UNITED STATES U.S. ATOMIC ENERGY COMMISSION

Eighteenth Semiannual Report

OF THE

ATOMIC ENERGY COMMISSION

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LETTER OF SUBMITTAL

WASHINGTON, D. C.
29 July 1955.

SIRS: We have the honor to submit herewith the Eighteenth Semi-annual Report of the United States Atomic Energy Commission, as required by the Atomic Energy Act of 1954.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION,
WILLARD F. LIBBY.
THOMAS E. MURRAY.
JOHN VON NEUMANN.
LEWIS L. STRAUSS, *Chairman.*

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

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SUMMARY

Bulking large in the record of atomic energy development of the past 6 months[1] has been the swift advance of the Atoms-for-Peace program around the world.

Within the past 60 days of the period under report here, 27 other nations entered into agreements for cooperation with the United States in developing the civil uses of atomic energy. To supply the fuel that would eventually be required for research reactors under these many agreements, the President authorized adding 100 kilograms (220 pounds) of uranium 235 to the original 100 kilograms set aside in late 1954 for atoms-for-peace programs. This was announced by the Chairman of the Commission in an address to the Overseas Press Club, New York, in late June. The President also enlarged the scope of the program in two statements. At the Associated Press luncheon in New York City, April 25, the President advocated construction of a nuclear-powered merchant ship and its use in demonstration cruises about the world to portray the peaceful uses of atomic energy. In May the Executive Branch placed before the Congress requests for funds for the atomic-powered ship program. At Pennsylvania State University in mid-June, the President in a speech proffered financial aid to other nations in the construction of research reactors, and training and technological aid in the development of power reactors by friendly nations.

Extensive preparations were made for the contributions of the United States to the International Conference on Peaceful Uses of Atomic Energy at Geneva in August. The conference originally was proposed by this Nation, and its management was assumed by the United Nations last December as noted in the following chapter.

Various training courses were inaugurated by the Atomic Energy Commission for technical men of other nations. Libraries of all the unclassified technical material published by the Commission were authorized for presentation to 23 other nations at their request. The record of major developments in the atoms-for-peace movement as it gathered momentum and gained wider participation is presented in the first section of this report.

The other activities of the Atomic Energy Commission continued at a growing rate and with increasing effectiveness. The program for developing civilian applications through the access of the American industrial and educational community to the accumulated knowledge in this field took shape and moved forward on various fronts.

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[1] This report notes certain events that have occurred subsequent to the reporting period.

Domestic production of uranium ore and concentrates during the first 6 months of 1955 reached record levels—making the United States one of the world's leading uranium producers—while production from foreign sources continued to increase. Greatly accelerated exploration activity by private industry resulted in the discovery of potentially large deposits of uranium ore in presently nonproducing areas off the Colorado Plateau. Research and process development studies on economic methods for recovery of uranium from its ores continued.

Increased availability of raw materials, along with the startup of new plant capacity, resulted in new high levels in the production of special nuclear materials, at lower unit cost.

All of the new gaseous diffusion facilities authorized in 1952 except that at Portsmouth, Ohio, were completed and contributing to production. Construction at Portsmouth proceeded on schedule. New facilities at the Hanford and Savannah River reactor sites began operation during this period. Design of additional feed materials processing facilities at Fernald, Ohio, St. Louis, Mo., and Paducah, Ky., progressed satisfactorily, and construction at the three sites began during March.

Largely as a result of this progress in construction, capital investment in atomic energy plant facilities was estimated to have reached about $6.6 billion before depreciation reserves.

A prominent event in the weapons research and development program was a successful test series (Operation TEAPOT) conducted at the Nevada Test Site from February 18–May 15. The Federal Civil Defense Administration conducted its "Operation Cue" in connection with the 13th nuclear test of this series. This was the most comprehensive civil-defense exercise held in Nevada to date. Details of the exercise are given under "Civil Effects Experiments" (pp. 81–83).

