agreement. The proper utilization of the conference by the Board is in large part responsible for attaining this result. Of the 16 appeals which have been disposed of in 1966, 9 were settled during, or subsequent to, the conference or as a result of a preconference order.

A large proportion of the appeals docketed by the board have involved subcontractors. Of the appeals docketed in 1966, five were direct appeals of subcontractors and six were appeals of prime contractors on behalf of subcontractors. This is a decrease from the preceding year of five direct subcontractor appeals and an increase of four appeals by primes on behalf of subcontractors.

Dispositions Speeded Up

An accelerated procedure which provides for the consideration and disposition of appeals without regard to their normal position on the docket has proved successful in bringing about a speedy resolution of those appeals in which the procedure has been used. The procedure may be used when the amount in dispute does not exceed $10,000 or for other good causes. The average pendency of appeals utilizing this procedure during 1966 was 84 days.

The average pendency of an appeal before the board from the date of docketing to final disposition during 1966 amounted to 101 days. At the end of the calendar year nine appeals were pending before the board.

In order to avoid hardships which administrative proceedings may cause small businesses, the board has made every effort to accommodate small businesses in granting promptly the accelerated procedure and in traveling to the location of the small business for the purpose of holding conferences and hearings. The board, aware of the cost associated with any appeal proceeding, has endeavored to reduce the cost to all appellants and the Government.

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Jurisdiction Enlarged

During 1966, the jurisdiction of the BCA was enlarged to include the conduct of hearings in debarment proceedings. The board has the final authority to decide debarment cases after the holding of a hearing.

A study of the problems involved in transferring to the BCA the authority delegated to the Atomic Energy Commission by the President under Public Law 85–804 has been undertaken. This law permits the President to authorize any department or agency exercising functions in connection with the national defense to take certain contractual actions without regard to other provisions of law. By Executive Order 10789 of November 14, 1958, the AEC was authorized to exercise this authority.

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.[5]

YEAR'S ACTIVITIES

The hearing examiners' principal functions during 1966 were to serve as chairman of atomic safety and licensing boards which adjudicate facility licensing cases under the Atomic Energy Act and the Administrative Procedure Act. Except for one remaining contract dispute appeal (filed prior to establishment of the Board of Contract Appeals) in which a decision was issued in February, the year's work involved only reactor licensing proceedings.

Reactor Hearings

Atomic reactor licensing actions by boards presided over by hearing examiners in 1966 included: (*a*) a supplemental initial decision in the SEFOR case (General Electric Co. and Southwest Atomic Energy Associates); (*b*) a posthearing conference in April and an initial decision in July in the Malibu Nuclear Plant case (Los Angeles

[5] 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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Department of Water and Power); (*c*) a prehearing conference, two days of hearing, and an initial decision in March and April for the Robert Emmet Ginna Power Plant (Rochester Gas and Electric Corp.); (*d*) two days of prehearing conference, two days of hearing, and an initial decision in the Indian Point Station Unit 2 case (Consolidated Edison Co. of New York, Inc.), which at year's end was under review by the Commission in regard to intervention; and (*e*) a prehearing conference, two days of hearing, and an initial decision in the Dresden Nuclear Power Station Unit 3 case (Commonwealth Edison Co.). In each of these proceedings—except for Malibu which was also under review consideration by the Commission—provisional construction permits have been issued. (The above cases are discussed in Chapter 2—Reactor and Other Nuclear Facility.)

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APPENDIX 1

ORGANIZATION AND PRINCIPAL STAFF OF U.S. ATOMIC ENERGY COMMISSION

COMMISSIONERS

Atomic Energy Commission	GLENN T. SEABORG, *Chairman*
	ARNOLD R. FRITSCH, *Special Assistant*
	JAMES T. RAMEY
	JAMES R. YORE, *Special Assistant*
	GERALD F. TAPE
	WILLIAM C. BARTELS, *Technical Assistant*
	WILFRID E. JOHNSON
	GERARD F. HELFRICH, *Technical Assistant*
	SAMUEL M. NABRIT
	JUSTIN L. BLOOM, *Technical Assistant*
Secretary to the Commission	W. B. MCCOOL
Controller	JOHN P. ABBADESSA
General Counsel	JOSEPH F. HENNESSEY
Director, Division of Inspection	CURTIS A. NELSON
Chairman, AEC Board of Contract Appeals	PAUL H. GANTT
Chief Hearing Examiner	SAMUEL W. JENSCH

OPERATING AND PROMOTIONAL FUNCTIONS

General Manager	ROBERT E. HOLLINGSWORTH
Executive Assistant to 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
Deputy General Manager	EDWARD J. BLOCH
Assistant 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, JR.
Director, Office of Congressional Relations	JOHN J. BURKE
Special Assistant for Disarmament	ALLAN M. LABOWITZ

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Assistant General Manager for Operations	JOHN A. ERLEWINE
Director, Office of Economic Impact and Conversion	JOHN C. RYAN
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
Assistant General Manager for Research and Development	SPOFFORD G. ENGLISH
Director, Division of Biology and Medicine	CHARLES L. DUNHAM, M.D.
Director, Division of Isotopes Development	E. 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	HAROLD B. FINGER
Assistant General Manager for International Activities	JOHN A. HALL
Director, Division of International Affairs	MYRON B. KRATZER
Assistant General Manager for Administration	JOHN V. VINCIGUERRA
Director, Division of Classification	C. L. MARSHALL
Director, Division of Headquarters Services	EDWARD H. GLADE
Director, Division of Nuclear Materials Management	DOUGLAS E. GEORGE
Director, Division of Personnel	DONALD E. BOSTOCK
Director, Division of Security	JOHN A. WATERS, JR.
Director, Division of Technical Information	EDWARD J. BRUNENKANT
Director, Division of Military Application	Brig. Gen. DELMAR L. CROWSON USAF
Controller, Office of the Controller	JOHN P. ABBADESSA
General Counsel, Office of the General Counsel	JOSEPH F. HENNESSEY

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Buenos Aires,
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London, Engl
Paris, France
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Managers of Field Offices

Albuquerque (N. Mex.) Operations Office	LAWRENCE P. GISE
Amarillo (Tex.) Area	H. JACK BLACKWELL
Burlington (Iowa) Area	E. W. GILES
Dayton (Miamisburg, Ohio) Area	WILLIS B. CREAMER
Kansas City (Mo.) Area	HENRY A. NOWAK
Los Alamos (N. Mex.) Area	CHARLES C. CAMPBELL
Pinellas (Fla.) Area	WALTER C. YOUNGS, JR.
Rocky Flats (Colo.) Area	SETH R. WOODRUFF, JR.
Sandia (N. Mex.) Area	LADDIE W. OTOSKI
South Albuquerque (N. Mex.) Area	WALTER W. STAGG
Brookhaven (Upton, N.Y.) Office	E. L. VAN HORN
Chicago (Ill.) Operations Office	KENNETH A. DUNBAR
Grand Junction (Colo.) Office	ALLAN E. JONES
Idaho (Idaho Falls) Operations Office	WILLIAM L. GINKEL
Nevada (Las Vegas) Operations Office	JAMES E. REEVES
Honolulu (Hawaii) Area	WILLIAM A. BONNET
New York (N.Y.) Operations Office	WESLEY M. JOHNSON
Health and Safety Laboratory (New York City)	JOHN HARLEY, M.D.
Oak Ridge (Tenn.) Operations Office	S. R. SAPIRIE
Cincinnati (Ohio) Area	CLARENCE L. KARL
New Brunswick (N.J.) Area	C. J. RODDEN
Paducah (Ky.) Area	BERNARD N. STILLER
Portsmouth (Ohio) Area	ROY V. ANDERSON
Puerto Rico (San Juan) Area	J. PERRY MORGAN
St. Louis (Mo.) Area	FRED H. BELCHER
Pittsburgh (Pa.) Naval Reactors Office	LAWTON D. GEIGER
Richland (Wash.) Operations Office	DONALD G. WILLIAMS
San Francisco (Calif.) Operations Office	ELLISON C. SHUTE
Canoga Park (Calif.) Area	JOEL V. LEVY
Palo Alto (Calif.) Area	LAWRENCE G. MOHR
Savannah River (Aiken, S.C.) Operations Office	NATHANIEL STETSON
Schenectady (N.Y.) Naval Reactors Office	STANLEY W. NITZMAN

AEC Scientific Representatives Abroad

Brussels, Belgium	DIXON B. HOYLE, *Senior Representative*
Buenos Aires, Argentina	(Vacant)
Chalk River, Ontario, Canada	MILLER N. HUDSON, JR.
London, England	CARL R. MALMSTROM
Paris, France	(Vacant)
Tokyo, Japan	WHITTIE J. MCCOOL

LICENSING AND REGULATORY FUNCTIONS

Director of Regulation	HAROLD L. PRICE
Deputy Director	CLIFFORD K. BECK
Assistant Director for Nuclear Safety	M. M. MANN

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Assistant Director for Administration	C. L. HENDERSON
Director, Division of Compliance	LAWRENCE D. LOW
Director, Division of Reactor Licensing	PETER A. MORRIS
Director, Division of Safety Standards	FORREST WESTERN
Director, Division of Materials Licensing	JOHN A. MCBRIDE
Director, Division of States and Licensee Relations	EBER R. PRICE

Directors of Compliance Field Organizations

Region I (New York)	ROBERT W. KIRKMAN
Region II (Atlanta)	JOHN G. DAVIS
Region III (Chicago)	ROY C. HAGEMAN
Region IV (Denver)	DONALD I. WALKER
Region V (San Francisco)	RICHARD W. SMITH

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APPENDIX 2

MEMBERSHIP OF COMMITTEES DURING 1966

STATUTORY COMMITTEES AND BOARDS

Joint Committee on Atomic Energy—89th Congress (Second 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 1966, the Committee was composed of:

Representative CHET HOLIFIELD (California), *Chairman.*[1]
Senator JOHN O. PASTORE (Rhode Island), *Vice Chairman.*
Senator RICHARD B. RUSSELL (Georgia).
Senator CLINTON P. ANDERSON (New Mexico).
Senator ALBERT GORE (Tennessee).
Senator HENRY M. JACKSON (Washington).
Senator BOURKE B. HICKENLOOPER (Iowa).
Senator GEORGE D. AIKEN (Vermont).
Senator WALLACE F. BENNETT (Utah).
Senator CARL T. CURTIS (Nebraska).
Representative MELVIN PRICE (Illinois).
Representative WAYNE N. ASPINALL (Colorado).
Representative JOHN YOUNG (Texas).
Representative THOMAS G. MORRIS (New Mexico).
Representative CRAIG HOSMER (California).
Representative WILLIAM H. BATES (Massachusetts).
Representative JOHN B. ANDERSON (Illinois).
Representative WILLIAM M. MCCULLOCH (Ohio).
JOHN T. CONWAY, *Executive Director.*

Military Liaison Committee

Under Section 27 of the Atomic Energy Act of 1954, "there is hereby established a Military Liaison Committee consisting of (*a*) a Chairman, who shall be the head thereof and who shall be appointed by the President, by and with the advice and consent of the Senate, who shall serve at the pleasure of the President; and (*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

[1] Under Section 203 of the Atomic Energy Act of 1954, as amended, the Chairmanship alternates between the Senate and the House with each Congress; it is expected that Senator Pastore will be the Chairman and Representative Holifield the Vice Chairman during the 90th Congress.

Defense, to be assigned from each Department by the Secretary thereof, and who will serve without additional compensation.

"The Chairman of the Committee may designate one of the members of the Committee as Acting Chairman to act during his absence. The Commission shall advise and consult with the Department of Defense, through the Committee, on all atomic energy matters which the Department of Defense deems to relate to military applications of atomic weapons or atomic energy including the development, manufacture, use and storage of atomic weapons; the allocation of special nuclear material for military research, and the control of information relating to the manufacture or utilization of atomic weapons; and shall keep the Department of Defense, through the Committee, fully and currently informed of all such matters before the Commission. The Department of Defense, through the Committee shall keep the Commission fully and currently informed on all matters within the Department of Defense which the Commission deems to relate to the development or application of atomic energy. The Department of Defense through the Committee, shall have the authority to make written recommendations to the Commission from time to time on matters relating to military applications of atomic energy as the Department of Defense may deem appropriate. If the Department of Defense at any time concludes that any request, action, proposed action, or failure to act on the part of the Commission is adverse to the responsibilities of the Department of Defense, the Secretary of Defense shall refer the matter to the President whose decision shall be final."

Hon. CARL WALSKE, *Chairman.*
Maj. Gen. LUCIUS D. CLAY, Jr., United States Air Force.
Brig. Gen. KENNETH F. DAWALT, United States Army.
RAdm. FRANCIS D. FOLEY, United States Navy.
Maj. Gen. OTTO J. GLASSER, United States Air Force.
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.

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HOWARD G. VESPER, 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 held four meetings in 1966, on February 2–4, April 28–30, July 12–14, and November 2–4.

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, Code, Grindle & Watson, Washington, D.C.

DOUGLAS MCLEOD COOMBS, Simmonds Precision Products, Inc., Tarrytown, N.Y.

MALCOLM W. FRASER, law firm of Fraser, Wilson, and Fraser, Toledo, Ohio.

HERMAN I. HERSH, firm of McDougall, Hersh, Scott, and Ladd, Chicago, Ill.

LAWRENCE C. KINGSLAND, firm of Kingsland, Rogers, Ezell, Eilers & Robbins, St. Louis, Mo.

During 1966, the Board met on March 15.

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 existing reactor facilities and the adequacy of proposed reactor safety standards, and performs such other duties as the Commission may request. The Committee's reports on applications for facility licenses become a part of the record of the application and available to the public, except for security material. Members are appointed by the Commission for a term of four years each, and one member is designated by the Committee as its chairman. This Committee was established as a statutory body in 1957.

Dr. DAVID OKRENT, *Chairman;* Senior Physicist, Laboratory Director's Office, Argonne National Laboratory, Argonne, Ill.

NUNZIO J. PALLADINO, *Vice Chairman;* Dean, College of Engineering, The Pennsylvania State University, University Park, Pa.

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, U.S. Weather Bureau, Oak Ridge, Tenn.

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Dr. STEPHEN H. HANAUER, Professor of Nuclear Engineering, University of Tennessee, Knoxville, Tenn.

Dr. JOSEPH M. HENDRIE, Physicist, Brookhaven National Laboratory, Upton, N.Y.

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. WILLIAM R. STRATTON, Physicist, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. CARROLL W. ZABEL, Associate Dean of Arts and Sciences, University of Houston, Houston, Tex.

R. F. FRALEY, *Executive Secretary;* U.S. Atomic Energy Commission, Washington, D.C.

During 1966, the Committee met 14 times, on January 6–8, February 10–12, March 10–12, April 4–6, May 5–7, June 9–11, July 14–16, August 4–5, August 11–13, September 8–10, October 6–8, November 10–12, December 2–3, and December 8–10.

Atomic Safety and Licensing Board Panel

Section 191 of the Atomic Energy Act of 1954 authorizes, in addition to other matters, the Commission to establish one or more atomic safety and licensing boards, each to be composed of three members, two of whom are to be technically qualified and one of whom is to be qualified in the conduct of administrative proceedings. Technically qualified alternates may be appointed to atomic safety and licensing boards, to serve in the event that a 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 panel to serve on atomic safety and licensing boards as assigned.

ALGIE A. WELLS, *Panel Chairman,** U.S. Atomic Energy Commission, Washington, D.C.

J. D. BOND, Hearing Examiner, U.S. Atomic Energy Commission, Washington, D.C.

R. B. BRIGGS, Director, Molten Salt Program, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. JOHN HENRY BUCK, Vice President and General Manager, Tatnall Measuring Systems and Nuclear Systems Divisions, The Budd Co., Philadelphia, Pa.

Dr. A. DIXON CALLIHAN, Oak Ridge National Laboratory, Oak Ridge, Tenn.

VALENTINE B. DEALE, Washington, D.C.

Dr. MILTON C. EDLUND, University of Michigan, Ann Arbor, Mich.

Dr. STUART GORDON FORBES, Manager, Electric Propulsion Department, Space Technology Laboratories, TRW Systems, Redondo Beach, Calif.

Dr. JOHN C. GEYER, Chairman, Department of Sanitary Engineering and Water Resources, The Johns Hopkins University, Baltimore, Md.

Dr. CLARK D. GOODMAN, Professor of Physics, and Department Chairman, University of Houston, Houston, Tex.

*Mr. Wells is expected to assume the new Panel Chairman position in April 1967 when he terminates his present assignment as Deputy Director General for Administration, Liaison, and Secretariat of the International Atomic Energy, Vienna, Austria.

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Dr. EUGENE GREULING, Professor of Physics, Duke University, Durham, N.C.

Dr. JOHN P. HOWE, Ford Professor of Engineering, Nuclear Reactor Laboratory, Department of Engineering Physics, Cornell University College of Engineering, Ithaca, N.Y.

Dr. DAVID B. HALL, Staff Member and K Division Leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

SAMUEL W. JENSCH, Chief Hearing Examiner, U.S. Atomic Energy Commission, Washington, D.C.

ARTHUR W. MURPHY, Columbia University School of Law, New York, N.Y.

WARREN E. NYER, Assist. Manager, Nuclear Safety Technology, Atomic Energy Division, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. HUGH PAXTON, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. THOMAS H. PIGFORD, Professor of Engineering, University of California, Berkeley, Calif.

Dr. LAWRENCE R. QUARLES, Dean, School of Engineering and Applied Science, University of Virgina, Charlottesville, Va.

REUEL C. STRATTON, Consulting Engineer, Hartford, Conn.

Dr. CLARKE WILLIAMS, Deputy Director, Brookhaven National Laboratory, Upton, 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.

Six new boards were drawn from the panel in 1966 for regulatory proceedings.

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.

WILLIAM T. BARNES, Certified Public Accountant, Lybrand, Ross Bros. & Montgomery, 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.

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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.

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.

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, Georgetown University Law Center, Washington, D.C.

During 1966, the full Board met once, on March 4. Appeals before the Board are handled by one- or three-member panels. Numerous panel meetings were held by the panel members designated to hear, consider, and decide appeals.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Atomic Energy Labor-Management Advisory Committee

This Committee was established in March 1962 for the purpose of bringing together representatives of organized labor with representatives of management and the AEC to discuss general problems, procedures, and requirements in connection with the radiological aspects of industrial safety. Its charter was expanded in 1963 to permit consideration of questions other than those concerned with the radiological aspects of industrial safety.

H. T. HERRICK, *Chairman;* Director, Division of Labor Relations, U.S. Atomic Energy Commission, Washington, D.C.

C. L. HENDERSON, *Vice Chairman;* Assistant Director of Regulation for Administration, U.S. Atomic Energy Commission, Washington, D.C.

ANDREW J. BIEMILLER, Director, Department of Legislation, AFL–CIO, Washington, D.C.

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, President, International Brotherhood of Electrical Workers, Washington, D.C.

CHARLES D. HARRINGTON, President, Douglas United Nuclear, Inc., Richland, Wash.

HOWARD K. NASON, President, Monsanto Research Corp., St. Louis, Mo.

P. L. SIEMILLER, Retired as President, International Association of Machinists and Aerospace Workers, Washington, D.C.

PETER T. SCHOEMANN, President, United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry, Washington, D.C.

ELWOOD D. SWISHER, Vice President, Oil, Chemical and Atomic Workers International Union, Denver, Colo.

The Committee met on January 13, May 19, and October 6 during 1966.

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Advisory Committe

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Historical Advisory

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Advisory Committee for Biology and Medicine

The Advisory Committee for Biology and Medicine was created in September 1947 at 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 Atomic Energy Project, University of Rochester, Rochester, N.Y.

Dr. ROBERT D. MOSELEY, Jr., Chairman of Department of Radiology, University of Chicago, Chicago, Ill.

Dr. LELAND C. MCGEE, Medical Director, Hercules, Inc., Wilmington, Del.

Dr. MORELL B. RUSSELL, Director, Agricultural Experiment Station, University of Illinois, Urbana, Ill.

Dr. HARVEY M. PATT, *Scientific Secretary;* Director, Laboratory of Radiobiology, San Francisco Medical Center, University of California, San Francisco, Calif.

ROSEMARY ELMO, *Executive Secretary;* U.S. Atomic Energy Commission, Washington, D.C.