The Commission's program of developing reactors for industrial and military power and for naval and aircraft propulsion made greater strides during the first 6 months of 1955 than in any earlier half-year. During this period the AEC moved toward greater participation by industry in advancing the development of competitive nuclear power. Toward this end, the Commission set up an expanded program for making classified information available to industry, established a classified schedule of prices and charges for materials furnished by the AEC, and prices for special nuclear material produced in power reactors. Four industrial proposals were received for the power demonstration reactor program. The number of industrial participation groups was increased from 18 to 25, bringing the number of individual firms now in the program to 81.

Major construction work is in progress at the Shippingport (Pa.) site of the Nation's first civilian nuclear powerplant. This 60,000-kilowatt version of the pressurized water reactor will be operated by the Duquesne Light Co. of Pittsburgh.

The first nuclear-powered submarine, the USS *Nautilus*, got under way on nuclear power on January 17, while the second such submarine, the USS *Seawolf*, was launched on July 21, at the Electric Boat Division, General Dynamics Corp., Groton, Conn. A 100–hour full power test of *SIR* Mark A, the land-based prototype of the engine designed to propel the *Seawolf*, was successfully completed. Surplus steam from *SIR* Mark A will be channeled into a 10,000-kilowatt turbine generator installed and operated by the General Electric Co. at no cost to the Government. The resulting electrical output will be sold by AEC as a demonstration of the first commercial usage of atomic-produced electricity.

Design and development work on the large ship reactor continued at the Bettis Plant by the Westinghouse Electric Corp. under AEC contract. The first phase of the Army's Package Power Reactor program was completed, and the Aircraft Nuclear Propulsion program accelerated, with the promise of nuclear-powered flight considerably brightened.

The physical research program continued to be the source of many of the new ideas contributing to the Nation's progress in atomic energy. University participation in this program is emphasized in this report. The leading role of academic institutions in the training of scientists is cited, and some major university contributions in physics, chemistry, and metallurgy are described. A few outstanding research accomplishments of the past 6 months at Commission laboratories are outlined here, such as the discovery of element 101 (Mendelevium).

In the biology and medicine program of the Commission advanced methods and procedures employing radiation as a tool helped to increase fundamental knowledge of the biological and chemical processes that take place in living things. Current progress herein reported on research projects is indicative of the broad scope of this program. Data on the biological and medical phases of the 1955 atomic test series in Nevada are given in this report. In April, the Commission announced that it will make radioisotopes for all biomedical and agricultural research, and research in medical therapy and diagnosis available to domestic users at 20 percent of the AEC established price, effective July 1.

In its community operations, the Commission's revised proposed legislation to facilitate the establishment of local self-government, and to provide for disposal of Federally-owned properties at Oak

Ridge, Tenn. and Richland, Wash. was introduced in the Congress on April 26, by members of the Joint Committee on Atomic Energy.

The Division of Civilian Application (formerly the Division of Licensing) was established in June to administer the Commission's licensing function and related responsibilities pertaining to the civilian use of atomic energy under the Atomic Energy Act of 1954.

On March 15 Dr. John von Neumann took office as Commissioner, following his confirmation by the Senate. Appointment of Brigadier General Kenneth E. Fields as General Manager was announced by the Commission, effective May 1. General Fields, former Director of the Division of Military Application, retired from the Army. He succeeded K. D. Nichols who resigned from the AEC on April 30 to become an engineering consultant.

In the staff, David F. Shaw was appointed Assistant General Manager for Manufacturing. Mr. Shaw had been manager of the Hanford Operations Office since June 1950. Harold L. Price, Deputy General Counsel, formerly designated Special Assistant to the General Manager for Licensing, was appointed director of the new Division of Civilian Application (formerly the Division of Licensing). W. Kenneth Davis who had been serving since January 1 as Acting Director, Division of Reactor Development, was appointed Director of the Division. Col. Alfred D. Starbird, USA, was appointed Director, Division of Military Application. William C. Wampler was appointed Special Assistant to the General Manager (Congressional).

MAIN DEVELOPMENTS IN THE ATOMS-FOR-PEACE PROGRAM

" . . . the United States pledges . . . to devote its entire heart and mind to find the way by which the miraculous inventiveness of man shall not be dedicated to his death but consecrated to his life."

President Eisenhower addressing the
United Nations General Assembly
December 8, 1953.

Following the President's historic address before the General Assembly of the United Nations, December 8, 1953, the United States Government embarked on a program of international cooperation which has become generally known as the Atoms-for-Peace program. The pace of events was quickened and the scope of the Atoms-for-Peace program broadened in late 1954 after passage of the Atomic Energy Act of 1954. This revision of the basic atomic energy statute authorized various actions in the international field which had been impossible previously.

The acceleration continued into the first half of 1955. Support for the growing number of projects involved took an increasing share of the time and attention of the Commission and staff. This first section of the Eighteenth Semiannual Report of the Commission to the Congress sums up the main developments of the Atoms-for-Peace program in which the AEC played a part during this period.

Five major projects were underway including (1) drafting and negotiations looking toward early establishment of an International Atomic Energy Agency; (2) negotiation of bilateral agreements for cooperation between the United States and other nations in the civil uses of atomic energy; (3) preparations for United States participation in the International Conference on the Peaceful Uses of Atomic Energy, to be held in Geneva, Switzerland, August 8–20, 1955 under the aegis of the United Nations; (4) organization and conduct of United States programs for training and orientation of students and professional men of other countries in the peaceful uses of atomic energy; (5) provision of Atoms-for-Peace libraries of AEC-published reference materials on atomic energy development to other nations which desire such a collection of technical literature in this field. There were several other single actions supporting the Atoms-for Peace idea during the 6 months and these will be noted.

Steps Toward an International Atomic Energy Agency

The early establishment of an International Atomic Energy Agency of the type proposed in President Eisenhower's address was endorsed by the General Assembly of the United Nations in December 1954. Earlier, the United States, under the leadership of Ambassador Morehead Patterson, appointed especially to negotiate for such an agency, had exchanged views with the United Kingdom, Canada, France, Australia, Belgium, South Africa, and Portugal on the initial organization and functions of such an agency. The initiative taken by these eight countries was approved in the UNGA resolution. Following the resolution, discussions were extended, and the drafting of a statute for the Agency was set underway. The Atomic Energy Commission has provided technical assistance in the drafting, and has furnished technical information for the use of the United States negotiators carrying on the conversations with other states.

While the negotiations looking toward an International Atomic Energy Agency proceeded, the Commission and the Department of State made great progress with the second phase of the Atoms-for-Peace program.

BILATERAL AGREEMENTS FOR COOPERATION IN THE CIVIL USES OF ATOMIC ENERGY

Negotiation of bilateral agreements for cooperation between other nations and the United States in the civil uses of atomic energy was set underway early in 1955. By early July agreements with 27 nations were initialed or signed. After Presidential approval, each agreement was forwarded to the Joint Committee on Atomic Energy in accordance with the requirements of the Atomic Energy Act of 1954. By the date of this report, the statutory waiting period had expired on all but 5 of the 27 agreements and they had either been signed or were ready for signature and entrance into force.

Standard Agreements for Research Assistance

Of the agreements 23 are of similar nature, providing for cooperation in research in the peaceful uses of atomic energy. This group of agreements sets the arrangements for cooperation between the Governments of the United States and Argentina, Brazil, Chile, China, Colombia, Denmark, Greece, Israel, Italy, the Republic of Korea, Japan, Lebanon, the Netherlands, Pakistan, Peru, Philippines, Portugal, Spain, Sweden, Switzerland, Thailand, Turkey, Venezuela, and Uruguay.

Under each agreement the United States Atomic Energy Commission will provide to the cooperating government unclassified information as to the design, construction and operation of research reactors and their use as research, training, development and engineering tools. It is contemplated that private American citizens and organizations would be authorized to supply to the cooperating government or authorized private persons under its jurisdiction appropriate equipment and services.

The proposed agreements further provide that the AEC will lease to each cooperating government up to six kilograms (13.2 pounds) of contained U 235 in uranium enriched up to a maximum of 20 percent U 235. Each recipient government assumes responsibility for using and safeguarding the fissionable material in accordance with the terms of the agreement. Each agreement provides for the exchange of unclassified information in the research reactor field, related health and safety problems and on the use of radioactive isotopes in physical and biological research, medical therapy, agriculture, and industry.