The Committee met five times during 1966, January 13–15, March 10–12, May 13–14, September 9–10, and November 11–12.

Historical Advisory Committee

The Historical Advisory Committee was established by the Commission in February 1958 to advise the Commission and its historical staff on matters relating to the preparation of the history of the Atomic Energy Commission.

Dr. JAMES P. BAXTER, III, *Chairman;* President Emeritus, Williams College, Williamstown, Mass.

Dr. JAMES L. CATE, Professor of History, University of Chicago, Chicago, Ill.

Dr. CONSTANCE MCL. GREEN, Washington, D.C.

Dr. RALPH W. HIDY, Professor of Business History, Graduate School of Business Administration, Harvard University, Cambridge, Mass.

Dr. GEORGE E. MOWRY, Professor of History and Dean, Department of Social Sciences, University of California, Los Angeles, Calif.

Dr. ISADORE PERLMAN, Associate Director, Lawrence Radiation Laboratory, Berkeley, Calif.

Dr. DON K. PRICE, Jr., Dean, Graduate School of Public Administration, Harvard University, Cambridge, Mass.

Dr. ROBERT R. WILSON, Director, Laboratory of Nuclear Studies, Cornell University, Ithaca, N.Y.

Dr. RICHARD G. HEWLETT, AEC representative, Chief Historian, U.S. Atomic Energy Commission, Washington, D.C.

The Committee did not meet during 1966.

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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, Associate Director of Research, Ethicon, Inc., a Division of Johnson & Johnson Co., Somerville, N.J.

Dr. JOHN C. BRANTLEY, President, Nuclear Science and Engineering Corp., Pittsburgh, Pa.

H. ROY CHOPE, Executive Vice-President, Industrial Nucleonics Corp., Columbus, Ohio

Dr. WILLARD P. CONNER, Technical Assistant to the Director, Hercules Research Center, Hercules Powder Co., Wilmington, Del.

Dr. DAVID E. HARMER, Head, Radiation Chemistry Section, Nuclear & Basic 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.

E. ROBERT KINNEY, President, Gorton Corp., Gloucester, Mass.

HOWARD K. NASON, President, Monsanto Research Corp., St. Louis, Mo.

Dr. DONALD W. PRITCHARD, Chairman of Department of Oceanography, Johns Hopkins University, Baltimore, Md.

Dr. LEONARD REIFFEL, Instructional Dynamics, Inc., Chicago, Ill.

Dr. RODMAN A. SHARP, President, Sharp Laboratories Div., Beckman Instruments, Inc., La Jolla, Calif.

Dr. NATHAN W. SNYDER, Professor of Nuclear Engineering, Georgia Institute of Technology, Atlanta, Ga.

Dr. VIVIAN T. STANNETT, Associate Director, Camile Dreyfus Lab., Research Triangle Institute, Durham, N.C.

Dr. PAUL M. STIER, Program Manager—Corporation Research, Union Carbide Corp., Tarrytown, N.Y.

Dr. ERNST STUHLINGER, Army Ballistic Missile Agency, Marshall Space Flight Center, NASA, Huntsville, Ala.

DAVID E. TRUMBULL, Manager—Planning Projects, Atomic Products Division, General Electric Co., San Jose, Calif.

The Committee met twice in 1966, on March 3–4 and October 6–7.

Advisory Committee on Medical Uses of Isotopes

The Committee was established in 1958 and replaced the Subcommittee on Human Applications of the Advisory Committee on Isotope Distribution. The Committee will advise the Commission on policies and standards for the regulation and licensing of medical uses of radioisotopes in humans.

Dr. JOHN A. MCBRIDE, *Chairman;* Director, Division of Materials Licensing, U.S. Atomic Energy Commission, Washington, D.C.

Dr. WALLACE D. ARMSTRONG, Professor of Physiological Chemistry, Department of Biochemistry, University of Minnesota Medical Center, Minneapolis, Minn.

Dr. JOHN E. CHRISTIAN, Head, Bionucleonics, Purdue University, Lafayette, Ind.

Dr. REYNOLD F. BROWN, Department of Radiology, University of California Medical School, San Francisco, Calif.

Dr. JOHN A. D. COOPER, Dean of Sciences, Northwestern University, Chicago, Ill.

Dr. ROBERT H. GREENLAW, Associate Professor of Radiology, University of Kentucky, Lexington, Ky.

Dr. E. RICHARD KING, Professor of Radiology, Medical College of Virginia, Richmond, Va.

Dr. GEORGE V. LEROY, Medical Director, Metropolitan Hospital, Detroit, Mich.

Dr. RULON W. RAWSON, Attending Physician and Chairman, Memorial Hospital, New York, N.Y.

Dr. HARALD ROSSI, Professor of Radiology, College of Physicians and Surgeons, Columbia University, New York, N.Y.

Dr. ROBERT J. SHALEK, Associate Physicist, University of Texas, M. D. Anderson Hospital and Tumor Institute, Houston, Tex.

The Committee met once during 1966, on January 15.

Technical Advisory Panel on Peaceful Use Safeguards

This Panel was established by the Commission during 1965 to advise the AEC on technical matters relating to safeguards for providing assurance of the peaceful uses of nuclear materials and equipment including: development of safeguard procedures, implementation of safeguard procedures, and research and development in safeguards.

MYRON B. KRATZER, *Chairman;* Director, Division of International Affairs, U.S. Atomic Energy Commission, Washington, D.C.

FLOYD L. CULLER, Jr., Assistant Director, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. WILLIAM E. DEAL, Jr., Assistant GMX Division Leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

WENDALL P. JOHNSON, Plant Superintendent, Yankee Atomic Electric Co., Rowe, Mass.

JOHN W. LANDIS, General Manager, Washington Operations, The Babcock & Wilcox Co., Washington, D.C.

Dr. HORACE W. NORTON, III, Professor of Statistical Design and Analysis, University of Illinois, Urbana, Ill.

Dr. BERNARD I SPINRAD, Director, Reactor Engineering Division, Argonne National Laboratory, Argonne, Ill.

Dr. EVERETT B. SHELDON, Superintendent, Separations Technology Section, Savannah River Plant, Aiken, S.C.

WILBER A. STRAUSER, *Secretary;* Assistant Director for Safeguards, Division of International Affairs, U.S. Atomic Energy Commission, Washington, D.C.

The Panel met three times in 1966, January 24–25, March 29, and November 14–15.

Plowshare Advisory Committee

The Plowshare Advisory Committee was established in September 1959. The Committee's function is to advise the Commission and the General Manager on selecting and carrying out particular Plowshare projects; developing and making

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available various applications of Plowshare, and determining the general orientation and policies of the Plowshare program.

Dr. SPOFFORD G. ENGLISH, *Chairman;* Assistant General Manager for Research and Development, U.S. Atomic Energy Commission, Washington, D.C.

WILLARD BASCOM, President, Ocean Science & Engineering, Inc., Washington, D.C.

Lt. Gen. JAMES H. DOOLITTLE, USA (ret.), Consultant, Los Angeles, Calif.

Dr. HYMER L. FRIEDELL, Professor of Radiobiology, Western Reserve University, Cleveland, Ohio.

Dr. LOUIS H. HEMPELMANN, Professor, Experimental Radiology, Strong Memorial Hospital, University of Rochester, Rochester, N.Y.

Dr. RICHARD LATTER, Research Council, The RAND Corp., Santa Monica, Calif.

Dr. WILLARD F. LIBBY, Director, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, Calif.

Dr. DONALD H. MCLAUGHLIN, Chairman of the Board, Homestake Mining Co., San Francisco, Calif.

Dr. PHILIP C. RUTLEDGE, Partner, Mueser, Rutledge, Wentworth & Johnston, New York, N.Y.

Dr. PAUL B. SEARS, Professor Emeritus and former Chairman, Conservation Program, Yale University, New Haven, Conn.

Lt. Gen. ALFRED D. STARBIRD, USA, Director, Defense Communications Agency, Arlington, Va.

The Committee met once during 1966, November 1–20.

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. MARK NELKIN, Professor, Nuclear Reactor Laboratory, Cornell University, Ithaca, N.Y.

Dr. LOTHAR W. NORDHEIM, Chairman, Theoretical Physics Department, General Atomic, San Diego, Calif.

Dr. THOMA M. SNYDER, Manager, Physics, Atomic Power Equipment Dept., Vallecitos Atomic Laboratory, General Electric Co., Pleasanton, Calif.

Dr. ALVIN RADKOWSKY, *Secretary;* Division of Naval Reactors, U.S. Atomic Energy Commission, Washington, D.C.

The Committee met three times during 1966: on February 10–11 at San Diego; April 28–29 at Washington; and December 5–6 at Brookhaven National Laboratory.

Advisory Committee for Standard Reference Materials and Methods of Measurement

The Committee was originally established by the Commission in March 1956, as the Committee for Uranium Isotopic Standards. The Commission approved its reconstitution in January 1958, under its present title, to reflect the broadened scope of its activities. The Committee reviews, evaluates, and recommends means for providing standard reference materials (*i.e.*, certified chemical and isotopic standards for uranium, plutonium, etc.) and approved methods of measurement for materials of special importance to atomic energy activities.

Dr. SAMUEL C. T. MCDOWELL, *Chairman;* Assistant Director for Control, Division of Nuclear Materials Management, U.S. Atomic Energy Commission, Washington, D.C.

JOHN L. HAGUE, Chief, Inorganic Standards, Office of Standard Reference Materials, U.S. National Bureau of Standards, Washington, D.C.

Dr. CHARLES F. METZ, Group Leader, Chemical and Instrumental Analysis, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. HORACE W. NORTON, III, Professor of Statistical Design and Analysis, University of Illinois, Urbana, Ill.

Dr. LEONARD P. PEPKOWITZ, Vice President, Nuclear Materials & Equipment Corp., Apollo, Pa.

C. J. RODDEN, Area Manager, New Brunswick Area Office, U.S. Atomic Energy Commission, New Brunswick, N.J.

CHARLES M. STEVENS, Associate Physicist, Chemistry Division, Argonne National Laboratory, Argonne, Ill.

C. D. W. THORNTON, Technical Director, North America, International Telephone & Telegraph Corp., New York, N.Y.

Dr. J. ERNEST WILKINS, Assistant Chairman, Theoretical Physics Department, General Atomic, San Diego, Calif.

RALPH J. JONES, Secretary, Chief, Technical Branch, Division of Nuclear Materials Management, U.S. Atomic Energy Commission, Washington, D.C.

The Committee met twice in 1966, March 2–3 and December 9.

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.

Dr. ALBERT E. HEUSTIS, State Health Commissioner, Michigan Department of Health, Lansing, Mich.

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 1966.

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.

Dr. HOYLANDE YOUNG FAILEY, Chicago, Ill.

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.

NORMAN H. JACOBSON, Technical Publishing Co., Barrington, Ill.

JOHN W. LANDIS, General Manager, Washington Operations, The Babcock & Wilcox Co., Washington, D.C., representing American Nuclear Society, Chicago, Ill.

FRED P. PETERS, Vice President, Reinhold Publishing Co., New York, N.Y.

KARL T. SCHWARTZWALDER, Director of Research, A–C Spark Plug Division, General Motors Corp., Flint, Mich., representing the American Ceramic Society, Inc., Columbus, Ohio.

OLIVER H. TOWNSEND, Director, New York State Office of Atomic Development, New York, N.Y.

JOHN W. WIGHT, Vice President, McGraw-Hill Book Co., Inc., New York, N.Y.

The Committee met once, during 1966 on November 21–22.

Committee of Senior Reviewers

The Committee of Senior Reviewers studies the major technical activities of the Atomic Energy Commission program and advises the Commission on classification and declassification matters, making recommendations with respect to the rules and guides for the control of scientific and technical information. The Committee consists of eight members each of whom is appointed for a 1-year term.

Dr. WARREN C. JOHNSON, *Chairman;* Vice President, Special Scientific Programs, University of Chicago, Chicago, Ill.

Dr. EUGENE EYSTER, Alternate GMX Division Leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. A. C. HAUSSMANN, A Division Leader, Lawrence Radiation Laboratory, Livermore, Calif.

Dr. JOHN P. HOWE, Professor of Engineering, Cornell University, Ithaca, N.Y.

Dr. FRANK C. HOYT, Missiles Systems Division, Lockheed Aircraft Corp., Palo Alto, Calif.

Dr. J. REGINALD RICHARDSON, Professor of Physics, University of California at Los Angeles, Calif.

Dr. JESSE W. BEAMS, Professor of Physics, University of Virginia, Charlottesville, Va.

ROBERT W. HENDERSON, Vice President, Sandia Corp., Albuquerque, N. Mex.

The Committee met 9 times during 1966, on April 25–27, May 15–17, June 1–3, June 13–15, August 15–17, September 19–21, October 31–November 2, November 28–30, and December 20.

Mathematics and Computer Sciences Research Advisory Committee

The Mathematics and Computer Sciences Research Advisory Committee was established in 1960 as an advisory board to the Division of Research of the AEC to make recommendations on computer research and development programs and provide advice and guidance on problems in this field.

Dr. JOHN R. PASTA, *Chairman;* Digital Computer Laboratory, University of Illinois, Urbana, Ill.

SAMUEL N. ALEXANDER, Senior Research Fellow, National Bureau of Standards, Washington, D.C.

Prof. FREDERICK P. BROOKS, Department of Information Science, University of North Carolina, Chapel Hill, N.C.

Dr. SIDNEY FERNBACH, Computation Division, Lawrence Radiation Laboratory, Livermore, Calif.

Dr. ALSTON S. HOUSEHOLDER, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. MARIO L. JUNCOSA, The Rand Corp., Santa Monica, Calif.

Dr. YOSHIO SHIMAMOTO, Brookhaven National Laboratory, Upton, N.Y.

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Dr. JAMES J. STOKER, Courant Institute of Mathematical Sciences, New York University, New York, N.Y.

Dr. CHARLES V. L. SMITH, Mathematics and Computers Branch, Physics and Mathematics Programs, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.

Dr. WILLIAM F. MILLER, *Secretary;* Stanford Linear Accelerator Center, Stanford University, Palo Alto, Calif.

The Committee met twice in 1966, on May 4 and September 30.

Nuclear Cross Sections Advisory Group

This Group, appointed on a yearly basis, provides consultation and guidance for the Commission's program of nuclear cross-section measurements. Information from this program is of fundamental importance to many activities of the AEC.

Dr. ALAN B. SMITH, *Chairman*; Argonne National Laboratory, Argonne, Ill.

Prof. HERBERT GOLDSTEIN, Columbia University, New York, N.Y.

DON R. HARRIS, Bettis Atomic Power Laboratory, Pittsburgh, Pa.

Dr. WILLIAM H. KOCH, U.S. National Bureau of Standards, Washington, D.C.

Dr. MICHAEL S. MOORE, Idaho Nuclear Corp., Idaho Falls, Idaho.

Prof. HENRY W. NEWSON, Department of Physics, Duke University, Durham, N.C.

HARRY PALEVSKY, Brookhaven National Laboratory, Upton, N.Y.

Prof. GERALD C. PHILLIPS, Department of Physics, Rice University, Houston, Tex.

Dr. GEORGE L. ROGOSA, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.

Dr. EUGENE HADDAD, Division of Research, U.S. Atomic Energy Commission, Washington, D.C. (*Alternate*)

Prof. EDWIN F. SHRADER, Case Institute of Technology, Cleveland, Ohio.

Dr. PAUL H. STELSON, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. N. F. WIKNER, Defense Atomic Support Agency, U.S. 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. HENRY MOTZ, *Secretary;* Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Ex-Officio Members:

Dr. RICHARD F. TASCHEK, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. GEORGE A. KOLSTAD, Division of Research, U.S. Atomic Energy Commission, Washington, D.C.

Prof. WILLIAM W. HAVENS, Jr., Department of Physics, Columbia University, New York, N.Y.

Official Observers:

CHARLES M. GOTTSCHALK, Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C.

MURREY D. GOLDBERG, Brookhaven National Laboratory, Upton, N.Y.

The Committee met twice in 1966, on March 25–26 and November 10–11.

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Personnel Security Review Board

This Board was appointed in March 1949 primarily to review specific personnel security cases which arise under the Commission's administrative review procedure and to make recommendations concerning them to the General Manager. The Board also advises the Commission on the broader considerations regarding personnel security, such as criteria for determining eligibility for security clearance and personnel security procedures.

GANSON PURCELL, *Chairman*; Purcell & Nelson, Washington, D.C.

JOHN J. WILSON, firm of Whiteford, Hart, Carmody & Wilson, Washington, D.C.

LOUIS A. TURNER, Princeton University, Princeton, N.J.

The Board met twice during 1966, on April 1 and September 8.

Technical Information Panel

The Panel was established in 1948 to advise and assist the AEC in the planning, testing, development, and execution of the Commission's technical information program, primarily on matters of interest to the National Laboratories and major operating contractors.

EDWARD J. BRUNENKANT, *Chairman;* Director, Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C.

BREWER F. BOARDMAN, Director, Technical Information, Nuclear Energy Corp., Idaho Falls, Idaho.

CLARENCE T. BROCKETT, Head, Technical Information, Lawrence Radiation Laboratory, Livermore, Calif.

Dr. THOMAS S. CHAPMAN, Technical Information Office, Dow Chemical Co., Golden, Colo.

DONALD H. CULVER, Manager, Technical Information, General Electric-NMPO, Cincinnati, Ohio.

W. E. DREESZEN, Administrative Aide to Director, Ames Laboratory, Ames, Iowa.

DOROTHY DUKE, 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, Head, Legal and Information Control Department, Union Carbide Corp., Oak Ridge, Tenn.

Dr. C. P. KEIM, Director, Technical Information Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

MAX K. LINN, Director, Technical Information and Publications, Sandia Corp., Sandia Base, Albuquerque, N. Mex.

FRANK R. LONG, General Supervisor, Information Services, Atomics International, Canoga Park, Calif.

JOHN H. MARTENS, Director, Technical Publications Department, Argonne National Laboratory, Argonne, Ill.

W. A. MINKLER, Supervisor, Bettis Technical Information, Westinghouse Electric Corp., 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.

DENNIS PULESTON, Head, Information Division, Brookhaven National Laboratory, Upton, N.Y.

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HELEN REDMAN, Librarian, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

FRANK D. SHEARIN, Technical Editor, Monsanto Research Corp., Mound Laboratory, Miamisburg, Ohio.

C. G. STEVENSON, Manager, Technical Information Operations, 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 once in 1966, on January 26–27.

Standing Committee for Controlled Thermonuclear Research

The Commission established on June 21, 1966, a Standing Committee for Controlled Thermonuclear Research. This Committee will review, on a continuing basis, the AEC's controlled thermonuclear program and will provide advice and recommendations to the Division of Research and the Commission relative to the program. The Committee has been established to ensure closer cooperative effort within the program and to provide guidance on implementing major program decisions. The Committee will have nine members. Four members of the Committee are directors of the controlled thermonuclear research in their respective laboratories; four members are 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, U.S. National Bureau of Standards, Washington, D.C.

Dr. SOLOMON J. BUCHSBAUM, Bell Telephone Laboratories, Murray Hall, 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 W. LEWIS, University of California at Santa Barbara, Santa Barbara, Calif.

The Committee met on August 5–6, September 7–8, and November 6–7.

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ARGONNE NATI
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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
Associate Director ---------- Dr. H. A. WILHEIM
Assistant Director ---------- Dr. ADOLPH F. VOIGT

ARGONNE NATIONAL LABORATORY (University of Chicago and Argonne Universities Association, contractors), Argonne, Ill.

Director ---------- Dr. ALBERT V. CREWE**
Associate Director ---------- Dr. STEPHEN LAWROSKI
Associate Director ---------- Dr. WINSTON M. MANNING
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. FRED HARRINGTON
President ---------- Dr. PHILIP N. POWERS

The 26 member institutions of the Argonne Universities Association are:

University of Arizona	Marquette University
Carnegie Institute of Technology	Michigan State University
Case Institute of Technology	The University of Michigan
The University of Chicago	University of Minnesota
University of Cincinnati	University of Missouri
Illinois Institute of Technology	Northwestern University
University of Illinois	University of Notre Dame
Indiana University	Ohio State University
Iowa State University	Purdue University
State University of Iowa	St. Louis University
Kansas State University	Washington University
University of Kansas	Wayne State University
Loyola University	University of Wisconsin

BETTIS ATOMIC POWER LABORATORY (Westinghouse Electric Corp., contractor), Pittsburgh, Pa.