Looking to the future, each agreement expresses the hope and expectation of the parties that this initial agreement for cooperation will lead to consideration of further cooperation in the peaceful uses of atomic energy.

Switzerland. The agreement with Switzerland covers the sale by the United States and purchase by Switzerland of the research reactor which is to be a central feature of the official United States exhibit at the International Conference on Peaceful Uses of Atomic Energy at Geneva in August.

The price of the reactor, building, associated machinery and exhibits is to be $180,000. The United States will lease to Switzerland sufficient uranium enriched in the isotope U 235 for initial and replacement fuel for the reactor. The quantity of uranium under such lease shall not contain more than 6 kilograms of U 235 (maximum enrichment—20 percent), plus such additional quantity as the AEC may determine is necessary to permit the efficient and continuous operation of the reactor while replaced fuel elements are radioactively cooling in Switzerland or while fuel elements are in transit.

The relocation of the reactor at another site and the restoration of the Geneva site to its original condition are to be undertaken at the expense of Switzerland. Other provisions of the agreement cover the exchange of information relating to the reactor and its operation, and the sale or lease of materials other than special nuclear materials required in the operation of the reactor and not obtainable on the commercial market.

Sale of heavy water. As part of the President's program, the Commission has agreed to sell heavy water for use in research reactors to Italy, India, France and Australia.

The agreements with the Governments of Belgium, Canada, and the United Kingdom are of a special and more extensive character. Principal provisions in each, as summarized to the President in the Atomic Energy Commission's recommendation for his approval are as follows:

Belgium. There exists a special relationship between the Government of Belgium and the Government of the United States in the field of atomic energy, and beginning with discussions initiated in 1940 the two Governments have closely cooperated with each other in this field. Under an arrangement made in 1944, the Belgian Government agreed with the Governments of the United States and the United Kingdom that all uranium ores wherever located should be subject to effective control for the protection of civilization, and the Government of Belgium undertook to insure the effective control of such ores located in all territories subject to its authority.

The Belgian Government also agreed that all uranium ores in the Belgian Congo, including ore from the rich Shinkolobwe Mine, should be made available to the United States and the United Kingdom through commercial contracts, and that it would use its best endeavors to supply such quantities of uranium ores as might be required by the Governments of the United States and the United Kingdom. The Governments of the United States and of the United Kingdom, on their part, agreed that the Belgian Government should participate on equitable terms in the utilization of these ores as a source of energy for commercial power at such time as the two Governments should decide to employ the ores for this purpose.

Since the 1944 arrangement, the Government of Belgium, through commercial contracts, has made available to the United States and to the United Kingdom a vitally important quantity of uranium produced in the Belgian Congo. This has constituted a unique contribution to the defense of the western world and to our strength as a nation dedicated to the preservation of peace and freedom.

In addition to being the principal foreign supplier of uranium, Belgium's interest in atomic energy is also evident in its strong scientific and technical community. This interest led in 1950 to the establishment of a Nuclear Research Center to coordinate the country's atomic energy programs, and current plans call for work in both the research and power fields.

The agreement with Belgium calls for an exchange of classified and unclassified information relating to the development of peaceful uses of atomic energy, and, particularly, the development of atomic power, including general information on the overall progress and economies of power reactor programs and technological information required for the construction of specific reactors for the Belgian program and other specified reactor information. The agreement also provides for an exchange of research materials not available commercially, and for the transfer of equipment and devices.

However, the parties will not exchange Restricted Data under the agreement relating to design or fabrication of atomic weapons or information which, in the opinion of the Commission, is primarily of military significance; and no Restricted Data concerning the production of special nuclear materials will be exchanged except that concerning the incidental production of special nuclear materials in a power reactor. Further, the Commission will not transfer any materials or equipment and devices which in the opinion of the Commission are primarily of military significance.