General Manager ---------- N. A. BELDECOS

*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—1966."

**Dr. Crewe resigned on December 6, 1966, but continues to serve as the director until his successor is named.

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BROOKHAVEN NATIONAL LABORATORY (Associated Universities, Inc., contractor), Upton, N.Y.

Laboratory Director ---------- DR. MAURICE GOLDHABER
Deputy Director ---------- DR. CLARKE WILLIAMS
Associate Director ---------- DR. GEORGE VINEYARD

Associated Universities, Inc.

Chairman, Board of Trustees ---------- DR. ERNEST F. JOHNSON
President ---------- DR. T. KEITH GLENNAN

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
Program Planning Manager ---------- A. S. PETER, Jr.
Administrative Assistant ---------- B. W. CALVIT

FEED MATERIALS PRODUCTION CENTER (National Lead Co. of Ohio, contractor), Fernald, Ohio

Vice President ---------- GEORGE WUNDER
Manager ---------- JAMES H. NOYES
Assistant Manager ---------- M. S. NELSON

HANFORD FACILITIES (five contractors), Richland, Wash.

Douglas United Nuclear, Inc., Richland, Wash.

General Manager ---------- C. D. HARRINGTON
Deputy General Manager ---------- RAYMON W. HALLET, Jr.
Assistant General Manager for Operation ---- O. C. SCHROEDER
Assistant General Manager for Finance and Administration ---------- S. KOEPCKE

General Electric Co., Hanford Atomic Products Department, Richland, Wash.

General Manager ---------- R. L. DICKEMAN

Isochem Inc., Richland, Wash.

President ---------- J. N. JUDY
Vice President, Plant Operations ---------- P. E. REED
Vice President, Business Management ---------- H. D. GILBERT
Vice President, Marketing ---------- E. T. O'SULLIVAN

Pacific Northwest Laboratory (Battelle Memorial Institute, Columbus, Ohio, contractor), Richland, Wash.

Director ---------- Dr. S. L. FAWCETT
Associate Director ---------- Dr. F. W. ALBAUGH
Associate 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

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Manager, Radiochemistry ---------- D. P. ARGYLE
Manager, Engineering Services ---------- N. W. HAAGENSON

KANSAS CITY PLANT (The Bendix Corp., Kansas City Division, contractor), Kansas City, Mo.

General Manager ---------- R. J. QUIRK
Assistant General Manager ---------- V. L. RITTER
Director, Manufacturing ---------- F. J. TAYLOR
Director, Engineering ---------- R. M. SOMERS

KNOLLS ATOMIC POWER LABORATORY (General Electric Co., contractor), Schenectady, N.Y.

General Manager ---------- K. A. KESSELRING

E. O. LAWRENCE RADIATION LABORATORY (University of California, contractor), Berkeley and Livermore, Calif.

Director ---------- Dr. EDWIN M. MCMILLAN
Associate Director and Director, Livermore Laboratory ---------- Dr. MICHAEL M. MAY
Associate Director and Director, Donner Laboratory ---------- Dr. JOHN H. LAWRENCE
Business Manager ---------- RICHARD P. CONNELL

LOS ALAMOS SCIENTIFIC LABORATORY (University of California, contractor), Los Alamos, N. Mex.

Director ---------- Dr. NORRIS E. BRADBURY
Technical Associate Director ---------- Dr. RAEMER E. SCHREIBER
Assistant Director ---------- Dr. JANE H. HALL
Assistant Director, Production ---------- Dr. MAX F. ROY

MOUND LABORATORY (Monsanto Research Corp., contractor), Miamisburg, Ohio

Project Director (President, Monsanto Research Corp.) ---------- H. K. NASON
Plant Manager (Vice President, Monsanto Research Corp.) ---------- DAVID L. SCOTT
Director, Production ---------- JOHN E. BRADLEY
Director, Development ---------- LLOYD B. GNAGEY
Director, Research ---------- G. RICHARD GROVE

NATIONAL REACTOR TESTING STATION (NRTS) (six contractors—Argonne National Laboratory, General Electric, General Atomic, 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 ---------- R. S. ZENO

General Atomic Division, General Dynamics Corp., Idaho Falls

EBOR Site Manager ---------- GEORGE E. KIDD

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Idaho Nuclear Corp., Idaho Falls (jointly owned subsidiary of Aerojet General Corp. and Allied Chemical Corp.)

President and Manager ..... Dr. C. H. TRENT
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 Division Manager, Technical ..... W. E. NYER
Assistant Division Manager, Administration ..... L. L. LEEDY

Westinghouse Electric Corp., Idaho Falls

Manager, Naval Reactors Facility ..... R. C. MAIRSON

NEVADA TEST SITE (Reynolds Electrical & Engineering Co., Inc., 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., contractor), Oak Ridge, Tenn., and Paducah, Ky.

General Manager (President, Union Carbide Nuclear Div.) ..... Dr. C. E. LARSON

Oak Ridge Production Facilities

Manager of Production (Vice President, Union Carbide Nuclear Division) ..... CLARK E. CENTER
Superintendent, Y-12 Plant ..... R. F. HIBBS
Superintendent, Oak Ridge Gaseous Diffusion Plant ..... ROBERT G. JORDAN
Superintendent, Paducah Gaseous Diffusion Plant ..... ROBERT A. WINKEL

Oak Ridge National Laboratory

Director (Vice President, Union Carbide Nuclear Division) ..... Dr. ALVIN M. WEINBERG
Deputy Director ..... Dr. H. G. MACPHERSON

PANTEX PLANT (Mason & Hanger-Silas Mason Co., Inc., contractor) Amarillo, Tex.

Contract Manager (Vice President) ..... R. B. JEWELL
Plant Manager ..... JOHN C. DRUMMOND
Chief Engineer ..... MARION L. OTT
Production Manager ..... ROBERT B. CARROLL

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PORTSMOUTH GASEOUS DIFFUSION PLANT (Goodyear Atomic Corp., contractor), Piketon, Ohio

General Manager ---------- C. H. REYNOLDS
Deputy General Manager ---------- C. R. MILONE

ROCKY FLATS PLANT (Dow Chemical Co., contractor), Rocky Flats, Colo.

General Manager ---------- Dr. LLOYD M. JOSHEL
General Services Manager ---------- ROBERT R. HARRISON
Director of Research and Development ---------- LORNE A. MATHESON
Director of Technical Services ---------- EDWARD J. WALKO

SANDIA LABORATORY (Sandia Corp., contractor), 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
Vice President ---------- C. W. CAMPBELL
Vice President ---------- R. C. FLETCHER
Vice President ---------- C. T. ROSS, JR.
Vice President ---------- R. A. BICE
Vice President ---------- B. S. BIGGS
Vice President ---------- G. A. FOWLER

SAVANNAH RIVER LABORATORY (E. I. du Pont de Nemours & Co., contractor), Aiken, S.C.

Director ---------- W. P. OVERBECK
Assistant Director ---------- A. A. JOHNSON
Section Director—Physics Section ---------- G. DESSAUER
Section Director—Nuclear Engineering and Materials Section ---------- J. W. MORRIS
Section Director—Separations Chemistry and Engineering Section ---------- C. H. ICE

SAVANNAH RIVER PLANT (E. I. du Pont de Nemours & Co., contractor), Aiken, S.C.

Plant Manager ---------- JULIAN D. ELLETT
Assistant Plant Manager ---------- J. A. MONIER, JR.
General Superintendent, Works Technical Dept ---------- W. P. BEBBINGTON
General Superintendent, Production ---------- KENNETH W. FRENCH

SOUTH ALBUQUERQUE WORKS (ACF Industries, Inc., contractor), Albuquerque, N. Mex.

Vice President and General Manager ---------- W. J. JACKEL
Assistant General Manager ---------- J. C. O'HARA
Director, Engineering ---------- W. T. GEYER
Director, Applied Research and Development ---------- C. R. GARR

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APPENDIX 4

CENTRAL STATION NUCLEAR POWERPLANTS*

(Listed under each category by date of public announcement)

OPERABLE PLANTS

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public annc't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Shippingport Atomic Power Station (Duquesne Light Co. & AEC), Shippingport, Pa.	[3] 90	(a) PWR (b) West.	10/53	(a) [4] (b) [4]	(a) 12/2/57 (b) 12/18/57	(a) [4] (b) 12/57	Continuing to operate on 2nd core. Providing important scientific information about long-life fuel elements, new physics concept, and new control rod concepts.
Indian Point Station, Unit 1 (Cons. Edison Co. of New York) Indian Point, N.Y.	270	(a) PWR (b) B&W	2/55	(a) 4/2/55 (b) 5/4/56	(a) 8/2/62 (b) 9/16/62	(a) 3/26/62 (b) 9/62	Achieved criticality 3/27/66 on new low-enrichment uranium-oxide core of modified design which replaced original highly enriched uranium-oxide and thorium-oxide core. Reached full power, including conventional superheating of steam, in May. Operating on normal load-following basis.
Dresden Nuclear Power Station, Unit 1 (Commonwealth Edison Co.) Morris, Ill.	200	(a) BWR (b) GE	4/55	(a) 4/1/55 (b) 5/4/56	(a) 10/15/59 (b) 4/15/60	(a) 9/28/59 (b) 10/60	Some cracks detected in small diameter piping early in year; cause unknown. Cracked pipe sections removed, tested, and replaced. Refueling scheduled for Jan. 1967.

See footnotes at end of table.

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CENTRAL STATION NUCLEAR POWERPLANTS—Continued

OPERABLE PLANTS—Continued

Project (owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public annc't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Yankee Nuclear Power Station (Yankee Atomic Electric Co.) Rowe, Mass.[D]	175	(a) PWR (b) West.	4/55	(a) 7/9/56 (b) 11/4/57	(a) 8/19/60 (b) 11/10/60	(a) 7/9/60 (b) 7/61	Achieved 6 billion net kilowatt-hours cumulative electrical generation on Aug. 27. Refueling started Oct. 4 with core 6. Returned to power operation Nov. 7.
Hallam Nuclear Power Facility (Consumers Pub. Pwr. Dist. & AEC) Hallam, Nebr. (Shutdown 9/27/64) [D]	75	(a) SGR (b) AI	4/55	(a) [5] (b) 6/28/60	(a) 8/25/62 (b) 5/29/63	(a) 1/2/62 (b) 2/64	On 5/24/66, AEC was notified that Consumers would not exercise its option to purchase AEC-owned portion of the sodium graphite reactor facility. Activities in progress to dismantle plant and render premises radiation-safe by end of 1967.
Enrico Fermi Atomic Power Plant (Power Reactor Dev. Co.) Lagoona Beach, Mich.[D]	61	(a) FBR (b) PRDC	4/55	(a) 1/7/56 (b) 8/4/56	(a) 8/23/63 (b) 8/5/66	(a) 5/10/63 (b)	Stepwise approach to full power proceeded satisfactorily until October 5 when reactor was shut down following malfunction presumed to involve fuel damage. Fuel pin warping evident in at least one assembly. *Investigations in progress to determine extent of damage and remedial action required to place facility back in operation.*
Elk River Nuclear Plant (Rural Coop. Pwr. Ass'n. & AEC) Elk River, Minn.[D]	22	(a) BWR (b) A-C	2/56	(a) [5] (b) 1/9/60	(a) 11/19/62 (b) 8/24/63	(a) 11/6/62 (b) 6/65	Shut down 4/15/66 for refueling, maintenance, and thorough inspection to determine status and future serviceability of control rods and pressure vessel. Minor repairs found to be

Mich.[D]							damage. Fuel pin warping evident in at least one assembly. Investigations in progress to determine extent of damage and remedial action required to place facility back in operation.
Elk River Nuclear Plant (Rural Coop. Pwr. Ass'n. & AEC) Elk River, Minn.[D]	22	(a) BWR (b) A–C	2/56	(a) [5] (b) 1/9/60	(a) 11/19/62 (b) 8/24/63	(a) 11/6/62 (b) 6/65	Shut down 4/15/66 for refueling, maintenance, and thorough inspection to determine status and future serviceability of control rods and pressure vessel. Minor repairs found to be needed to control rods were made. Reactor started up on 7/9 with one-third of core 2 in place, and by 7/13 was at full power. Shut down 8/27–9/14 to plug evaporator tube leaks. Operation continues at, or near, full power.
Piqua Nuclear Power Facility (City of Piqua & AEC) Piqua, Ohio.[D]	11	(a) OMR (b) AI	2/56	(a) [5] (b) 1/28/60	(a) 6/10/63 (b) 11/4/63	(a) 8/23/62 (b) 8/64	Extensive deposits of carbonaceous material in the moderator regions of the core were encountered in mid-January 1966 which adversely affected reactor operation. Entire core unloaded and thoroughly examined. Carbonaceous deposits, which caused fuel element control rod binding, were removed and reactor vessel and systems are being flushed. New slightly modified fuel elements will be loaded into core, and plant will be returned to service in 1967.
Pathfinder Atomic Power Plant (Northern States Pwr. Co.) Sioux Falls, S. Dak.[D]	59	(a) BWR (b) A–C	2/57	(a) 4/1/59 (b) 5/12/60	(a) 3/24/64 (b) 7/25/66	(a) 3/12/64 (b)	Stepwise approach to power began early in June, and plant produced first electricity on July 25. Full power operation scheduled to be reached in 1967.

See footnotes at end of table.

CENTRAL STATION NUCLEAR POWERPLANTS—Continued

OPERABLE PLANTS—Continued

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public annc't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Carolinas-Virginia Tube Reactor (Carolinas-Virginia Nuclear Pwr. Assoc., Inc.) Parr, S.C.[D]	17	(a) HWR (b) West.	8/57	(a) 7/9/59 (b) 5/4/60	(a) 3/30/63 (b) 12/18/63	(a) 11/27/62 (b) 5/64	Operated satisfactorily at full power from May 1964 to March 8, 1966, when stress corrosion cracks were found in stainless steel pipes and vessels of an auxiliary system. First refueling of CVTR carried out in April concurrently with repair work. Reactor resumed power operation May 13. Shut down 8/26 to 10/3 for partial refueling. Shut down 10/27 for removal of defected fuel assembly. Subsequent operation has been intermittent; second defective element found and removed. Power operation resumed mid-December.
Humboldt Bay Power Plant, Unit 3 (Pacific Gas & Elec. Co.), Eureka, Calif.	69	(a) BWR (b) GE	2/58	(a) 4/30/59 (b) 11/9/60	(a) 2/16/63 (b) 4/18/63	(a) 8/28/62 (b) 8/63	Operating satisfactorily at reduced power level to extend life of fuel until late November when reactor was shut down, as scheduled, to refuel ½ of core with zircaloy-clad fuel. Power operation scheduled to be resumed by early 1967.
Boiling Nuclear Superheat Power Station (BONUS) (Puerto Rico Water Resources Authority & AEC), Puerto Rico	17	(a) BWR (b) Comb. Eng.	6/58	(a) [8] (b) 7/19/60	(a) 4/13/64 (b) 8/8/64	(a) 4/2/64 (b)	Began 6-month extended load test at full power 1/13/66. Testing passed 50% mark when buildup of hydrogen was discovered in housings for control rod drive mechanism. Reactor shut down April 10–22 to install vent system to purge accumulated

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Boiling Nuclear Superheat Power Station (BONUS) (Puerto Rico Water Resources Authority & AEC), Punta Higuera, P.R.[D]	17	(a) BWR (b) Comb. Eng.	6/58	(a)[s] (b) 7/19/60	(a) 4/13/64 (b) 8/8/64	(a) 4/2/64 (b)	Began 6-month extended load test at full power 1/13/66. Testing passed 50% mark when buildup of hydrogen was discovered in housings for control rod drive mechanism. Reactor shut down April 10–22 to install vent system to purge accumulated gases and prevent their future buildup. Operating responsibility for reactor transferred to Puerto Rico Water Resources Authority on July 8, and full-term operating authorization issued. Reactor achieved full power (50 Mwt) on 10/14.
Peach Bottom Atomic Power Station, Unit 1 (Philadelphia Elec. Co.), Peach Bottom, Pa.[D]	40	(a) HTGR (b) GA	11/58	(a) 7/25/60 (b) 2/23/62	(a) 3/3/66 (b)	(a) 1/24/66 (b)	After achieving initial criticality March 3, 1966, reactor completed low-power testing, then was shut down in mid-May to request full power operating permit and to repair and modify steam generators and other equipment. Work and plant checkout prior to rise-to-power completed. Authorization made for power operation of reactor to begin in January 1967.

See footnotes at end of table.

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CENTRAL STATION NUCLEAR POWERPLANTS—Continued

OPERABLE PLANTS—Continued

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public annc't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Big Rock Point Nuclear Plant (Consumers Pwr. Co. of Mich.) Big Rock Point, Mich.[D]	70	(a) BWR (b) GE	12/59	(a) 1/18/60 (b) 5/31/60	(a) 9/27/62 (b) 12/8/62	(a) 8/30/62 (b) 9/63	In mid-February, reactor power was reduced to minimize radioactivity in off-gas system. Operated satisfactorily at lower power level until April 9 when it was shut down for first partial refueling (30%). Beginning May 8, facility began production of cobalt 60 (a radioisotope widely used in industry, medicine, and research) in addition to production of power. The cobalt production is a joint venture of Consumers and Neutron Products, Inc. Shut down 9/17–10/20 for second partial refueling with zircaloy-clad, vibratorily compacted UO_2 fuel. Power operation was delayed to 11/9 because of control rod drive problems.
"N" Reactor (New Production Reactor) (Washington Public Power Supply System) Hanford, Wash. (AEC owns [illegible] WPPSS	786	(a) Grap. (b) GE	4/62	(a) [6] (b) [6]	(a) 12/31/63 (b) 4/8/66	(a) [6] (b)	Initial power production began on 4/8 and full power (800 Mwe, gross) achieved on 12/10. Failure of a high voltage transformer occurred on 12/10 and at year's end the output was being held to 400 Mwe.

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"N" Reactor (New Production Reactor) (Washington Public Power Supply System) Hanford, Wash. (AEC owns reactor; WPPSS owns generating facilities. Burns & Roe is contractor for WPPSS.)	786	(a) Grap. (b) GE	4/62	(a) [6] (b) [6]	(a) 12/31/63 (b) 4/8/66	(a) [5] (b)	Initial power production began on 4/8 and full power (800 Mwe, gross) achieved on 12/10. Failure of a high voltage transformer occurred on 12/10 and at year's end the output was being held to 400 Mwe.
UNDER CONSTRUCTION							
San Onofre Nuclear Generating Station (S. Calif. Edison and San Diego Gas & Elec.), San Clemente, Calif.[D]	430	(a) PWR (b) West.	4/60	(a) 2/4/63 (b) 3/2/64			Construction completed in November. Initial criticality scheduled to be achieved in early 1967. Delay from originally-scheduled December 1966 criticality attributed to deliberateness in following startup program and not to problems.
LaCrosse Boiling Water Reactor (Dairyland Pwr. Coop. & AEC), Genoa, Wis.[D]	50	(a) BWR (b) A-C	4/61	(a) 11/5/62 [5] (b) 3/29/63			Construction completion and start of fuel loading now scheduled for March 1967. Additional delay occasioned by need to repair leaking seal welds on control rod drive nozzle flanges.

See footnotes at end of table.

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CENTRAL STATION NUCLEAR POWERPLANTS—Continued

UNDER CONSTRUCTION—Continued

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public anno'c't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Connecticut Yankee Atomic Power Plant (Conn. Yankee Atomic Pwr. Co.), Haddam Neck, Conn.[D]	462	(a) PWR (b) West.	12/62	(a) 9/9/63 (b) 5/26/64			Construction more than 80% plete and proceeding essentially on schedule. Fuel loading scheduled to start about March 1967.
Oyster Creek Nuclear Power Plant, Unit 1 (Jersey Central Pwr. & Light Co.), Toms River, N.J.	515	(a) BWR (b) GE	5/63	(a) 3/30/64 (b) 12/15/64			Construction more than 40% complete. Initial criticality expected by late 1967, with start of commercial operation scheduled for early 1968.
Nine Mile Point Nuclear Station (Niagara Mohawk Pwr. Corp.) Scriba, N.Y.	500	(a) BWR (b) GE	7/63	(a) 4/1/64 (b) 4/12/65			Construction about 50% complete. Reactor scheduled to go critical by mid-1968 and reach full power by late 1968.
Dresden Nuclear Pwr. Station, Unit 2 (Commonwealth Edison Co.) Morris, Ill.	715	(a) BWR (b) GE	2/65	(a) 4/15/65 (b) 1/10/66			Construction scheduled to be completed by fall of 1968, and criticality to be attained by end of 1968.
Millstone Nuclear Pwr. Station (Conn. Light & Pwr.; Hartford Elec. Light; Western Mass	549	(a) BWR (b) GE	4/65	(a) 11/15/65 (b) 5/19/66			Construction scheduled to be essentially completed by early 1969. Initial criticality scheduled for April 1969, with start of commercial operation in August 1969. Public hearing

(Commonwealth Edison Co.) Morris, Ill.		(a) GE		(b) 1/10/66			completed by fall of 1968, and criticality to be attained by end of 1968.
Millstone Nuclear Pwr. Station (Conn. Light & Pwr.; Hartford Elec. Light; Western Mass. Elec.; and Millstone Point Co.) Waterford, Conn.	549	(a) BWR (b) GE	4/65	(a) 11/15/65 (b) 5/19/66			Construction scheduled to be essentially completed by early 1969. Initial criticality scheduled for April 1969, with start of commercial operation in August 1969. Public hearing held by ASLB (Atomic Safety and Licensing Board) April 21–22; initial decision made May 9, and provisional construction permit issued.
Robert Emmett Ginna Nuclear Power Plant, Unit 1 (Rochester Gas & Elec. Co.) Ontario, N.Y.	420	(a) PWR (b) West.	8/65	(a) 11/1/65 (b) 4/25/66			(Formerly called "Brookwood".) Construction about 10% complete and on schedule. Initial criticality scheduled for early 1969. Public hearing held by ASLB April 5; initial decision, April 14. Provisional construction permit issued.
Indian Point Station, Unit 2 (Cons. Ed. Co. of N.Y.) Indian Point, N.Y.	873	(a) PWR (b) West.	11/65	(a) 12/6/65 (b) 10/14/66			Construction about 15% complete. Construction completion and criticality scheduled for spring of 1969. Public hearing held by ASLB, September 14–15; initial decision, October 3. Provisional construction permit issued.
Dresden Nuclear Power Station, Unit 3 (Commonwealth Edison Co.) Morris, Ill.	715	(a) BWR (b) GE	1/66	(a) 2/10/66 (b) 10/14/66			Reactor scheduled to achieve initial criticality late 1969. Unit No. 3 expected to be last reactor addition at the Morris, Ill. site. Public hearing by ASLB held September 27–28; initial decision October 4. Provisional construction permit issued.

See footnotes at end of table.

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CENTRAL STATION NUCLEAR POWERPLANTS—Continued

APPLICATIONS UNDER REVIEW

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public anno'ct	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Malibu Nuclear Plant, Unit 1 (Los Angeles Dept. of Water & Power) Corral Canyon, Calif.[D]	462	(a) PWR (b) West.	11/62	(a) 11/26/63 (b)			Present schedule calls for construction to be completed and full power to be attained early in 1971, and commercial operation to begin in mid-1971. Issuance of construction permit awaiting formal Commission review at year's end.
Fort St. Vrain Nuclear Generating Station (Public Serv. Co. of Colo.) Platteville, Colo.[D]	330	(a) HTGR (b) GA	3/65	(a) 10/20/66 (b)			Proposed plant site is about 35 miles north of Denver. Preliminary design nearing completion. Construction scheduled to begin in early 1968. Plant expected to be in service in late 1971 or early 1972. Application for construction permit is under review.
Turkey Point Station, Unit 3 (Florida Pwr. & Light Co.) Turkey Point, Fla.	722	(a) PWR (b) West.	11/65	(a) 3/28/66 (b)			Two-reactor station to be located 25 miles south of Miami. Units 1 and 2 oil-fired; 3 and 4 to be nuclear. First nuclear unit scheduled to go into operation during 1970, and the second about one year later. Application for construction permit under review.
Turkey Point Station, Unit 4 (Florida Pwr. & Light Co.) Turkey Point, Fla.	722	(a) PWR (b) West.	11/65	(a) 3/28/66 (b)			(See preceding item.)
Vermont Yankee Nuclear Power Station (Vermont Yankee	514	(a) BWR (b) GE	12/65	(a) 12/2/66 (b)			Plant, to be located on Conn. River at Vernon, Vt., expected to be ready for service in late

							under review.
Turkey Point Station, Unit 4 (Florida Pwr. & Light Co.) Turkey Point, Fla.	722	(a) PWR (b) West.	11/65	(a) 3/28/66 (b)			(See preceding item.)
Vermont Yankee Nuclear Power Station (Vermont Yankee Nuclear Pwr. Corp.) Vernon, Vt.	514	(a) BWR (b) GE	12/65	(a) 12/2/66 (b)			Plant, to be located on Conn. River at Vernon, Vt., expected to be ready for service in late 1970. Application for construction permit under review.
Palisades Nuclear Power Station (Consumers Pwr. Co. of Mich.) Palisades Park, Mich.	700	(a) PWR (b) Comb. Eng.	1/66	(a) 6/3/66 (b)			Plant site about 35 miles west of Kalamazoo on Lake Michigan. Plant scheduled for operation by spring of 1970. Application for construction permit under review.
H. B. Robinson S.E. Plant, Unit 2 (Carolina Pwr. & Light Co.) Hartsville, S.C.	663	(a) PWR (b) West.	1/66	(a) 7/25/66 (b)			Unit No. 1 at the Robinson plant is a coal-fired generator; Unit No. 2 will be nuclear. Construction scheduled to be essentially completed early in 1970, with commercial operation to start about mid-1970. Application for construction permit is under review.
Point Beach Nuclear Plant, Unit 1 (Wisconsin Mich. Pwr. Co.) Two Creeks, Wis.	455	(a) PWR (b) West.	2/66	(a) 8/31/66 (b)			Construction scheduled to begin early 1967 on site near Green Bay, 90 miles northeast of Milwaukee, and be completed by end of 1969. Initial criticality and commercial operation expected by mid-1970. Application for construction permit is under review.

See footnotes at end of table.

CENTRAL STATION NUCLEAR POWERPLANTS—Continued

APPLICATIONS UNDER REVIEW—Continued

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public annc't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Quad-Cities Station, Unit 1 (Commonwealth Ed. Co.) Cordova, Ill.	715	(a) BWR (b) GE	4/66	(a) 5/31/66 (b)			Reactor scheduled to achieve initial criticality very late in 1969 or early in 1970. Application for construction permit under review.
Monticello Nuclear Generating Plant (Northern States Pwr. Co.) Monticello, Minn.	472	(a) BWR (b) GE	4/66	(a) 8/8/66 (b)			Plant, planned to be first in U.S. with field-fabricated reactor pressure vessel, to be located on Mississippi River 35 miles northwest of Minneapolis. Full power operation scheduled to begin mid-1970. Application for construction permit is under review.
Burlington Nuclear Generating Station, Unit 1 (Pub. Serv. Elec. & Gas; Phila. Elec., Atlantic City Elec., and Delmarva Pwr. & Light) Burlington, N.J.	993	(a) PWR (b) West.	5/66	(a) 12/13/66 (b)			Westinghouse to furnish one reactor for operation in 1971. Westinghouse has also provided utilities with option to purchase a second identical unit to be operable in 1974. Proposed plant site is adjacent to PSE&G's existing fossil-fired Burlington, N.J., station. Application is under review for first unit.
Browns Ferry Nuclear Power Plant, Unit 1 (Tennessee Valley Authority) Decatur, Ala.	1,065	(a) BWR (b) GE	6/66	(a) 7/13/66 (b)			First unit of a two-unit plant. Scheduled to be in operation in fall of 1970 on north shore of Wheeler Reservoir about 10 miles northwest of Decatur, Ala. Application for construction permit is under review.

Browns Ferry Nuclear Power Plant, Unit 1 (Tennessee Valley Authority) Decatur, Ala.	1,065	(a) BWR (b) GE	6/66	(a) 7/13/66 (b)		First unit of a two-unit plant. Scheduled to be in operation in fall of 1970 on north shore of Wheeler Reservoir about 10 miles northwest of Decatur, Ala. Application for construction permit is under review.
Browns Ferry Nuclear Power Plant, Unit 2 Tennessee Valley Authority) Decatur, Ala.	1,065	(a) BWR (b) GE	6/66	(a) 7/13/66 (b)		Second unit of a two-unit plant, on which TVA holds an option to cancel, is tentatively scheduled for late 1971 or early 1972 operation. Application for construction permit is under review.
Quad-Cities Station, Unit 2 (Commonwealth Ed. Co.) Cordova, Ill.	715	(a) BWR (b) GE	7/66	(a) 8/18/66 (b)		"Substantially similar" to Quad-Cities Unit 1 which Commonwealth Edison ordered 3½ months earlier. Added to original application by amendment filed August 18. Both units to be located near Quad Cities of Rock Island, Moline, and East Moline, Ill., and Davenport, Iowa. Application for construction permit is under review.
Oconee Nuclear Station, Unit 1 (Duke Power Co.) Clemson, S.C.	839	(a) PWR (b) B&W	7/66	(a) 12/1/66 (b)		Two reactor unit plant, to be located near Keowee Dam. First unit scheduled for completion by mid-1971, the second, one year later.
Oconee Nuclear Station, Unit 2 (Duke Power Co.) Clemson, S.C.	839	(a) PWR (b) B&W	7/66	(a) 12/1/66 (b)		Application for construction of both units is under review.

See footnotes at end of table.

CENTRAL STATION NUCLEAR POWERPLANTS—Continued

PLANNED PLANTS ANNOUNCED, BUT APPLICATIONS NOT RECEIVED

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public anno't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Shoreham Atomic Power Project (Long Island Lighting Co.) Long Island, N.Y.	500	(a) (b)	4/65				Utility announced intention to build in 1965, and in 1966 announced selection of a site. Construction scheduled to begin by late 1969 on north shore of Long Island between Shoreham and Wading River.
Pilgram Station (Boston Edison Co.) Rocky Point, Mass.	549	(a) BWR (b) GE	8/65				Plant proposed for siting 5 miles east of Plymouth, Mass., on Cape Cod Bay. Start of commercial operation scheduled for late 1971.
Bailey Point Station (Maine Yankee Atomic Pwr. Corp.) Bailey Point, Maine.	700	(a) (b)	1/66				Proposed plant site is about 3 miles south of Wiscasset, and 35 miles northeast of Portland, Maine. Central Maine Pwr. Co., Bangor Hydro-Electric Co., and Maine Pub. Serv. Co., will own 50% of plant and take one-half its output; 8 other participating New England utilities will share the balance of output and costs.
Peach Bottom Atomic Power Station, Unit 2 (Phila. Elec., Pub. Serv. Elec. & Gas, Atlantic City Elec., &	1, 065	(a) BWR (b) GE	5/66				G.E. to furnish two reactors, the first to be operational in 1971 and the second in 1973. Site for the second unit of this 2-unit station has not been selected.

Peach Bottom Atomic Power Station, Unit 2 (Phila. Elec., Pub. Serv. Elec. & Gas, Atlantic City Elec., & Delmarva Pwr. & Light) Peach Bottom, Pa. (near, but not at, present site).	1, 065	(a) BWR (b) GE	5/66				G.E. to furnish two reactors, the first to be operational in 1971 and the second in 1973. Site for the second unit of this 2-unit station has not been selected.
Second Unit (Phila. Elec., Pub. Serv. Elec. & Gas, Atlantic City Elec., & Delmarva Pwr. & Light) (not available).	1, 065	(a) BWR (b) GE	5/66				(See preceding item.)
Second Unit (Pub. Serv. Elec. & Gas; Phila. Elec., Atlantic City Elec., and Delmarva Pwr. & Light) possibly Burlington, N.J., but option not yet exercised.	993	(a) PWR (b) West.	5/66				(See item for Burlington Unit 1 in "Applications under review" section.)

See footnotes at end of table.

CENTRAL STATION NUCLEAR POWERPLANTS—Continued

PLANNED PLANTS ANNOUNCED, BUT APPLICATIONS NOT RECEIVED—Continued

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public annc't	Construction permit (a) Appl. recd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
Fort Calhoun Plant (Omaha Public Pwr. District) Ft. Calhoun, Nebr.	450	(a) PWR (b) Comb. Eng.	6/66				Plant proposed for siting on west side of Missouri River about 19 miles north of Omaha. Schedule calls for start of commercial operation by mid-1971.
Surry Pwr. Station, Unit 1 (Virginia Elec. & Pwr. Co.) Hog Island, Va.	783	(a) PWR (b) West.	6/66				First generating station to be located in Virginia. Proposed site is on Hog Island near Bacons Castle, across James River from Fort Eustis. Scheduled to be completed and ready for commercial operation by early 1971.
(Not available) (Consumers Public Pwr. Dist. & Iowa Pwr. & Light) Nebraska City, Nebr.	800	(a) (b)	6/66				Plant, slated for completion in 1972, proposed for location on Nebraska side of Missouri River south of Omaha. CPPD will furnish the plant. IP&L will take half the plant's output and share in the costs.
(Not yet named) (Metro. Water Dist. of So. Calif.) Bolsa	800	(a) (b)	8/66				2-reactor nuclear power-desalting plant proposed for location on man-made island offshore between Huntington and Seal Beaches, Calif. One 800 Mwe
	800	(a) (b)					

(Not yet named) (Metro. Water Dist. of So. Calif.) Bolsa Chica, Calif.	800 800	(a) (b) (a) (b)	8/66				2-reactor nuclear power-desalting plant proposed for location on man-made island offshore between Huntington and Seal Beaches, Calif. One 800 Mwe (net) powerplant to be built by Los Angeles Dept. of Water & Power; the other, jointly by So. Calif. Edison & San Diego Gas & Elec. MWD to initially build one 50 million gallon per day (mgd) desalting module. If 50 mgd module operation is satisfactory, MWD would then expect to add additional desalting capacity of 100 mgd. Initial operation of Edison-San Diego reactor and 50 mgd desalting module currently scheduled for 1972.
(Not available) (Pacific Gas and Electric Co.), San Luis Obispo, Calif.	1, 060	(a) PWR (b) West.	9/66				Proposed plant site is near Diablo Canyon, 12 miles southwest of San Luis Obispo. Completion scheduled for fall of 1971.
(Not available) (Niagara Mohawk Pwr. Corp.), Stillwater, N.Y.	750	(a) BWR (b) GE	10/66				Plant prepared for siting at Stillwater, on east bank of Hudson River, about 20 miles north of Troy, N.Y. Commercial operation scheduled for late 1971 or early 1972.
Surry Power Station, Unit 2 (Virginia Elec. & Pwr. Co.), Hog Island, Va.	783	(a) PWR (b) West.	10/66				(See previous item on Surry Unit 1.) To be located on same Hog Island site as Unit 1 which utility announced in June. Unit 2 scheduled for completion in early 1972.

See footnotes at end of table.

CENTRAL STATION NUCLEAR POWERPLANTS—Continued

PLANNED PLANTS ANNOUNCED, BUT APPLICATIONS NOT RECEIVED—Continued

Project-(owner)-location	Capacity (net Mwe)	Reactor (a) Type [1] (b) Contractor [2]	Public annc't	Construction permit (a) Appl. rec'd (b) P'mt. issued	Initial (a) Criticality (b) Electricity	Operation (a) Permit for (b) Commercial	1966 Highlights
(Not available) (Metropolitan Edison Co., of Pennsylvania) (Not available).	839	(a) PWR (b) B&W	11/66				Site for proposed plant not yet determined. Construction tentatively scheduled for completion by mid-1971.
(Not available) (Indiana & Michigan Elec. Co., a subsidiary of Amer. Elec. Pwr. Co.) Benton Harbor, Mich.	1,100	(a) (b)	12/66				Plant announced for construction on southeast shore of Lake Michigan, about 11 miles southwest of Benton Harbor. Selection of contractor scheduled to be made about May 1967.

[1] PWR—Pressurized Water Reactor; BWR—Boiling Water Reactor; SGR—Sodium Graphite Reactor; OMR—Organic Moderated Reactor HWR—Heavy Water Reactor; FBR—Fast Breeder-type Reactor; HTGR—High-temperature Gas-cooled Reactor.

[2] West.—Westinghouse Electric Corp.; B&W—The Babcock & Wilcox Co.; GE—General Electric Co.; AI—Atomics International, a Division of North American Aviation, Inc.; A-C—Allis-Chalmers Mfg. Co.; Comb. Eng.—Combustion Engineering, Inc.; PRDC—Power Reactor Development Co.; GA—General Atomic Division, General Dynamics Corp.

[3] 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. Power operation with core 2 began April 30, 1965.

[4] Not applicable; this cooperative venture of the AEC and Duquesne Light Co. was initiated prior to the Power Reactor Demonstration Program (PRDP).

[5] AEC reactors operated by utilities under the PRDP receive construction authorization under procedures paralleling those used in processing construction permits for privately owned plants.

[6] Not applicable; AEC arrangement with WPPSS for power take-off.

*TID-8200, available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va. 22151, for $1.00, is a semiannual compilation containing unclassified information about facilities built, being built, or planned in the U.S. (including reactors for export) which are capable of sustaining a nuclear chain reaction.

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[a] AEC reactors operated by utilities under the PRDP receive construction authorization under procedures paralleling those used in processing construction permits for privately owned plants.

[b] Not applicable; AEC arrangement with WPPSS for power take-off.

[c] TID-8200, available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va. 22151, for $1.00, is a semiannual compilation containing unclassified information about facilities built, being built, or planned in the U.S. (including reactors for export) which are capable of sustaining a nuclear chain reaction.

[d] Plants in Power Reactor Demonstration Program.

APPENDIX 5

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 1966, are set forth below.

REGULATIONS AND AMENDMENTS PUT INTO EFFECT

Nuclear Facilities—Parts 2, 50, 55, and 115

Amendments to Parts 2, 50, 55, and 115 (Part 2, concerns "Rules of Practice"; Part 50, "Licensing of Production and Utilization Facilities"; Part 55, "Operators' Licenses"; Part 115, "Procedures for Review of Certain Reactors Exempted from Licensing Requirements") were published September 30, 1966, effective October 30, 1966, and included a Statement of General Policy appended to Part 2. The changes implemented several major recommendations of the Regulatory Review Panel, appointed in 1965, relating to the conduct of mandatory hearings in nuclear facility licensing cases. They also included liberalization of restrictions on intra-agency communications in uncontested initial licensing proceedings and an amendment to the section respecting termination of jurisdiction of presiding officers.

Review of Initial Decisions—Parts 2, 50, and 115

On March 12, 1966, amendments to Parts 2, 50, and 115 were published, effective April 11, 1966, which eliminated the procedure for Commission review of initial decisions by the filing of petitions for review, and substituted therefor appeals as of right by the filing of exceptions by the parties.

Service of Papers Upon Attorney—Part 2

On March 15, 1966, the Commission published an amendment to Part 2, effective April 14, 1966, which made mandatory service of papers upon the attorney of a party to Commission adjudicatory proceedings. The amendment implemented P.L. 89-332.

Labeling of Containers—Part 20

An amendment of Part 20 ("Standards for Protection Against Radiation") was published August 5, 1966, effective November 3, 1966, which requires that containers of licensed material be labeled with the radiation caution symbol and legend. The label will identify the radioactive material in the container and provide sufficient information to permit individuals using, handling, or working in the vicinity of the container to take precautions to avoid or minimize exposures to radiation or to radioactive materials.

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Exemption of Tritium Contained in Certain Items—Parts 30 and 32

Amendments to Parts 30 ("Rules of General Applicability to Licensing of Byproduct Material") and 32 ("Specific Licenses to Manufacture, Distribute or Import Exempted and Generally Licensed Items Containing Byproduct Material") were published April 2, 1966, and became effective May 2, 1966. The Part 30 amendments exempt from the requirements of Parts 20 and 30–36 of the AEC's regulations the following items: (*a*) automobile shift quadrants containing not more than 25 millicuries of tritium; (*b*) marine compasses containing not more than 750 millicuries of tritium; and (*c*) thermostat dials and pointers containing not more than 25 millicuries of tritium per thermostat.

The Commission deferred action on an amendment which would have exempted radio dials and pointers containing tritium.