It is provided in the agreement that the Commission will sell to the Government of Belgium such quantities of uranium enriched in the isotope U 235 as Belgium may require, during the period of the agreement, for use in research and power reactors, subject to any limitations in connection with quantities of such material available for such distribution by the Commission during any year, and subject to the further limitation that the quantity of uranium enriched in the isotope U 235 of weapon quality in the possession of Belgium by reason of transfer under the agreement shall not, in the opinion of the Commission, be of military significance. Enriched uranium to be sold under the agreement will be limited to uranium enriched in the isotope U 235 up to a maximum of 20 percent U 235.

The Government of Belgium, on its part, gives to the U. S. AEC an option to purchase any special nuclear materials produced in Belgium, the Belgium Congo, or Ruandi-Urundi, from materials purchased from the Commission and which are in excess of Belgium's need in its program for the peacetime uses of atomic energy.

The agreement also provides for the continuance of existing commercial contracts relating to the sale of uranium ores and concentrates; and the Government of Belgium undertakes to use its best endeavors to see that the Combined Development Agency (a contracting agency which acts on behalf of the United States and the United Kingdom with respect to the purchase of uranium and thorium ores and concentrates) will have a first option to purchase 90 percent of the uranium and thorium and concentrates produced in Belgium and the Belgian Congo during calendar years 1956 and 1957, and 75 percent of such ores and concentrates produced during the calendar years 1958, 1959, and 1960. Belgium also agrees to evaluate its requirements of uranium and thorium ore concentrates for the period of the agreement remaining after calendar year 1960 and to consult with the United

States for the purpose of establishing an agreed percentage of materials which thereafter the Combined Development Agency shall have the first option to purchase.

Equitable consideration has led to incorporating in the agreement a formula whereby the Government of Belgium may repurchase material in the event the diminution of available ore supply results in a decline in the rate of production of uranium ores and concentrates in Belgium and the Belgian Congo by as much as 80 percent of the rate of production in 1955 and if the strategic stockpiles of special nuclear material in the United States and the United Kingdom have been demilitarized, or if the civilian needs in the United States and the United Kingdom are covered without limitation by means of production and current imports of uranium ores and concentrates.

Canada. Canada and the United States were active partners in the wartime undertaking that resulted in the first release of atomic energy by man, and during World War II the collaboration between the two countries was close and invaluable. Since then, however, and until the passage of the Atomic Energy Act of 1954, United States participation in a cooperative effort to advance the peaceful uses of atomic energy was limited by law. Canada has closely cooperated with the United States in certain important areas and in a way which has made a valuable contribution to our common defense and security.

The agreement with Canada calls for an exchange of classified and unclassified information relating to the application of atomic energy to peaceful uses, for an exchange of research materials not available commercially, for the use of research and testing facilities, and for the transfer of equipment and devices. However, of the information which is classified, only that relevant to current or projected programs will be exchanged; and the parties to the agreement will not exchange Restricted Data under the agreement which, in the opinion of either country, is primarily of military significance or which relates to the design or fabrication of atomic weapons. Further, it is provided that the Commission will not transfer materials or equipment and devices which in its opinion are primarily of military significance, nor will it grant access to research and testing facilities which are primarily of military significance.

It is provided in the agreement that the Commission will sell to Atomic Energy of Canada Limited (a wholly-owned corporation of the Government of Canada) such quantities of uranium enriched in the isotope U 235 as may be required in the power reactor program in Canada during the period of the agreement, subject to the availability of this material for such distribution and to the limitation that the quantity of uranium enriched in the isotope U 235 of weapon quality in the possession of Atomic Energy of Canada Limited by reason of transfer under the agreement shall not be of military significance, as determined by the Commission. Enriched uranium to be sold under the agreement will be limited to uranium enriched in the isotope U 235 up to a maximum of 20 percent U 235.

The Government of Canada, on its part, will give to the Commission a first refusal of any special nuclear materials which it may desire to transfer outside of Canada, where such materials have been produced from the irradiation of fuel elements enriched with U 235 purchased from the Commission. The agreement also provides for continued collaboration between the two countries in the field of raw materials which already has resulted in the development of substantial uranium production in Canada which has been made available to the United States. Under the agreement, it will also be possible for the Commission to continue its use of Canadian reactors for special and unique irradiations of value in the Commission's weapons program. A still further benefit to the United States under the agreement will result from the strengthening of the United States domestic economy through the authorization granted United States industry to enter into commercial arrangements in the atomic energy field with the Government of Canada and its authorized nationals.

United Kingdom. Great Britain has from the beginning been one of the leaders in the development of atomic energy. Her scientists include great names in nuclear research, and her research and experimental centers are among the finest and most advanced in the world. British endeavor in the field of atomic energy preceded World War II, but in 1943 all work in this field was suspended in the British Isles, and the leading English scientists came to the United States and to Canada to labor jointly with the scientists of those countries in the development of the atomic bomb. The immense contribution made by the United Kingdom in the great scientific achievement which resulted is a matter of recorded history.

Since the war, the United Kingdom has developed and put into effect an impressive, comprehensive and highly integrated atomic energy program; but collaboration and the exchange of atomic energy information between the two Governments was, until the passage of the Atomic Energy Act of 1954, severely limited by law. The agreement negotiated under the Atomic Energy Act of 1954, represents an important step toward achieving in the field of the peaceful uses of atomic energy the friendly tradition of cooperation which prevails in the other areas of relationships with Her Majesty's Government and will result in mutual benefit.

The agreement with the United Kingdom calls for reciprocal assistance in the achievement of the use of atomic energy for peaceful purposes, for the exchange of information between the United States

Atomic Energy Commission and the United Kingdom Atomic Energy Authority of classified and unclassified information relating to the application of atomic energy for peaceful uses (including such general information on design and characteristics of various types of reactors as is required to permit evaluation and comparison of their potential use in a power production program), for an exchange of research materials not available commercially, for the use of research and reactor testing facilities, and for the transfer of equipment and devices. However, of the information which is classified, only that relevant to current or projective programs will be exchanged.

The parties to the agreement will not exchange Restricted Data under the agreement which is primarily of military significance nor will they grant access to facilities which are primarily of military significance. Further it is specifically provided that the parties will not transport or export, or permit the transfer or export, under the agreement of any material, equipment or device which is primarily of a military character; and, further, that the disposition and utilization of atomic weapons and the exchange of Restricted Data relating to the design or fabrication of atomic weapons shall be outside the scope of the agreement.

Special nuclear material will be exchanged under the agreement only for research purposes and in such quantities and under such terms and conditions as may be agreed, subject to the general limitation that no material which is primarily of a military character will be transferred.

Provision of Additional Fissionable Material for Agreement Programs

So rapid was the progress in concluding proposed agreements, that it became necessary before the end of June to make provision for additional quantities of fissionable material to carry out eventually the United States commitments involved. Accordingly, the Commission recommended and the President approved supplementing the original 100 kilograms (220 pounds) of uranium 235 the United States set aside by a second 100 kilograms. The making available of the additional amount was announced by Chairman Strauss in an address on June 24 to the Overseas Press Club in New York City.

Presidential Proposal To Enlarge Scope of Aid

In an address at Pennsylvania State University on June 11, the President briefly outlined new programs which would enlarge the scope of United States assistance to other nations in development of research and power reactor projects under agreements with other nations or through an International Atomic Energy Agency. The President's statement of these proposals was as follows:

First: We propose to offer research reactors to the people of free nations who can use them effectively for the acquisition of the skills and understanding essential to peaceful atomic progress. The United States, in the spirit of partnership that moves us, will contribute half the cost. We will also furnish the acquiring nation the nuclear material needed to fuel the reactor.

Second: Within prudent security considerations, we propose to make available to the peoples of such friendly nations as are prepared to invest their own funds in power reactors, access to and training in the technological processes of construction and operation for peaceful purposes.

If the technical and material resources of a single nation should not appear adequate to make effective use of a research reactor, we would support a voluntary grouping of the resources of several nations within a single region to acquire and operate it together.