Certain provisions of Part 32 which contain criteria for the issuance of specific licenses to manufacture or import the exempted items and certain reporting and quality control requirements applicable to holders of such specific licenses were also amended.

Exemption of Tritium Contained in Glow Lamps

An amendment of Part 30 was published on November 8, 1966, effective December 8, 1966, which exempted from licensing requirements glow lamps containing not more than 10 microcuries of tritium per lamp. Part 32 was also amended to except such glow lamps from certain quality control requirements.

Exports to Southern Rhodesia—Parts 36 and 40

Amendments to Part 36 ("Export and Import of Byproduct Material") were published June 14, 1966, effective immediately, which restricted the general licenses of sections 36.21, 36.22, and 36.23 for exports to Southern Rhodesia to byproduct material contained in medicinals or pharmaceuticals only. The general license for export of source material to Southern Rhodesia in section 40.23 of Part 40 ("Licensing of Source Material") was revoked.

Exports and Imports Clarification—Parts 36 and 40

Amendments to clarify Parts 36 and 40 had been published December 10, 1965, effective January 9, 1966. They permit exports of byproduct material under the general licenses of Part 36 if the exporter is licensed by either the AEC or an agreement State to possess the material. General licenses for import of both byproduct and source material are also provided for importers licensed to possess the material by an agreement State specific or general license.

Packaging of Radioactive Material for Transport—Part 71

A revision of Part 71 was published July 22, 1966, and became effective August 21, 1966. The rule contains: (*a*) packaging standards and procedures for the shipment of both irradiated and unirradiated fissile materials; and (*b*) packaging standards and procedures for the shipment of "large quantities" of licensed materials.

Designation of Applicants—Part 115

On September 21, 1966, an amendment was published to Part 115, effective October 21, 1966. The revision provides for the participation in Part 115 proceedings, of the appropriate AEC division or operations office and the utility which will eventually operate the reactor, as applicants at the construction authorization stage, along with the prime contractor for construction. At the

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Private Insurance Increased—Part 140

Amendments to Part 140 ("Financial Protection Requirements and Indemnity Agreements") were published November 30, 1965, effective January 1, 1966, which require holders of licenses for facilities with a capacity of 100 Mwe or more to have $74 million of nuclear energy liability insurance rather than $60 million. (The amount available was increased as of January 1, 1966.) The amendments also made a corresponding reduction in the amount of indemnity available from the AEC, as required by P.L. 89-210.

Miscellaneous Amendments

Miscellaneous amendments to Parts 20, 40, 50, 55, 70, 100, 115, 140, and 150 pertain to the addressing of communications, requests, reports, and applications with the AEC and correct certain cross references in the regulations. The amendments were published March 19, 1966, and became effective on publication.

Miscellaneous amendments to Parts 9, 20, 32, 40, 50, and 150 correct certain words and specific references in the regulations to sections of the Atomic Energy Act of 1954 which have been changed by amendments, and make minor editorial changes. The amendments were published December 2, 1966, and became effective on publication.

Finding of Practical Value

On January 7, 1966, the Commission published in the *Federal Register*, a determination that there has not yet been sufficient demonstration of the cost of construction and operation of light water, nuclear electric plants to warrant its making a statutory finding that any types of such facilities have been sufficiently developed to be of practical value within the meaning of section 102 of the Atomic Energy Act of 1954, as amended. Subsequently, on December 23, 1966, the Commission announced its denial of a new petition for a finding of practical value which had been filed by coal interests on October 18, 1966. The Commission held that the second petition's arguments were, to a large extent, the same as those stated in the first (May 14, 1964) petition and that the Commission's original findings for denial were still valid.

PROPOSED REGULATIONS AND AMENDMENTS

Exemption of Tritium in Marine Navigational Aids—Part 30

A proposed amendment of Part 30 to exempt from licensing requirements the possession and use of marine navigational instruments containing not more than 250 millicuries of tritium gas, was published on September 14, 1966, for a 60-day comment period. The proposed change also would require the tritium content of presently exempted marine compasses to be in the form of gas.

Exemption of Scandium 46 in Synthetic Plastic Resins—Parts 30 and 32

Proposed amendments to Parts 30 and 32 (Specific Licenses to Manufacture, Distribute, or Import Exempted and Generally Licensed Items Containing Byproduct Material) to exempt from license use of scandium 46 in synthetic plastic resins designed for consolidating loose sand in oil wells and to establish specific licensing requirements for manufacture or import of the resin for distribution under the exemption were published on December 14, 1966, for a 30-day comment period.

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Medical Licenses of Broad Scope—Part 35

On November 5, 1966, a proposed amendment of Part 35 ("Human Uses of Byproduct Material") was published for a 60-day comment period. It would permit the AEC to issue licenses for medical use of byproduct material covering radioisotopes and uses additional to those requested by the applicant.

Expiration of Licenses—Part 40

On December 22, 1966, the Commission published for a 30-day comment period a proposed amendment to Part 40 (Licensing of Source Material) to eliminate the restriction of the terms of source material licenses to 3 years. If the proposed amendment is adopted the Commission intends to issue source, byproduct and special nuclear material licenses for terms of five years except in cases where the nature of the applicant's proposed activities indicates the need for a shorter license period.

Technical Specifications and Safety Analysis Reports—Part 50

Proposed amendments to Part 50 ("Licensing of Production and Utilization Facilities") were published August 16, 1966, for a 120-day comment period and interim guidance. The proposed changes would (*a*) establish a revised system of technical specifications which focuses attention on items more directly related to public safety (*b*) provide for systematic documentation of the technical and operational bases for specifications, and (*c*) provide guidance on content of preliminary safety analysis reports and safety analysis reports required of applicants for facility construction permits and operating licenses.

Discontinuance of Procedures for Allocating and Distributing Special Nuclear Material—Parts 50 and 70

On November 24, 1966, the Commission published for a 60-day comment period proposed amendments of Parts 50 and 70 to discontinue procedures for allocation and distribution of special nuclear material to nuclear reactor licensees and special nuclear material licensees.

Safeguards for Special Nuclear Material—Part 70

On May 27, 1966, proposed amendments to Part 70 ("Special Nuclear Material") were published for a 60-day comment period. The revisions would require certain holders of special nuclear material licenses to establish and maintain written procedures to account for special nuclear material in their possession, to keep records showing the location and movement of such material and to perform physical inventories of the material. Applicants for such licenses would be required to submit a description of control and inventory systems as part of the application.

Reports on Special Nuclear Material—Parts 70 and 150

On March 29, 1966, the Commission published for a 60-day comment period proposed amendments of Parts 70 and 150 ("Exemptions and Continued Regulatory Authority in Agreement States Under Section 274") to require transfer and status reports for all privately owned special nuclear material, regardless of origin, possessed by either AEC licensees or agreement State licensees.

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Production facilities:
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orders
Licenses to opera

See footnotes at end of tabl

APPENDIX 6

SUMMARY OF LICENSING ACTIONS

Facilities [1]	Sept. 1, 1954, through Nov. 30, 1966	Nov. 30, 1965, through Nov. 30, 1966	Permits and licenses in effect as of Nov. 30, 1966
Power reactors (part 50):			
Construction permits	22	5	10
Construction permit amendments and orders	33	2	----------
Licenses to operate	13	1	13
License amendments, authorizations and orders	392	82	----------
Power reactors (part 115):			
Construction authorizations	5	0	1
Construction authorization amendments	1	0	----------
Operating authorizations	8	1	4
Operating authorization amendments	62	9	----------
Test Reactors:			
Construction permits	5	0	1
Construction permit amendments and orders	6	1	----------
Licenses to operate	4	0	4
License amendments and authorizations	57	5	----------
Research reactors:			
Construction permits	92	3	[2] 6
Construction permit amendments and orders	88	8	----------
Licenses to operate (including acquire and operate)	98	5	71
License amendments	528	73	----------
Terminations	27	2	----------
Reactor exports:			
Research reactor licenses	50	3	([3])
Test reactor licenses	3	0	([3])
Power reactor licenses	[4] 8	0	([3])
Critical experiment facilities	[5] 1	0	([3])
License amendments	84	5	----------
Critical experiment facilities:			
Construction permits	26	2	0
Construction permit amendments and orders	15	1	----------
Licenses to operate	24	1	17
License amendments	127	15	----------
Production facilities:			
Construction permits	2	0	0
Construction permit amendments and orders	7	2	----------
Licenses to operate	1	1	1

See footnotes at end of table.

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Facility operators	Sept. 1, 1954, through Nov. 30, 1966	Nov. 30, 1965, through Nov. 30, 1966	Permits and licenses in effect as of Nov. 30, 1966
Operator licenses (including senior)	2, 820	313	1, 523
Operator license amendments and renewals	1, 832	412	----------
Operator license denials	388	99	----------
MATERIALS			
Special nuclear material licenses	972	54	584
SNM license amendments and renewals	2, 893	380	----------
SNM license denials	8	1	----------
Source material licenses issued or renewed	9, 522	110	439
Source material export licenses	5, 256	120	(3)
Source material license denials	12	0	----------
Byproduct material licenses (domestic use)	[6] 21, 294	975	8, 431
Byproduct material license amendments	[7] 50, 550	6, 514	----------

[1] Applications to construct and operate are filed simultaneously; conversions from construction permits to licenses to operate are made upon satisfactory completion of construction.
[2] Permits authorize construction of 10 reactors.
[3] Export licenses terminate upon completion of shipment.
[4] Two power reactors exported under a single license, July 17, 1964.
[5] A power reactor and a critical facility exported under a single license, Mar. 16, 1962.
[6] Prior to Feb. 10, 1956, procurement authorizations were issued.
[7] From July 1956 through Nov. 30, 1966.

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Australia
Austria
Brazil
Canada
China, Republi
Colombia
Denmark
Germany:
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Greece [1]
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Indonesia
Iran [2]
Ireland
Israel
Italy
Japan
Korea
Netherlands
Norway
Panama
Philippines
Portugal
South Africa
Spain
Sweden
Switzerland
Thailand
Turkey
United Kingdom
United Kingdom
Venezuela
Vietnam
Special arrangem
US–USSR [3]

See footnotes at end c

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Permits and licenses in effect as of Nov. 30, 1966
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584

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(3)

8, 431
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ruction permits

APPENDIX 7

INTERNATIONAL COOPERATION

TABLE 1.—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, 1967
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	Research	Mar. 29, 1963	Mar. 28, 1967
Denmark	Research	July 25, 1955	Sept. 7, 1968
Germany:			
Federal Republic of	Research and Power	Aug. 7, 1957	Aug. 6, 1967
City of West Berlin	Research	Aug. 1, 1957	July 31, 1967
Greece [1]	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 [2]	Research	Apr. 27, 1959	Apr. 26, 1964
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
Netherlands	Research and Power	Aug. 8, 1957	Aug. 7, 1967
Norway	Research and Power	June 10, 1957	June 9, 1967
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, 1967
Spain	Research and Power	Feb. 12, 1958	Mar. 31, 1988
Sweden	Power	Sept. 15, 1966	Sept. 14, 1996
Switzerland	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:			
US–USSR [3]	Agreement of 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.	2/18/59	12/31/85
Euratom	Additional Agreement to Joint Nuclear Power Program.	7/25/60	12/31/95
International Atomic Energy Agency (IAEA).	Supply of materials, etc	8/ 7/59	8/ 6/75

Trilateral Safeguards Agreements

Participants	Scope	Effective date
US/IAEA/Argentina	Trilateral for application of IAEA safeguards to US-supplied materials.	3/ 1/66
US/IAEA/Australia	do.	9/26/66
US/IAEA/Austria	do.	12/13/65
US/IAEA/Republic of China	do.	10/29/65
US/IAEA/Greece	do.	1/13/66
US/IAEA/Israel	do.	6/15/66
US/IAEA/Japan	do.	11/ 1/63
US/IAEA/Philippines	do.	9/24/65
US/IAEA/Portugal	do.	12/15/65
US/IAEA/South Africa	do.	10/8/65
US/IAEA/Spain	do.	12/22/66
US/IAEA/Thailand	do.	9/16/65
US/IAEA/Vietnam	do.	10/21/65
US/IAEA/Iran	do.	(4)
US/IAEA/Norway	do.	(4)

Agreements for Cooperation for Mutual Defense Purposes [5]

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	July 3, 1958

[1] Provisionally in force.
[2] Extending amendment signed but not yet in force.
[3] Notes were exchanged on 12/3/66 extending this agreement through 1968.
[4] Effective date to be established.
[5] Except for 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.

Pursuant to tl
Cargo Act 46 U
ments for the ac
shown:

1. Charleston,
2. Savannah,
3. Norfolk, Va.
4. Philadelphia.
5. Seattle, Wasl
6. Houston, Te
7. Port Evergla
8. Wilmington,
9. Morehead C
10. New Orleans
11. Portland, M
12. Searsport, M
13. Los Angeles,
14. Gulfport, Mi
15. Albany, N.Y.
16. Buffalo, N.Y.
17. Corpus Chri
18. Redwood Ci
19. Portland, Or
20. Tampa, Fla.
21. New York, N
22. Jacksonville,
23. Baton Rouge
24. Port St. Joe,
25. Benton, Wa
26. Bellingham,
27. Baltimore, M
28. Olympia, W
29. Willapa Har
30. Anacortes, W
31. Grays Harb
32. Mattawa, W
33. Everett, Wa
34. Longview, W
35. Tacoma, Wa
36. San Francis
37. Lake Charle
38. Hilo, Hawai
39. Kawaihae, H
40. Kahului, Ha
41. Honolulu, H
42. Nawiliwili,
43. Port Allen,
44. Kennewick,

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TABLE 2.—LIST OF U.S. PORTS CLEARED

Pursuant to the requirement of Title 46 Part 146 of CFR, and the Dangerous Cargo Act 46 USC 170, the following U.S. ports have met Coast Guard requirements for the acceptance of "spent" (radioactive) fuel elements, as of the dates shown:

Port	Date of letter of clearance from U.S. Coast Guard
1. Charleston, S.C	February 20, 1962
2. Savannah, Ga	February 20, 1962
3. Norfolk, Va	June 12, 1962
4. Philadelphia, Pa	July 18, 1962
5. Seattle, Wash	August 22, 1962
6. Houston, Tex	January 3, 1963
7. Port Everglades, Fla	February 4, 1963
8. Wilmington, N.C	February 7, 1963
9. Morehead City, N.C	February 13, 1963
10. New Orleans, La	February 26, 1963
11. Portland, Maine	March 5, 1963
12. Searsport, Maine	March 5, 1963
13. Los Angeles, Calif	April 10, 1963
14. Gulfport, Miss	July 11, 1963
15. Albany, N.Y	October 4, 1963
16. Buffalo, N.Y	October 25, 1963
17. Corpus Christi, Tex	November 1, 1963
18. Redwood City, Calif	January 3, 1964
19. Portland, Oreg	April 8, 1964
20. Tampa, Fla	September 21, 1964
21. New York, N.Y	October 26, 1964
22. Jacksonville, Fla	April 5, 1965
23. Baton Rouge, La	May 14, 1965
24. Port St. Joe, Fla	June 15, 1965
25. Benton, Wash	June 16, 1965
26. Bellingham, Wash	July 14, 1965
27. Baltimore, Md	September 3, 1965
28. Olympia, Wash	September 8, 1965
29. Willapa Harbor, Wash	September 23, 1965
30. Anacortes, Wash	September 23, 1965
31. Grays Harbor, Wash	September 29, 1965
32. Mattawa, Wash	October 6, 1965
33. Everett, Wash	October 19, 1965
34. Longview, Wash	October 19, 1965
35. Tacoma, Wash	December 13, 1965
36. San Francisco, Calif	March 1, 1966
37. Lake Charles, La	April 28, 1966
38. Hilo, Hawaii	May 26, 1966
39. Kawaihae, Hawaii	May 26, 1966
40. Kahului, Hawaii	May 26, 1966
41. Honolulu, Hawaii	May 26, 1966
42. Nawiliwili, Hawaii	May 26, 1966
43. Port Allen, Hawaii	May 26, 1966
44. Kennewick, Wash	June 13, 1966

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TABLE 3.—DISTRIBUTION ABROAD OF AEC-PRODUCED NUCLEAR MATERIAL

	Enriched uranium (kilograms U-235)				U-233 (grams)		Plutonium (grams)		Heavy water (tons)	
	Less than 20 percent U-235 [1]		Greater than 20 percent U-235 [2]							
	Through calendar year 1965	Calendar year 1966 through Nov. 30	Through calendar year 1965	Calendar year 1966 through Nov. 30	Through calendar year 1965	Calendar year 1966 through Nov. 30	Through calendar year 1965	Calendar year 1966 through Nov. 30	Through calendar year 1965	Calendar year 1966 through Nov. 30
Argentina			15.4	7.2						
Australia	(*)		9.1	2.7	1,009.0		6,004	243	14	
Austria			13.1		1.0		161			
Brazil			19.8				80			
Canada	125.8	77.8	271.8	66.8			195		346	82
China, Republic of			4.7				95		(*)	
Colombia			2.2				80			
Denmark	(*)		15.3	1.6	1.0		81		18	
Euratom	(*)		.2				2		(*)	
Belgium	106.1	11.5	169.4	21.5	28.0		3,682	6,376		
Eurochemic		53.0			3.0		11	2,799		
France	954.8	593.5	513.0	404.4			7,261	78		
Germany	132.7	491.7	599.8	669.0		1.0	234,175	143,672		
Italy	2,354.5	4.2	94.5						36	
Netherlands	.1	4.2	61.8							
France	668.2	116.3	456.1	81.7	89.0		6,119	104	54	113
Germany	347.3	47.7	338.7	22.5	13.0		2,485		173	
Greece			6.0				112			
IAEA							(*)			
Argentina			3.8							
Austria	(*)		.2				96			
Congo			2.0							
Finland			2.5							
Greece							80			
Norway	59.7									
Pakistan				5.2				112		
Yugoslavia			(*)	2.7			(*)			
India									10	
Indonesia			2.3							
Ireland			(*)				16			
Israel	(*)		9.1		5.0		526		4	
Italy	4.6		66.2	7.9	5.0		138		5	
Japan	377.6	15.0	80.1	7.9	4.0	6.0	280	1,500	51	

Argentina							112			
Austria			3.8				(*)			
Congo	(*)		.2							
Finland			2.0				96			
Greece			2.5							
Norway	59.7						80			
Pakistan				5.2				112		
Yugoslavia			(*)	2.7			(*)			
India									10	
Indonesia			2.3							
Ireland			(*)				16			
Israel	(*)		9.1		5.0		526		4	
Italy	4.6		66.2	7.9	5.0		138		5	
Japan	377.6	15.0	80.1	7.9	4.0	6.0	280	1,500	51	
Korea			2.4				8			
Netherlands	73.8		19.2		(*)		381		2	
New Zealand							80			
Norway	39.4	6.8	(*)				6		28	
Philippines	4.3		(*)				32			
Portugal			6.0							
South Africa			7.0					159	6	
Spain	(*)		18.0	4.3			5		5	
Sweden	57.2	11.0	184.3	1.3	2.0		1,123	11	29	
Switzerland	18.8	60.9	18.3		30.0		890	610	25	26
Thailand			4.8				80			
Turkey	1.2		4.8				288			
United Kingdom	2.6	28.3	483.8	175.3	512.0		812	206	70	54
Venezuela			4.9				10			
Vietnam			2.4				80			
Total	5,328.7	1,521.9	3,503.4	1,482.0	1,687.0	7.0	265,362	155,870	876	275

[1] Primarily for fueling power reactors.
[2] Primarily for fueling research and test reactors and other research applications.
(*) Minute quantities.

APPENDIX 8

TECHNICAL INFORMATION

TABLE 1.—SPECIALIZED INFORMATION AND DATA CENTERS SUPPORTED BY AEC*

Name of Center	Location	Address
Accelerator Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830.
Argonne Code Center	Argonne National Laboratory.	Argonne, Ill. 60440
Atomic and Molecular Processes Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Charged Particle Cross Section Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Computer Index Neutron Data Center.	AEC Division of Technical Information Extension.	Oak Ridge, Tenn. 37830
Criticality Data Center	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Fused Salts Information Center.	Sandia Corp	Albuquerque, N. Mex. 87115
Gamma-Ray Spectrum Catalogue.	National Reactor Testing Station.	Idaho Falls, Idaho 83401
Information Center for Internal Exposure.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Information Integration Group.	Lawrence Radiation Laboratory.	Livermore, Calif. 94551
Isotopes Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Laboratory Animal Information Center.	Argonne National Laboratory.	Argonne, Ill. 60440
Liquid Metals Information Center.	Atomics International	Canoga Park, Calif. 91304.
National Oceanographic Data Center.	U.S. Naval Oceanographic Office	Washington, D.C. 20309
Nuclear Data Project	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Nuclear Desalination Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Nuclear Safety Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Radiation Chemistry Data Center.	University of Notre Dame.	Norte Dame, Ind. 46556

See footnote at end of table.

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TABLE 1.—SPECIALIZED INFORMATION AND DATA CENTERS SUPPORTED BY AEC—Continued

Name of Center	Location	Address
Radiation Effects Information Center.	Battelle Memorial Institute.	Columbus, Ohio 43201
Radiation Shielding Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Rare-Earth Information Center.	Ames Laboratory	Iowa State University, Ames, Iowa 50010
Reactor Physics Constants Center.	Argonne National Laboratory.	Argonne, Ill. 60440
Research Materials Information Center.	Oak Ridge National Laboratory.	Oak Ridge, Tenn. 37830
Scientific Systems Information Group.	Lawrence Radiation Laboratory.	Livermore, Calif. 94551
Sigma Center	Brookhaven National Laboratory.	Upton, N.Y. 11973
Thermodynamic Properties of Metals and Alloys.	Lawrence Radiation Laboratory.	Berkeley, Calif. 94720

*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.

Collections o
tions listed be
U.S. libraries l
of other counti

ALABAMA
Auburn, Aub
ALASKA
College, Univ
ARIZONA
Tucson, Univ
ARKANSAS
Fayetteville,
CALIFORNIA
Berkeley, Un
Davis, Unive
Los Angeles
fornia
San Diego, P
Stanford, Sta
COLORADO
Boulder, Uni
Denver, Publ
CONNECTICU
New Haven,
DELAWARE
Newark, Uni
DISTRICT OI
Washington,
FLORIDA
Coral Gables
Gainesville, l
Tallahassee,
versity
GEORGIA
Atlanta, Geo
nology
HAWAII
Honolulu, Ui
IDAHO
Pocatello, I
Library
ILLINOIS
Chicago, Joh
Chicago, Uni
Evanston, N
Urbana, Uni
INDIANA
Bloomington
Lafayette, P
IOWA
Ames, Iowa

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TABLE 2.—AEC DEPOSITORY LIBRARIES

Collections of AEC reports are maintained in the libraries of the organizations listed below. Facilities for making photocopies are available. In the U.S. libraries listed, the AEC also makes available those atomic energy reports of other countries which are abstracted in "Nuclear Science Abstracts."

Libraries in the United States

ALABAMA
- Auburn, Auburn University

ALASKA
- College, University of Alaska

ARIZONA
- Tucson, University of Arizona

ARKANSAS
- Fayetteville, University of Arkansas

CALIFORNIA
- Berkeley, University of California
- Davis, University of California
- Los Angeles, University of California
- San Diego, Public Library
- Stanford, Stanford University

COLORADO
- Boulder, University of Colorado
- Denver, Public Library

CONNECTICUT
- New Haven, Yale University

DELAWARE
- Newark, University of Delaware

DISTRICT OF COLUMBIA
- Washington, Library of Congress

FLORIDA
- Coral Gables, University of Miami
- Gainesville, University of Florida
- Tallahassee, The Florida State University

GEORGIA
- Atlanta, Georgia Institute of Technology

HAWAII
- Honolulu, University of Hawaii

IDAHO
- Pocatello, Idaho State University Library

ILLINOIS
- Chicago, John Crerar Library
- Chicago, University of Chicago
- Evanston, Northwestern University
- Urbana, University of Illinois

INDIANA
- Bloomington, Indiana University
- Lafayette, Purdue University

IOWA
- Ames, Iowa State University

KANSAS
- Manhattan, Kansas State University

KENTUCKY
- Lexington, University of Kentucky
- Louisville, University of Louisville

LOUISIANA
- Baton Rouge, Louisiana State University
- New Orleans, Tulane University

MARYLAND
- Baltimore, Johns Hopkins University
- College Park, University of Maryland

MASSACHUSETTS
- Cambridge, Harvard University
- Cambridge, Massachusetts Institute of Technology

MICHIGAN
- Ann Arbor, University of Michigan
- Detroit, Public Library
- East Lansing, Michigan State University

MINNESOTA
- Minneapolis, University of Minnesota

MISSISSIPPI
- State College, Mississippi State University

MISSOURI
- Kansas City, Linda Hall Library
- Rolla, University of Missouri School of Mines and Metallurgy
- St. Louis, Washington University

MONTANA
- Bozeman, Montana State College

NEVADA
- Las Vegas, Nevada Southern University
- Reno, University of Nevada

NEW JERSEY
- Princeton, Princeton University
- Teaneck, Fairleigh Dickinson University

TABLE 2.—AEC DEPOSITORY LIBRARIES—Continued

Libraries in the United States—Continued

NEW MEXICO
- Albuquerque, University of New Mexico

NEW YORK
- Albany, The University of the State of New York
- Buffalo, State University of N.Y. at Buffalo
- Ithaca, Cornell University
- New York, Atomic Industrial Forum, Inc.
- New York, Columbia University
- New York, New York University
- Rochester, University of Rochester
- Schenectady, Union College
- Syracuse, Syracuse University
- Troy, Rensselaer Polytechnic Institute

NORTH CAROLINA
- Charlotte, Public Library of Charlotte and Mecklenburg County
- Durham, Duke University
- Raleigh, North Carolina State College

NORTH DAKOTA
- Grand Forks, University of North Dakota

OHIO
- Cincinnati, University of Cincinnati
- Cleveland, Public Library
- Columbus, Ohio State University
- Toledo, University of Toledo
- Youngstown, Youngstown University

OKLAHOMA
- Norman, University of Oklahoma
- Stillwater, Oklahoma State University

OREGON
- Corvallis, Oregon State University
- Portland, Reed College

PENNSYLVANIA
- Philadelphia, University of Pennsylvania
- Pittsburgh, Carnegie Library
- University Park, Pennsylvania State University

PUERTO RICO
- Rio Piedras, University of Puerto Rico

RHODE ISLAND
- Providence, Brown University

SOUTH CAROLINA
- Columbia, University of South Carolina

TENNESSEE
- Knoxville, University of Tennessee
- Memphis, Public Library
- Nashville, Joint University Libraries
- Oak Ridge, Oak Ridge Associated Universities

TEXAS
- Austin, University of Texas
- College Station, Texas A & M University
- Dallas, Southern Methodist University
- Houston, Rice University
- Lubbock, Texas Technological College
- San Antonio, Public Library

UTAH
- Salt Lake City, University of Utah

VIRGINIA
- Blacksburg, Virginia Polytechnic Institute
- Charlottesville, University of Virginia
- Norfolk, Old Dominion College

WASHINGTON
- Pullman, Washington State University
- Seattle, University of Washington

WEST VIRGINIA
- Morgantown, West Virginia University

WISCONSIN
- Madison, University of Wisconsin
- Milwaukee, Public Library

WYOMING
- Laramie, University of Wyoming

L

ARGENTINA
- Buenos Aires, de Energía At

AUSTRALIA
- Canberra, Aust brary
- Sutherland, New tralian Atomi sion

AUSTRIA
- Vienna, Zentra Physikalischer versität
- Vienna, Interna ergy Agency

BELGIUM
- Mol-Donk, Centr ergie Nucleair
- Brussels, La B TOM

BOLIVIA
- La Paz, Comisi ergia Nuclear

BRAZIL
- Rio de Janerio, de Bibliografi
- São Paulo, Ins Atomica, Cid São Paulo

BURMA
- Rangoon, Union Research Inst ergy Center Lil

CANADA
- Hamilton, McMa
- Ottawa, Nationa Library
- Vancouver, Uni Columbia

CHILE
- Santiago, Depar Universidad de

CHINA
- Hsinchu, Taiwar tional Tsing H

COLOMBIA
- Bogota, Institut cleares

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TABLE 2.—AEC DEPOSITORY LIBRARIES—Continued

Libraries in Countries Other than the United States

ARGENTINA
Buenos Aires, Comisión Nacional de Energía Atomica

AUSTRALIA
Canberra, Australian National Library
Sutherland, New South Wales, Australian Atomic Energy Commission

AUSTRIA
Vienna, Zentral Bibliothek der Physikalischen Institute der Universität
Vienna, International Atomic Energy Agency

BELGIUM
Mol-Donk, Centre d'Etude de l'Energie Nucleaire
Brussels, La Bibliotheque EURATOM

BOLIVIA
La Paz, Comisión Nacional de Energia Nuclear

BRAZIL
Rio de Janerio, Instituto Brasileiro de Bibliografia e Documentacao
São Paulo, Instituto de Energia Atomica, Cidade Universitaria São Paulo

BURMA
Rangoon, Union of Burma Applied Research Institute, Atomic Energy Center Library

CANADA
Hamilton, McMaster University
Ottawa, National Research Council Library
Vancouver, University of British Columbia

CHILE
Santiago, Departamento de Fisica, Universidad de Chile

CHINA
Hsinchu, Taiwan, Free China, National Tsing Hua University

COLOMBIA
Bogota, Instituto De Asuntos Nucleares

COSTA RICA
San Pedro, University of Costa Rica Library

DENMARK
Risö, Danish Atomic Energy Commission

ECUADOR
Quito, Escuela Politecnica Nacional

EL SALVADOR
San Salvador, Universidad de El Salvador, Biblioteca de Energia Nuclear

FINLAND
Helsinki, Teknillisen Korkeakoulun Kirjasto

FRANCE
Gif-sur-Yvette, Centre d'Etudes Nucléaires de Saclay
Paris, Académie de Sciences
Paris, European Nuclear Energy Agency, O.E.C.D.

GERMANY
Berlin, Hahn-Meitner-Institut für Kernforschung Berlin
Frankfurt/Main, Gmelin-Institut
Munich, Technische Hochschule, Bibliothek

GHANA
Accra, University College of Ghana

GREECE
Athens, Nuclear Research Center "Democritus"

GUATEMALA
Guatemala, Comisión Nacional de Energía Nuclear

INDIA
Bombay, Department of Atomic Energy

IRAN
Tehran, Tehran University Nuclear Centre

IRAQ
Baghdad, Iraqi Atomic Energy Commission

IRELAND
Dublin, University College

TABLE 2.—AEC DEPOSITORY LIBRARIES—Continued

Libraries in Countries Other Than the United States—Continued

ISRAEL
- Rehovoth, Israel Atomic Energy Commission

ITALY
- Rome, Centro di Studi Nucleari della Casaccia
- Rome, Comitato Nazionale per l'Energia Nucleare
- Ispra, EURATOM Research Center

JAPAN
- Tokyo, National Diet Library

KOREA
- Seoul, Office of Atomic Energy

LEBANON
- Beirut, Lebanese National Council for Scientific Research

LUXEMBOURG
- Luxembourg, Ministry of Transport and Electricity

MALAYSIA
- Kuala Lunpur, University of Malaysia

MEXICO
- Mexico, D.F., Comisión Nacional de Energía Nuclear

NETHERLANDS
- The Hague, Reactor Centrum Nederland

NEW ZEALAND
- Lower Hutt, Institute of Nuclear Sciences

NIGERIA
- Ibadan, University of Ibadan

NORWAY
- Lillestrom, Institutt för Atomenergi

PAKISTAN
- Islamabad, Pakistan Institute of Nuclear Science and Technology

PERU
- Lima, Junta de Control de Energia Atomica

PHILIPPINE REPUBLIC
- Manila, Philippine Atomic Energy Commission

POLAND
- Warsaw, Biura Pelnomocnika Rzadu do Spraw Wykorzystania Energii Jadrowej

PORTUGAL
- Sacavem, Junta de Energía Nuclear

REPUBLIC OF SOUTH AFRICA
- Pretoria, Atomic Energy Board Library

REPUBLIC OF THE CONGO
- Leopoldville, Université Lovanium

SPAIN
- Madrid, Junta de Energía Nuclear, Biblioteca Documentación y Publicaciones, Ciudad Universitaria

SWEDEN
- Nyköping, Aktiebolaget Atomenergi

SWITZERLAND
- Zürich, Eidgenössiche Technische Hochschule, Bibliothek
- Geneva, United Nations Library

THAILAND
- Bangkok, Office of the Thai Atomic Energy Commission, Department of Science

TURKEY
- Ankara, Turkish Atomic Energy Commission, Atomic Energy Library

UNITED ARAB REPUBLIC
- Cairo, Atomic Energy Commission

UNITED KINGDOM
- Birmingham, Central Library
- Boston Spa, National Lending Library for Science and Technology
- Kingston upon Hull, Central Library
- Liverpool, Central Library
- London, Central Library, Acton
- London, National Reference Library
- London, Science Museum Library, South Kensington
- Manchester, Central Library
- Newcastle upon Tyne, Central Library
- Nottingham, Central Library
- Sheffield, Central Library

URUGUAY
- Montevideo, Comision Nacional de Energia Atomica

VENEZUELA
- Caracas, Instituto Venezolano de Investigaciones Cientificas

VIETNAM
- Saigon, Atomic Energy Office

YUGOSLAVIA
- Belgrade, Federal Commission for Nuclear Energy

TABLE 3.—INTERN

Title or Subject of

Symmetry Princi
High Energy.
Intermediate En
Physics.
Neutron Noise, V
and Pulse Prop
Isobaric Spin in
Physics.
Isochronous Cycl

Seventh Japan C
on Radioisotop
31st Cold Spring
Conference on
tative Biology-
"Genetic Code
Third Congress f
ation Research

Eleventh Pacific
Congress.
Second Internati
physics Congr
International Co
Radiation Pro

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TABLE 3.—INTERNATIONAL SCIENTIFIC CONFERENCES FINANCIALLY SUPPORTED BY THE AEC

Title or Subject of Conference	Conducted By	Place	Dates (1966)
Symmetry Principles at High Energy.	University of Miami	Coral Gables, Fla.	Jan. 20–22.
Intermediate Energy Physics.	College of William and Mary.	Williamsburg, Va.	Feb. 10–12.
Neutron Noise, Waves and Pulse Propagation.	University of Florida.	Gainesville, Fla	Feb. 14–16.
Isobaric Spin in Nuclear Physics.	Florida State University.	Tallahasse, Fla	March 17–19.
Isochronous Cyclotrons	Oak Ridge National Laboratory and Int'l Union of Pure and Applied Physics.	Gatlinburg, Tenn.	May 2–5
Seventh Japan Conference on Radioisotopes.	Japan Atomic Industrial Forum.	Tokyo, Japan	May 16–19.
31st Cold Spring Harbor Conference on Quantitative Biology—"Genetic Code".	Cold Spring Harbor Laboratory.	Cold Spring Harbor, N.Y.	June 2–9
Third Congress for Radiation Research.	National Academy of Sciences (NAS)-National Research Council (NRC).	Cortina, Italy	June 26–July 2
Eleventh Pacific Science Congress.	NAS-NRC	Tokyo, Japan	Aug. 22–Sept. 10
Second International Biophysics Congress.	NAS-NRC	Vienna, Austria	Sept. 5–9
International Congress on Radiation Protection.	U.S. Health Physics Society.	Rome, Italy	Sept. 5–10

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TABLE 4.—IAEA CONFERENCES FOR WHICH AEC COORDINATED U.S. PARTICIPATION

Subject	Place	Dates (1966)
Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters.	Vienna, Austria	May 16–20
Food Irradiation	Karlsruhe, Germany	June 6–10
Magnetohydrodynamic Electrical Power Generation.	Salzburg, Austria	July 4–8
Use of Radioisotopes and Radiation in Dairy Science and Technology.	Vienna, Austria	July 12–15
Neutron Monitoring for Radiological Protection.	Vienna, Austria	Aug. 29–Sept. 2
Use of Isotopes in Plant Nutrition and Physiology Studies.	Vienna, Austria	Sept. 5–9
Solid-State and Chemical Radiation Dosimetry in Medicine and Biology.	Vienna, Austria	Oct. 3–7
Standardization of Radionuclides	Vienna, Austria	Oct. 10–14
Nuclear Data—Microscopic Cross Sections and Other Data Basic for Reactors.	Paris, France	Oct. 17–21
Use of Isotopes in Hydrology	Vienna, Austria	Nov. 14–18
Radioisotope Tracers in Industry and Geophysics.	Prague, Czechoslovakia	Nov. 21–25
Alkali Metal Coolants	Vienna, Austria	Nov. 28–Dec. 2

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TABLE 5.—AEC-SPO

Titl
BOOK
Reactor Technolo Selected Revie
Fast Reactor Tec Plant Design.
Environment of t Thompson Reg
Biological Effects Radiation—An Bibliography c years 1898–195
Neutron Cross Se 325 Supplemen (Z = 41–60).
MONOGRAPHS (SOCIE
Beryllium: Its In Hygiene Aspec Industrial Hyg
Thorium: Its Inc giene Aspects (Industrial Hyg
Tissue Grafting a (American Inst logical Sciences
SYMPOSIUM PI
Radioactive Pha
Neutron Dynami trol.
Accelerator Radi etry and Expe
Commercial Plut Conference.
Neutron Cross S nology.
Large Scale Prod Applications o topes.
Swine in Biomed

*Available at indica Springfield, Va. 22151.

TABLE 5.—AEC-SPONSORED BOOKS, MONOGRAPHS, AND PROCEEDINGS PUBLISHED IN 1966

Title	Author(s) or Editor(s)	Publisher and Price
BOOKS		
Reactor Technology—Selected Reviews—1965.	L. E. Link, Ed.	U.S. Atomic Energy Commission,* $4.50.
Fast Reactor Technology Plant Design.	J. G. Yevick, Ed.	M.I.T. Press Cambridge, Mass., $35.00.
Environment of the Cape Thompson Region, Alaska.	N. J. Wilimovsky, J. N. Wolfe, Eds.	U.S. Atomic Energy Commission,* $9.25.
Biological Effects of Ionizing Radiation—An Annotated Bibliography covering the years 1898–1957.	Marylou Ingram, Compiler.	U.S. Atomic Energy Commission,* $12.00.
Neutron Cross Sections, BNL-325 Supplement 2 ($Z = 41$–60).	Brookhaven National Laboratory.	U.S. Atomic Energy Commission,* $8.00.
MONOGRAPHS (COOPERATING SOCIETY)		
Beryllium: Its Industrial Hygiene Aspects (American Industrial Hygiene Assoc.).	H. E. Stokinger, Ed.	Academic Press, New York City, $11.60.
Thorium: Its Industrial Hygiene Aspects (American Industrial Hygiene Assoc.).	Roy E. Albert	Academic Press, New York City, $7.00.
Tissue Grafting and Radiation (American Institute of Biological Sciences).	H. S. Micklem, H. F. Loutit.	Academic Press, New York City, $7.00.
SYMPOSIUM PROCEEDINGS		
Radioactive Pharmaceuticals	G. A. Andrews, R. M. Kniseley, H. N. Wagner, E. B. Anderson, Eds.	U.S. Atomic Energy Commission,* $5.00.
Neutron Dynamics and Control.	D. L. Hetrick, L. E. Weaver, Eds.	U.S. Atomic Energy Commission,* $4.50.
Accelerator Radiation Dosimetry and Experience.	----------	U.S. Atomic Energy Commission,* $6.75.
Commercial Plutonium Fuels Conference.	----------	U.S. Atomic Energy Commission,* $3.00.
Neutron Cross Section Technology.	----------	U.S. Atomic Energy Commission,* $11.25.
Large Scale Production and Applications of Radioisotopes.	----------	U.S. Atomic Energy Commission,* $7.00.
Swine in Biomedical Research	L. K. Bustad, M. P. Burns.	Frayn, Seattle $16.50.

*Available at indicated prices from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151.