UNITED STATES PARTICIPATION IN THE INTERNATIONAL CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY

Early in December 1954 the United Nations General Assembly endorsed President Eisenhower's proposals both for an International Agency and for a UN conference of scientists and engineers on peaceful applications of atomic energy.

The Secretary-General of the United Nations in January convened an Advisory Committee for the conference composed of representatives of seven nations, one being the United States. The United States member is Dr. I. I. Rabi of Columbia University, who is Chairman of the General Advisory Committee to the AEC. The place selected for the conference was Geneva; the time August 8–20. Secretary-General Hammarskjold named a staff for the United Nations management of the conference, including as Secretary-General Professor Walter G. Whitman of Massachusetts Institute of Technology. On February 1, invitations were sent to 84 nations to take part in the conference. To the time of writing of this report in mid-July, 66 nations had accepted.

The United Nations had not completed its final program at this writing but United Nations Conference officials indicated that about 400 of the more than 1,000 papers accepted will be presented or discussed during the 165 hours of sessions at Geneva. The remainder will appear in the proceedings to be published by the United Nations. Papers from at least 25 nations will be included in the proceedings.

Each nation accepting the United Nations invitation to the conference may send an official delegation of up to five persons. On July 1, President Eisenhower approved the designation of the official United States Delegation. The members are:

Chairman, Mr. Lewis L. Strauss, Chairman, U. S. Atomic Energy Commission.

Vice Chairman, Dr. Willard F. Libby, Commissioner, U. S. Atomic Energy Commission.

Dr. I. I. Rabi, Professor of Physics, Columbia University, and Chairman, General Advisory Committee to the AEC.

Dr. Detlev W. Bronk, President, National Academy of Sciences; President, Rockefeller Institute for Medical Research.

Dr. Shields Warren, Scientific Director, Cancer Research Institute, New England Deaconess Hospital, Boston, Mass.

In addition to the official delegates, each nation may send technical advisers. These will be principally the scientists, engineers and economists who will present or discuss the topics on the Geneva agenda. The technical advisers from the United States will number about 150 and will represent a strong cross section of all segments of the public and private nuclear research and application programs in this country.

In February, the Commission organized the Office for International Conference (OIC) and named as its head Dr. George L. Weil, one of the pioneers in atomic energy research and formerly Assistant Director of the AEC Division of Reactor Development.

Under his direction, invitations were sent to more than 3,000 persons to submit ideas for papers for the Geneva Conference. The response was overwhelming and nearly 1,100 technical abstracts were received.

The abstracts, and later the papers developed from them, were processed by a number of reviewing committees set up by the OIC. This review included evaluation, checking for restricted data under the new tripartite classification guide and patent review. Duplications were eliminated and where a stronger United States contribution could be made, papers were combined. The work of these reviewing committees has been an important factor in the conference planning and preparation.

More than 500 United States abstracts were submitted to the United Nations. Although the conference program is not yet completed, it appears that about 175 United States papers will be read or discussed during the Geneva sessions. All of the remainder will appear in the proceedings. The United States will make contributions to every section of the conference agenda which includes more than 60 specific topics.

In addition to processing the abstracts and then the papers, the OIC worked out and put into effect a comprehensive plan for other contributions by the United States, including a research reactor which will be in actual operation at the conference site; technical and popular exhibits and a reference library at the Palais des Nations, the conference headquarters building.

Research Reactor

This will be the first United States actual operating reactor to be exhibited outside this country. It is of the pool type, one of the prototypes of research reactors which will become available to the nations with which the United States enters into bilateral agreements for cooperation. Two research reactors of this type are under construction on college campuses in the United States—at Pennsylvania State University and the University of Michigan. After the Geneva Conference, this particular reactor will be sold to the Government of Switzerland, as reported earlier.

The reactor will operate in a cylinder of purified water 10 feet in diameter and 21 feet deep. The core of the reactor—the fuel elements containing 18 kilograms of uranium, enriched to 20 percent (3.6 kilograms) in uranium 235—will be near the bottom of the tank, sitting on a pedestal.