TABLE 6.—TITLES OF BOOKLETS IN THE AEC'S "UNDERSTANDING THE ATOM" SERIES[1]

Accelerators [F,S]
Atomic Fuel [F,S]
Atomic Power Safety
Atoms at the Science Fair
Atoms in Agriculture [F,S]
Atoms, Nature, and Man [2]
Careers in Atomic Energy
Computers [2]
Controlled Nuclear Fusion
Direct Conversion of Energy [F,S]
Fallout from Nuclear Tests [3]
Food Preservation by Irradiation [S]
Genetic Effects of Radiation [2]
Microstructure of Matter
Neutron Activation Analysis [F,S]
Nondestructive Testing
Nuclear Clocks [2]
Nuclear Energy for Desalting [2,F,S,I]
Nuclear Power and Merchant Shipping
Nuclear Power Plants [2]
Nuclear Reactors [F,S]
Nuclear Terms, A Brief Glossary [2]
Our Atomic World [F,S]
Plowshare [2,S]
Plutonium [3]
Popular Books on Nuclear Science
Power From Radioisotopes [2]
Power Reactors in Small Packages
Radioactive Wastes
Radioisotopes and Life Processes [2]
Radioisotopes in Industry
Radioisotopes in Medicine [2]
Rare Earths [3]
Research Reactors
SNAP, Nuclear Space Reactors [2]
Synthetic Transuranium Elements
Whole Body Counters
Your Body and Radiation [2]

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[1] Single copies (limit: three titles per request) available free from USAEC, P.O. Box 62, Oak Ridge, Tenn. 37830.
[2] Published in 1966.
[3] Revised in 1966.
[F] French translation available.
[S] Spanish translation available.
[I] Italian translation available.

As part of its
picture libraries
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"public service"
ing AEC offices

Washington, D.C

New York, N.Y.

Aiken, S.C.

Idaho Falls, Ida
Berkeley, Calif.
Grand Junction,
Argonne, Ill.

Oak Ridge, Tenn

Albuquerque, N.
Richland, Wash.

Foreign Loan
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Buenos Aires, t
Stockholm, the
Vienna, the Am
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APPENDIX 9

AEC FILM LIBRARIES

As part of its information and education program, the AEC maintains motion picture libraries 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 in unsponsored "public service" telecasts. The domestic film libraries are located at the following AEC offices and service requests from the states as indicated:

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 PUBLIC DURING 1966

Professional Level

EXTRACORPOREAL IRRADIATION OF BLOOD AND LYMPH: 7½ minutes, color, produced by AEC's Brookhaven National Laboratory. Shows how blood and/or lymph may be irradiated in a well-shielded gamma ray source outside of the body through a closed circuit of teflon tubes from artery to vein.

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SHEAR-LEACH PROCESS FOR SPENT NUCLEAR FUELS: 11 minutes, color, produced by AEC's Oak Ridge National Laboratory. Illustrates the development of a mechanical method for reprocessing spent stainless steel or zircaloy-2 clad power reactor fuels. The film also summarizes data obtained from various shearing and leaching tests conducted at ORNL.

WASTE DISPOSAL BY HYDRAULIC FRACTURING: 10 minutes, color, produced by AEC's Oak Ridge National Laboratory. Depicts the process for the disposal of intermediate-level radioactive wastes in underground bedded shale formations for permanent disposal.

Professional and Popular Level

CONTROLLING RECORDS FIRES WITH HI-EXPANSION FOAM: 11 minutes, color, produced by AEC's Idaho Operations Office. Records a series of actual fire tests in which detergent foam extinguishes file room fires with little damage to records.

THE MASS OF ATOMS: 47 minutes, black and white, demonstrates the step-by-step operations in an experiment performed by two Mound Laboratory scientists to determine the masses of a helium and a polonium atom.

RETURN TO BIKINI: 28½ minutes, color, produced by the AEC by the Laboratory of Radiation Biology, University of Washington. Describes the latest scientific survey to determine the condition of Bikini and Eniwetok atolls six years after the last nuclear detonations, and how it found tremendous recovery to the biological processes that form the life chain linking man with the tiniest plants, fish and animals.

SAFETY IN THE PLOWSHARE PROGRAM: 22 minutes, color, produced by AEC's Nevada Operations Office. This companion to the AEC film "Plowshare," documents the means taken to insure the safety of the public during experiments or projects in the program to develop peaceful uses of nuclear explosives.

Popular Level

THE ATOM AND EVE: 15 minutes, color, produced for the Connecticut Yankee Atomic Power Co. shows how nuclear power has grown—and what 11 New England utility companies are doing to use nuclear power effectively because electric power is an integral part of everyday life.

ATOMIC ENERGY FOR SPACE: 17 minutes, color, produced by the Handel Film Corp. with the cooperation of the AEC and NASA. Explains why only atomic energy can satisfy some of the future power needs for the exploration of deep space—the nuclear rocket for space propulsion, and isotopic or reactor powerplants which can produce the electricity essential for spacecraft operations.

ATOMIC POWER TODAY: SERVICE WITH SAFETY: 28½ minutes, color, produced for the Atomic Industrial Forum, Inc., and the AEC by Seneca Productions, Inc. Tells the many ways that safety is built into the planning, reviewing, constructing and inspecting of central station atomic powerplants to serve the country now and in the future.

FARM FRESH TO YOU: 13½ minutes, color, produced for the AEC by the Army Pictorial Center. Describes the new method of preserving certain fresh fruits and vegetables by irradiation pasteurization.

THE FRESHER THE BETTER: 13½ minutes, color, produced for the AEC by the Army Pictorial Center. Shows the preservation of fresh seafoods by radiation pasteurization, to extend refrigerated shelf life up to three times that of non-irradiated fresh seafood.

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MIRACLE IN THE DESERT—THE HANFORD STORY: 29 minutes, color, produced by AEC's Richland Operations Office. Tells the historical summary of plutonium production and other varied nuclear activities at Hanford Works including the special diversified industrial-government relationships now in effect.

PROJECT LONG SHOT: 11½ minutes, color, produced by USAF for DASA. Report on operation Long Shot, an underground nuclear test on the Aleutian Islands chain, part of the Vela Uniform Program to increase the U.S. capability to detect, identify and locate underground nuclear detonations.

SNAP-8: SYSTEM FOR NUCLEAR AUXILIARY POWER: 10 minutes, color, produced for the AEC by the Aerojet-General Corp. Describes the principal components, subsystems, and testing of the mercury-vapor-turbogenerator system to convert heat from a nuclear reactor into useful electricity.

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APPENDIX 10
MANPOWER IN THE ATOMIC ENERGY FIELD[1]

Economic Segment	Total Employees		Scientists		Engineers		Technicians		All Other Employees		Percent S&E in R&D	
	Government	Private	Government	Private	Government	Private	Government	Private	Government	Private	Government	Private
AEC Laboratories & Research Facilities	47,207	-------	7,221	------	7,672	------	10,288	------	22,026	-------	87.0	------
Atomic Energy Defense Production	29,338	429	1,114	------	2,614	71	3,060	96	22,550	262	29.8	56.3
Production of Feed Materials	6,696	343	415	15	484	16	516	54	5,281	258	43.3	41.9
Reactors & Reactor Components	2,097	12,068	134	695	798	2,983	294	2,116	871	6,274	88.1	63.0
Nuclear Design & Engineering	1,832	2,223	10	77	301	1,158	333	512	1,188	476	10.3	59.0
Power Reactor Optns. & Maint	250	764	5	5	46	130	54	207	145	422	------	8.1
Production of Spl. Mtls. for Reactors	-------	1,503	------	50	-------	132	-------	240	-------	1,081	------	30.8
Uranium Milling	-------	2,054	------	22	-------	146	-------	129	-------	1,757	------	4.2
Fuel Element Fabr. & Rcvy. Act	-------	1,693	------	58	-------	218	-------	415	-------	1,002	------	24.6
Radioactive Waste Disposal	-------	58	------	------	-------	4	-------	29	-------	25	------	------
Nuclear Instrument Manufacturing	1,401	4,068	122	251	176	521	712	738	391	2,558	82.6	48.8
Industrial Radiography Services	-------	534	------	6	-------	44	-------	434	-------	50	------	6.0
Processing & Packaging Radioisotopes	-------	642	------	189	-------	29	-------	222	-------	202	------	22.9
Private Research Laboratories [2]	-------	1,703	------	415	-------	341	-------	541	-------	406	------	82.4
Particle Accelerator Manufacturing	-------	1,098	------	72	-------	187	-------	266	-------	573	------	39.0
Miscellaneous	12,556	2,073	493	118	842	541	884	429	10,337	985	67.2	56.3
TOTAL	101,377	31,253	9,514	1,973	12,933	6,521	16,141	6,428	62,789	16,331	73.3	56.1

[1] Employment by occupational categories in government-owned and privately owned industrial establishments by economic segment, March 1966.
[2] Excludes nonprofit establishments.

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AEC records.

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Financial Report
Printing Office, V

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APPENDIX 11

AEC FINANCIAL SUMMARY FOR FISCAL YEAR 1966*

The Atomic Energy Commission is an independent agency responsible to the President and Congress. It was established by the Atomic Energy Act of 1946 to assume the responsibilities for the development, use, and control of atomic energy and for the production of nuclear weapons previously assigned to the U.S. Army. In 1954 the functions and responsibilities of the AEC were expanded to provide for greater emphasis on developing and promoting peaceful uses of atomic energy. Ownership of all special nuclear materials was vested in the United States Government until 1964 when legislation was enacted to permit such material to be owned privately.

The AEC's operating expenses are approximately $2.5 billion per year. In accomplishing its assigned mission, the AEC uses assets totaling nearly $8.7 billion. These assets include $1.5 billion in cash and funds available from the U.S. Treasury, $1.1 billion in inventory and $5.9 billion in Government-owned production and research facilities.

Most of the work involved in actually achieving the AEC goals is performed by commercial firms or educational and other non-profit organizations under contract to the AEC. Many of these contractors operate Government-owned facilities. Employees of the contractors who operate the Government facilities total approximately 112,000. The AEC has about 7,400 employees.

The AEC has a decentralized organization with offices located in various parts of the country to administer one or more of the major production or research and development contracts.

Since the AEC is engaged in large-scale industrial and research activities, those responsible for its management require knowledge of the cost of each step in its operations. At the same time, the AEC accounting system 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. Major contractors maintain complete accounting records for their AEC activities, and these are an integral part of the AEC's accounting system. The summary contained in the following pages is a consolidation of information obtained from financial reports made to the AEC by its contractors and information obtained from the AEC records.

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*Material in this appendix is extracted from the "U.S. Atomic Energy Commission—1966 Financial Report," available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, price 50 cents.

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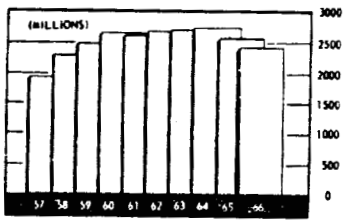
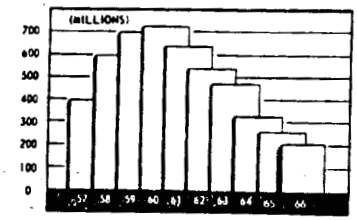
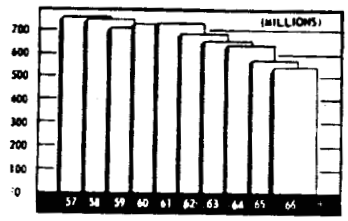
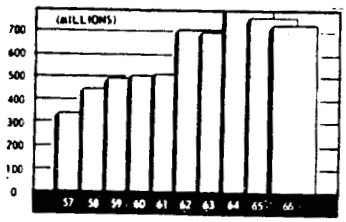
SUMMARY OF NET OPERATING COSTS

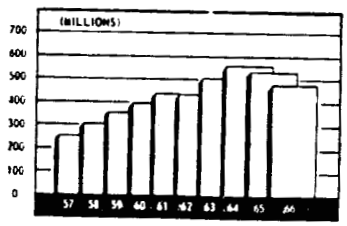


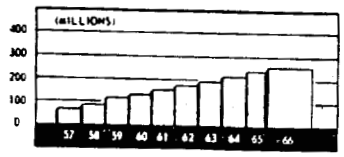
	1966 (Millions)	
TOTAL OPERATING COSTS . . .	$2,440	100%
PROCUREMENT OF RAW MATERIALS	$206	8%
PRODUCTION OF NUCLEAR MATERIALS . .	$544	22%
WEAPONS DEVELOPMENT AND FABRICATION . . .	$730	30%
REACTOR DEVELOPMENT . .	$484	20%
PHYSICAL RESEARCH . . .	$265	11%
OTHER PROGRAMS	$211	9%

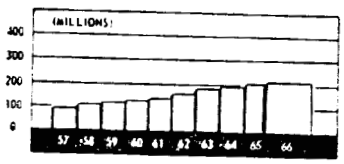












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STATEMENT OF OPERATIONS

	Fiscal Year 1966	Fiscal Year 1965
	[In thousands]	
Production		
Procurement of raw materials	$206,310	$261,082
Production of nuclear materials	543,931	571,301
Weapons development and fabrication	729,570	763,128
	1,479,811	1,595,511
Research and development		
Development of nuclear reactors	483,718	536,135
Physical research	265,002	236,980
Biology and medicine research	90,757	84,417
Plowshare	15,766	12,316
Isotope development	12,801	9,593
	868,044	879,441
Community operations		
Expenses	7,838	8,903
Revenues	(5,006)	(5,341)
	2,832	3,562
Sales of materials and services		
Cost	52,917	28,615
Revenue	(61,097)	(34,168)
	(8,180)	(5,553)
Education and training	10,014	9,536
AEC administrative expenses	83,872	80,258
Security investigations	6,340	5,286
Other expenses	9,639	9,271
Other income	(12,642)	(7,514)
Net cost of operations*	2,439,730	2,569,798
Special items		
Adjustments to costs of prior years—net	52,847	91,814
Transfers to inventories—net	(145,203)	(120,363)
Net cost of operations—after special items*	$2,347,374	$2,541,249

*Includes depreciation of $329 million in 1966 and $324 million in 1965.

BALANCE SHEET

[In thousands]

Assets*	June 30, 1966	June 30, 1965
Cash		
Funds in U.S. Treasury	$1,522,072	$1,559,105
Cash on hand and with contractors	11,678	21,398
Transfers from other agencies	5,765	7,777
	1,539,515	1,588,280
Accounts receivable		
Federal Agencies	53,707	36,143
Other	54,261	27,342
	107,968	63,485
Inventories		
Source and nuclear materials leased and at research installations	842,780	789,523
Special reactor materials	103,864	102,505
Stores	88,891	84,896
Isotopes	39,988	33,662
Other special materials	14,667	14,385
	1,090,190	1,024,971
Plant		
Completed plant and equipment	8,747,500	8,470,362
Less—Accumulated depreciation	3,194,952	2,914,493
	5,552,548	5,555,869
Construction work in progress	300,044	400,677
	5,852,592	5,956,546
Other	66,169	56,618
TOTAL ASSETS	$8,656,434	$8,689,900

Liabilities and AEC Equity*	June 30, 1966	June 30, 1965
Liabilities		
Accounts payable and accrued expenses	$313,900	$300,759
Advances from other agencies	14,200	18,585
Funds held for others	15,037	14,979
Accrued annual leave of AEC employees	9,582	9,290
Deferred credits	16,799	11,709
Total Liabilities	369,518	355,322
AEC Equity, July 1	8,334,578	8,257,591
Additions		
Funds appropriated—net	2,365,893	2,624,555
Non-reimbursable transfers from other agencies	7,326	13,535
	2,373,219	2,638,090
Deductions		
Net cost of operations—after special items	2,347,374	2,541,249
Non-reimbursable transfers to other agencies	73,498	19,838
Funds returned to U.S. Treasury	9	16
	2,420,881	2,561,103
AEC Equity, June 30	8,286,916	8,334,578
TOTAL LIABILITIES AND AEC EQUITY	$8,656,434	$8,689,900

... in progress	300,044	400,677	AEC Equity, June 30	8,286,916	8,334,578
Other	5,852,592	5,956,546			
	66,169	56,618			
TOTAL ASSETS	$8,656,434	$8,689,900	TOTAL LIABILITIES AND AEC EQUITY	$8,656,434	$8,689,900

*The notes on the following page are an integral part of this statement.

NOTES TO THE BALANCE SHEET

1. *The Balance Sheet does not include in assets:*
   a. Certain inventories for security reasons.
   b. 64,751,316 troy ounces of silver loaned to 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 market quotations at June 30, 1966, the value of the silver on loan was $83,723,000. The value of silver lost and the cost of recovering and processing that on hand and returning it to the Treasury is estimated at $678,000.
   c. Plant and equipment on loan from other Federal Agencies at June 30, 1966, amounting to $36,393,000.
   d. Contested claims against others of $5,957,000.
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, 1966, the estimated liabilities would have amounted to $184,090,000.
   b. Contingent liabilities as guarantor of loans to the extent of $1,374,000.
   c. Contingent liabilities for claims against the AEC of $20,549,000.
   d. Commitments for an estimated 39,379 tons of U_3O_8 at an estimated cost of $559,500,000.
   e. 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 $553,000 for fiscal year 1967 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.
   f. Outstanding contracts, purchase orders, and other commitments of $1,114,000,000.

COSTS INCURRED BY RESEARCH LABORATORIES

A major portion of AEC research and development is conducted in Government-owned laboratories. On June 30, 1966, the AEC's investment in research facilities totaled $2.7 billion. Of this amount, $1.8 billion was invested in the major Government-owned laboratories. These facilities included research reactors, particle accelerators, general laboratory buildings, equipment, and research devices. This research and development work conducted in AEC laboratories includes 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 ten laboratories listed below are the principal AEC-owned research centers. The operating costs of these laboratories, together with the costs incurred at other AEC-owned installations, and the cost of the work performed in facilities owned by universities, industrial, and other privately owned organizations are included in the costs of the various research areas shown throughout this summary.

[In thousands]

Laboratories	Cost of Completed Plant June 30, 1966	Operating Costs Fiscal Year	
		1966	1965
Ames Research Laboratory	$18,450	$8,326	[illegible]
Argonne National Laboratory [1]	310,195	82,872	77,9[illegible]
Bettis Atomic Power Laboratory [1]	126,711	57,627	6[illegible]
Brookhaven National Laboratory	212,767	58,616	82,[illegible]
Knolls Atomic Power Laboratory [1]	138,548	41,717	5[illegible]
Lawrence Radiation Laboratory [2]	272,045	161,370	151,[illegible]
Los Alamos Scientific Laboratory [2]	227,955	104,373	97,[illegible]
Oak Ridge National Laboratory [3]	320,097	84,877	78,[illegible]
Pacific Northwest Laboratory	86,014	34,186	28,[illegible]
Savannah River Laboratory	68,765	12,835	15,[illegible]

[1] Includes facilities at NRTS, Idaho.
[2] Includes facilities at Mercury, Nev.
[3] Includes Experimental Gas Cooled Reactor formerly held by TVA.

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COSTS INCURRED BY GEOGRAPHICAL LOCATIONS

The following table shows the costs incurred by the AEC in fiscal year 1966. 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	$97		$97
Alaska	55		55
Arizona	7,930	$1	7,931
Arkansas	263		263
California	262,363	76,176	338,539
Colorado	55,649	6,695	62,344
Connecticut	15,665	1,016	16,681
Delaware	45		45
District of Columbia	15,327	120	15,447
Florida	14,451	1,641	16,092
Georgia	960	35	995
Hawaii (including Pacific Test Area)	4,113	33	4,146
Idaho	50,670	17,544	68,214
Illinois	81,339	15,685	97,024
Indiana	2,970	73	3,043
Iowa	16,008	3,000	19,008
Kansas	581	13	594
Kentucky	61,951	587	62,538
Louisiana	333		333
Maine	349		349
Maryland	40,003	321	40,324
Massachusetts	23,908	4,227	28,135
Michigan	5,368	377	5,745
Minnesota	3,477	513	3,990
Mississippi	75		75
Missouri	82,793	4,938	87,731
Montana	91		91
Nebraska	799	5,249	6,048
Nevada	165,269	22,132	187,401
New Hampshire	86		86
New Jersey	16,152	3,543	19,695
New Mexico	360,952	46,647	407,599
New York	104,768	23,133	127,901
North Carolina	1,498	489	1,987
North Dakota	24		24
Ohio	111,025	7,966	118,991
Oklahoma	339		339
Oregon	1,278	22	1,300
Pennsylvania	89,237	4,333	93,570
Puerto Rico	2,831	1,019	3,850
Rhode Island	676		676
South Carolina	81,564	15,022	96,586
South Dakota	3,991		3,991
Tennessee	185,797	33,218	219,015
Texas	19,893	3,284	23,177
Utah	16,780	309	17,089
Vermont	30		30
Virginia	2,592	61	2,653
Washington	133,494	20,454	153,948
West Virginia	314		314
Wisconsin	3,715	3,105	6,820
Wyoming	34,734	14	34,748
Foreign Countries	55,747	200	55,947
Total	$2,140,419	$323,195	$2,463,614

*Excludes depreciation.

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 249 colleges or universities for atomic energy work. The table below shows that the cost of this work totaled about $120 million in fiscal year 1966 and identifies each university where costs in excess of $500,000 were incurred.

Colleges and Universities	Fiscal Year 1966	
	Rank by Dollar Volume of Costs Incurred	Total Costs (in thousands)
Brown University	37	[illegible]
California Institute of Technology	12	[illegible]
California, University of	3	2,4[illegible]
California, University of, at Los Angeles	11	[illegible]
Carnegie Institute of Technology	17	2,[illegible]
Case Institute of Technology	33	1,[illegible]
Chicago, University of	23	[illegible]
Colorado, University of	34	1,4[illegible]
Columbia University	6	[illegible]
Cornell University	22	4,[illegible]
Duke University	27	1,[illegible]
Florida State University	28	1,[illegible]
Florida, University of	42	1,[illegible]
Harvard University	4	[illegible]
Hawaii, University of	44	7,[illegible]
Illinois, University of	5	[illegible]
Johns Hopkins University	30	4,[illegible]
Maryland, University of	19	1,[illegible]
Massachusetts Institute of Technology	2	1,[illegible]
Michigan State University	20	7,[illegible]
Michigan, University of	13	1,[illegible]
Minnesota, University of	15	2,[illegible]
New York University	18	2,[illegible]
Notre Dame, University of	26	1,[illegible]
Oregon State University	43	1,[illegible]
Pennsylvania State University	39	[illegible]
Pennsylvania, University of	16	[illegible]
Princeton University	1	2,0[illegible]
Puerto Rico, University of	14	16,3[illegible]
Purdue University	25	2,2[illegible]
Rensselaer Polytechnic Institute	24	1,3[illegible]
Rice University	35	1,3[illegible]
Rochester, University of	7	[illegible]
Southern California, University of	38	4,[illegible]
Stanford University	40	[illegible]
Tennessee, University of	21	[illegible]
Texas A&M University	29	1,4[illegible]
Texas, University of	32	1,0[illegible]
Utah, University of	31	[illegible]
Virginia, University of	36	[illegible]
Washington, University of	10	[illegible]
Western Reserve University	41	2,6[illegible]
Wisconsin, University of	9	[illegible]
Yale University	8	3,1[illegible]
Other (205 colleges or universities)		3,7[illegible]
		13,5[illegible]
Total		$119,5[illegible]

*These costs exclude depreciation and include construction and capital equipment.

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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 1966, the AEC's principal prime industrial contractors accomplished work amounting to some $1,643 million. The following table 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 listed below.

Industrial Organizations	Fiscal Year 1966	
	Rank by Dollar Volume of Costs Incurred	Total Costs* (in thousands)
ACF Industries, Inc.	18	$20,940
Aerojet-General Corp.	9	41,777
American Metal Climax, Inc.	32	6,403
Anaconda Co.	26	12,043
Atlas Corp.	23	15,586
Atomics International Division, North American Aviation, Inc.	10	40,928
Bendix Corp.	6	75,623
Catalytic Construction Co.	39	5,025
Combustion Engineering Corp.	31	7,600
Douglas United Nuclear, Inc.	13	30,303
Dow Chemical Co.	11	36,351
Edgerton Germeshausen & Grier, Inc.	14	25,505
E. I. du Pont de Nemours & Co.	5	92,313
Federal-Radorock-Gas Hills Partners	34	6,018
Fluor Corp., Ltd.	37	5,524
General Atomic Division, General Dynamics Corp.	25	13,699
General Electric Co.	3	128,715
Goodyear Atomic Corp.	8	51,440
Holmes & Narver, Inc.	30	7,889
Homestake-Sapin Partners	21	17,402
Isotopes Inc.	20	17,708
Jones, J. A. Construction Co.	35	5,946
Kermac Nuclear Fuels Corp.-Kerr-McGee Oil Industries, Inc.	15	24,636
Mallinckrodt Chemical Works	29	8,541
Mason & Hanger-Silas Mason Co.	17	22,328
Mines Development, Inc.-Susquehanna Corp.	38	5,386
Monsanto Research Corp.-Monsanto Co.	16	22,882
National Lead Co.	19	20,485
Pan American World Airways, Inc.	24	13,739
Petrotomics Co.	36	5,881
Phillips Petroleum Co.	12	32,848
Reynolds Electrical and Engineering Co., Inc.	4	109,191
Sandia Corp.-Western Electric Co., Inc.	2	207,680
Union Carbide Corp.	1	269,692
United Nuclear Corp.	22	15,607
Utah Construction & Mining Co.	28	9,003
Western Nuclear, Inc.	27	9,745
Westinghouse Electric Corp.	7	53,069
Zia Co.	33	6,333
Other		141,578
Total		$1,643,362

*These costs exclude depreciation and include construction and capital equipment.

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AEC PLANT AND EQUIPMENT BY LOCATION

(At cost) June 30, 1966

Location and contractor	Authorized plant and equipment (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
CALIFORNIA				
University of California				
Lawrence Radiation Laboratory				
Berkeley	$95.7	$3.9	$12.4	$112.0
Livermore	166.9	9.3	47.9	224.1
Total	262.6	13.2	60.3	336.1
University of California, Davis Bio-Med Research Facilities	4.1	.2	.6	4.9
University of California at Los Angeles				
Medical Research Facilities	1.7	----------	.2	1.9
Stanford University, Palo Alto				
Linear Electron Accelerator	55.3	48.6	10.5	114.4
Other Research Facilities	4.7	4.1	14.0	22.8
Total	60.0	52.7	24.5	137.2
Sandia Corp., Livermore Research Facilities	22.8	1.1	1.7	25.6
California Institute of Technology, Pasadena				
Research Facilities	2.2	----------	2.0	4.2
Atomics International, Division of North American Aviation, Inc., Canoga Park and Santa Susana				
Reactor and Research Facilities	54.7	1.4	7.1	63.2
Westinghouse Electric Corp., Sunnyvale				
Project Rover Test Facilities	----------	1.2	.2	1.4
Aerojet-General Corp., Sacramento				
Reactor Facilities	.8	----------	----------	.8
Total California	408.9	69.8	96.6	575.3
COLORADO				
Lucius Pitkin, Inc., Grand Junction				
Uranium Handling, Sampling and General Facilities	4.2	----------	.1	4.3
Dow Chemical Co., Boulder				
Rocky Flats Plant	109.4	8.5	13.5	131.4
University of Colorado, Boulder	1.7	----------	.1	1.8
Total Colorado	115.3	8.5	13.7	137.5
CONNECTICUT				
Pratt and Whitney Aircraft, Inc., Middletown				
Lithium Cooled Experiment	[3] 57.2	----------	[4] .3	57.5
Yale University, New Haven				
Linear Accelerator	5.3	3.0	1.6	9.9
Combustion Engineering, Inc., Windsor				
Submarine Reactor Facilities	15.2	----------	----------	15.2
Total Connecticut	77.7	3.0	1.9	82.6

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 gIn Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
FLORIDA				
General Electric Co., Clearwater				
Pinellas Plant	$17.3	$0.8	$3.7	$21.8
IDAHO				
National Reactor Testing Station, Idaho Falls; Idaho Nuclear Corp.				
Chemical Processing Plant	65.1	.4	1.5	67.0
Experimental Organic Cooled Reactor	10.2	----------	----------	10.2
Flight Engine Test Facilities	4.2	----------	----------	4.2
Advanced Test Reactor	30.8	17.9	6.9	55.6
Materials Test Reactor	15.1	.1	.6	15.8
Engineering Test Reactor	15.8	----------	----------	15.8
Test Reactor Area	21.3	.2	2.6	24.1
Army Reactor Area	5.1	----------	----------	5.1
Low Power Test Facilities	2.1	----------	----------	2.1
General Facilities	54.0	.3	4.5	58.8
Total	223.7	18.9	16.1	258.7
Westinghouse Electric Corp.				
Large Ship Reactor	35.9	----------	----------	35.9
Submarine Thermal Reactor	16.2	1.4	10.0	27.6
Other Research Facilities	18.4	.5	2.8	21.7
Total	70.5	1.9	12.8	85.2
Phillips Petroleum Co.				
Nuclear Safety Test Engineering	5.4	4.9	14.6	24.9
Power Burst Facility	.1	1.8	7.5	9.4
Special Power Excursion Reactor Test	9.2	.1	.1	9.4
Total	14.7	6.8	22.2	43.7
Argonne National Laboratory				
Reactor Facilities	38.7	.9	3.7	43.3
General Electric Co.				
Knolls Atomic Power Laboratory	20.4	.1	.3	20.8
General Atomic Division of General Dynamics				
Experimental Beryllium Oxide Reactor	10.0	----------	.1	10.1
Total Idaho	378.0	28.6	55.2	461.8
ILLINOIS				
University of Chicago and Argonne Universities Assn.				
Argonne National Laboratory	271.5	13.9	85.4	370.8
University of Chicago				
Argonne Cancer Research Hospital	5.4	.1	1.1	6.6
Research Equipment	1.4	----------	.5	1.9
University of Illinois, Urbana				
Research Facilities	2.7	.2	.8	3.7
Total Illinois	281.0	14.2	87.8	383.0

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

Location and contractor	Authorized plant and equipment (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1] [2]	Total
INDIANA				
University of Notre Dame, Notre Dame				
Radiation Laboratory	$2.4	----------	$0.5	$2.9
IOWA				
Ames Research Laboratory, Ames				
Research Facilities	14.5	$1.5	2.8	18.8
Research Reactor	3.9	.8	.1	4.8
Mason and Hanger, Burlington				
AEC Plant	38.3	.5	4.1	42.9
Total Iowa	56.7	2.8	7.0	66.5
KENTUCKY				
Union Carbide Corp., Paducah				
Gaseous Diffusion Plant	755.7	.2	1.7	757.6
Feed Materials Plant	31.1	----------	----------	31.1
Total Kentucky	786.8	.2	1.7	788.7
MARYLAND				
AEC Headquarters, Germantown	20.5	----------	1.0	21.5
MASSACHUSETTS				
Harvard University, Cambridge				
Cambridge Electron Accelerator	19.5	.5	4.1	24.1
Edgerton, Germeshausen & Grier, Inc., Boston				
Research Facilities	20.4	.3	3.5	24.2
Massachusetts Institute of Technology, Cambridge				
Research Facilities	4.8	----------	5.4	10.2
Total Massachusetts	44.7	.8	13.0	58.5
MICHIGAN				
University of Michigan, Ann Arbor				
Research Facilities	1.9	----------	.2	2.1
MINNESOTA				
University of Minnesota, Minneapolis				
Linear Accelerator	2.2	2.6	.9	5.7
Rural Cooperative Power Assn., Elk River				
Elk River Reactor	9.1	.1	1.8	11.0
Total Minnesota	11.3	2.7	2.7	16.7
MISSOURI				
The Bendix Corp., Kansas City				
Kansas City Plant	65.9	4.4	10.3	80.6
Mallinckrodt Chemical Works, Weldon Spring				
Feed Materials Plant	62.6	.1	.3	63.0
Total Missouri	128.5	4.5	10.6	143.6

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

Location and contractor	Authorized plant and equipment (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1 2]	Total
NEBRASKA				
Consumers Public Power District, Hallam				
Hallam Nuclear Power Facility	[3] $41.3	----------	$0.3	$41.6
NEVADA				
Mercury:				
Reynolds Electrical & Engineering Co.				
Nevada Test Site	125.0	$3.9	17.8	146.7
Lawrence Radiation Laboratory				
Laboratory Facilities	9.4	----------	----------	9.4
Total	134.4	3.9	17.8	156.1
Jackass Flats:				
Nuclear Rocket Development Station				
Project Rover				
Los Alamos Scientific Laboratory	15.6	.1	1.2	16.9
Pan American World Airways, Inc	50.2	5.9	11.9	68.0
Westinghouse Electric Corp	.9	.2	.2	1.3
Other Research Facilities	1.8	----------	----------	1.8
Total	68.5	6.2	13.3	88.0
U.S. Highway 95 Improvement, Las Vegas	4.3	----------	.2	4.5
Sandia Corp., Tonapah				
Research Facilities	10.2	.1	.2	10.5
Total Nevada	217.4	10.2	31.5	259.1
NEW JERSEY				
Princeton University, Princeton				
Princeton-Pennsylvania Proton accelerator	29.0	4.2	4.9	38.1
Model C. Stellarator Facilities	24.4	.1	.4	24.9
Atomic Energy Commission, New Brunswick				
New Brunswick Laboratory	3.1	----------	----------	3.1
Total New Jersey	56.5	4.3	5.3	66.1
NEW MEXICO				
Albuquerque:				
Lovelace Foundation Laboratory	3.9	----------	.6	4.5
Sandia Corp.				
Sandia Laboratory	155.6	9.4	30.2	195.2
ACF Industries, Inc.				
South Albuquerque Works	36.4	.1	3.4	39.9
Total	195.9	9.5	34.2	239.6
Los Alamos:				
University of California				
Los Alamos Scientific Laboratory	212.3	16.2	34.0	262.5
The Zia Co.				
Community and General Maintenance Facilities	128.8	4.2	5.7	138.7
Total	341.1	20.4	39.7	401.2
Total New Mexico	537.0	29.9	73.9	640.8

See footnotes at end of table.

AEC PLANT AND EQUIPMENT BY LOCATION—Continued

Location and contractor	Authorized plant and equipment (in millions)			
	Completed	Construction Work In Progress	Estimated Cost to Complete Construction Projects [1,2]	Total
NEW YORK				
New York City:				
New York University				
Computing and Other Research Facilities	$1.5	----------	$0.2	$1.7
Columbia University				
Accelerator and Research Facilities	3.9	----------	.5	4.4
Atomic Energy Commission				
Health and Safety Laboratory	2.0	----------	.6	2.6
Total	7.4	----------	1.3	8.7
Associated Universities, Inc., Upton				
Brookhaven National Laboratory	212.8	$10.3	39.6	262.7
Nuclear Materials and Equipment Corp., Niagara Falls				
Boron Plant	7.4	----------	.3	7.7
University of Rochester, Rochester				
Medical Laboratory and 130″ Cyclotron	6.5	----------	.4	6.9
General Electric Co., Schenectady and West Milton				
Knolls Atomic Power Laboratory	118.1	3.4	10.2	131.7
Rensselaer Polytechnic Institute, Troy				
Accelerator Facility	2.6	.1	----------	2.7
Air-Preheater Division of Combustion Engineering, Wellsville				
Project Rover	----------	1.4	.1	1.5
Total New York	354.8	15.2	51.9	421.9
OHIO				
General Electric Co., Cincinnati				
Research Facilities	8.7	.5	1.4	10.6
Goodyear Atomic Corp., Portsmouth				
Gaseous Diffusion Plant	765.4	.5	1.7	767.6
National Lead Co., Fernald				
Feed Materials Plant	119.0	.7	2.1	121.8
Monsanto Chemical Co., Miamisburg				
Mound Laboratory	49.8	5.5	19.2	74.5
City of Piqua, Piqua				
Piqua Nuclear Power Facility	9.2	.1	1.0	10.3
Reactive Metals, Inc., Ashtabula				
Feed Materials Facility	1.7	.1	.2	2.0
Battelle Memorial Institute, Columbus				
Research Facilities	1.0	----------	----------	1.0
Total Ohio	954.8	7.4	25.6	987.8
PENNSYLVANIA				
Westinghouse Electric Corp., Pittsburgh				
Bettis Atomic Power Laboratory	54.4	.9	14.4	69.7
Carnegie Institute of Technology, Pittsburgh				
Accelerator and Research Facilities	1.5	----------	----------	1.5
Duquesne Light Co., Shippingport				
Shippingport Atomic Power Station	62.4	.4	.3	63.1
Westinghouse Electric Corp., Shippingport				
Research Facilities	2.0	2.5	1.1	5.6
Westinghouse Electric Corp., Large				
Astro Nuclear Laboratory	5.3	.2	.8	6.3
Total Pennsylvania	125.6	4.0	16.6	146.2

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
SOUTH CAROLINA				
E. I. duPont de Nemours & Co., Inc., Aiken				
Savannah River Plant				
Production Reactor and Separation Facilities	$899.4	$8.8	$24.8	$933.0
Feed Materials Production Facility	30.5	1.1	.7	32.3
Heavy Water Production Facilities	163.4	.2	----------	163.6
Works Laboratory	68.8	1.2	3.7	73.7
General Facilities	161.1	7.5	3.5	172.1
Total South Carolina	1,323.2	18.8	32.7	1,374.7
TENNESSEE				
Oak Ridge:				
Oak Ridge Associated Universities Research Laboratory	5.2	.1	.4	5.7
University of Tennessee				
Agriculture Research Laboratory and Farm	2.7	.5	.5	3.7
Union Carbide Corp.				
Gaseous Diffusion Plant	823.5	1.8	7.7	833.0
Y-12 Plant	380.1	6.7	10.8	397.6
Oak Ridge National Laboratory	320.1	15.9	29.0	365.0
Management Services Inc. of Tenn.				
Service Facilities	10.4	----------	.1	10.5
Total Tennessee	1,542.0	25.0	48.5	1,615.5
TEXAS				
Mason and Hanger, Amarillo				
Pantex Plant	51.9	.5	5.7	58.1
Rice University, Houston				
Research Facility	1.6	----------	----------	1.6
Total Texas	53.5	.5	5.7	59.7
UTAH				
University of Utah, Salt Lake City	1.1	.1	.1	1.3
WASHINGTON				
Hanford Works:				
General Electric Co.				
Production Reactor Facilities	188.7	2.3	4.8	195.8
Feed Materials Production Facilities	5.0	.3	.1	5.4
General Facilities	.8	----------	----------	.8
Total	194.5	2.6	4.9	202.0
Douglas United Nuclear, Inc.				
Production Reactor Facilities	493.9	3.6	3.0	500.5
Feed Materials Production Facilities	17.8	.2	.3	18.3
General Facilities	18.8	----------	----------	18.8
Total	530.5	3.8	3.3	537.6

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
WASHINGTON—Continued				
Isochem Inc.				
Separation Facilities	$245.1	$10.5	$14.0	[illegible]
General Facilities	2.9	----------	.3	[illegible]
Total	248.0	10.5	14.3	272.[illegible]
Battelle Memorial Institute				
Pacific Northwest Laboratory	86.0	13.6	12.5	112.[illegible]
ITT/Federal Support Services, Inc.				
General Facilities	82.1	.6	2.2	84.[illegible]
Computer Sciences Corp.				
General Facilities	3.9	----------	.1	4.[illegible]
J. A. Jones Construction Co.				
General Facilities	2.4	----------	----------	2.[illegible]
Total Washington	1,147.4	31.1	37.3	1,215.[illegible]
WEST VIRGINIA				
International Nickel Co., Huntington Pilot Plant	4.7	----------	----------	4.7
WISCONSIN				
University of Wisconsin, Madison				
Research Facilities	1.3	----------	----------	1.3
Dairyland Power Cooperative, Genoa				
LaCrosse Boiling Water Reactor	.1	10.0	.6	10.7
Total Wisconsin	1.4	10.0	.6	12.0
PUERTO RICO				
University of Puerto Rico, Mayaguez				
Puerto Rico Nuclear Center	5.7	.4	.7	6.8
Puerto Rico Water Resources Authority, Punta Higuera				
Boiling Nuclear Super Heat Reactor	10.2	3.2	.6	14.0
Total Puerto Rico	15.9	3.6	1.3	20.8
JAPAN				
National Academy of Sciences, Hiroshima				
Research Facilities	2.7	.1	.3	3.1
All Other	37.2	3.9	58.8	99.9
TOTALS	$8,747.5	$300.0	$686.0	$9,733.5

[1] Includes capital equipment.
[2] Includes plant and capital equipment authorized in Public Law 89-428, approved May 21, 1966.
[3] Deactivated and disposed of in August 1966.
[4] Estimated disposal cost.
[5] Deactivated.

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