The water acts as a shield to retain radiation and as a basic operating component—the moderator. Through the water, observers will be able to see the Cerenkov radiation effect, a blue glow emanating from the water in the immediate vicinity of the core. Operation will be at about 10 kilowatts, but the power will be flashed to about 100 kilowatts at times in order to emphasize the Cerenkov effect.

Delegates will be invited to watch demonstrations and experiments with the reactor. At other hours, the reactor will be open to the public. As a result of advances in instrumentation, it is possible for this reactor to be operated automatically from start to full power. Laboratory engineers point out that adaptation of this design will add safety factors for reactors of this type now under construction both in the United States and abroad.

The reactor was built at the Oak Ridge National Laboratory in the record time of 3 months. The Laboratory is operated under contract for the AEC by Union Carbide and Carbon Chemicals Co. The reactor was thoroughly tested before being dismantled, crated, and shipped in U. S. Government aircraft to Geneva over June 30–July 1. There it is housed in a temporary building adjacent to the Palais des Nations. The building contains about 3,000 square feet of floor space, which allows room not only for the reactor, but for exhibits of components and information related to the reactor.

Exhibits

The United States originated the idea of exhibits at the conference. Its application for exhibits space in the Palais des Nations was the first one, and some time was consumed thereafter by the United Nations in working out space allocations. While this went forward, many United States firms, universities, and agencies indicated interest in exhibiting. The range of subjects covered, the amount of floor space required, and the decision that the official exhibit at the Palais would be highly technical in nature, suited directly to the character of the conference, made it impossible to accommodate at one place all United States exhibits. The outcome was that only the official technical exhibits will be shown at the Palais. Two types of unofficial supplementary exhibits, both encouraged by the United Nations, will be presented in downtown Geneva at the Exhibition Palace. There will be wide United States participation, Governmental and private, in all three exhibits.

Official technical exhibits. The official technical exhibits at the Palais will occupy some 4,000 square feet of floor space. The framework for this exhibit has been designed and built under contract with the Atomic Energy Commission by the firm of Design and Production, Inc. It houses components, models, and displays contributed by many firms and organizations.

The exhibit provides an integrated story of peacetime atomic energy development on its technical side, from raw materials through fuel elements, models of reactors, reactor components, chemical processing, instrumentation, the uses of isotopes in biology and medicine and industry, and basic research. Every component or model in this exhibit has been supplied by an organization. The suppliers include 82 organizations, of which 63 are industrial and the remainder Government agencies or laboratories, universities and hospitals.

USIA exhibit. This exhibit, titled Atoms for Peace was built for the United States Information Agency and has been showing in West Germany. It will occupy 15,000 square feet of floor space in the Exhibition Palace in downtown Geneva. A number of the organizations which had originally offered materials for the official technical exhibit have found that these materials are adapted to supplementing and rounding out the USIA exhibit, and their contributions are being added to this display. Altogether 19 United States organizations, 17 of them industrial, have contributed extra materials for this educational showing.

Trade fair exhibit. This was organized by the management of the Exhibition Palace following U.N. encouragement of the enterprise. Twenty-two United States firms had taken space in this exhibit at the time this report was prepared.

In all some 100 American industrial and commercial firms, along with 50 academic, professional and private educational, medical and research organizations will be represented in one or more of the exhibits at the Geneva Conference.

Appendix 8 (pp. 155–160) lists the United States firms, universities, agencies and Government contractors who have contributed to the three types of exhibits and to the exhibit portion of the research reactor demonstration.

Technical Reference Library

For the use of the delegations at the conference, and as a display of certain atomic energy technical information resources available from the United States for use world-wide, the Delegation is installing a technical reference library in a room alongside the official technical exhibit. This library contains all the unclassified publications issued by the Atomic Energy Commission itself, and a cross section of the scientific and technical journals and the commercial books published in the United States and carrying atomic energy subject matter.

The AEC library is a replica of the ones being presented by the USAEC to other nations which wish them, as described in a separate section of this chapter (pp. 20–21). It includes 6,500 research and development reports, 1,500 printed and 5,000 reproduced in microcard; 34 case-bound books and 22 miscellaneous pamphlets; 11 volumes of the Commission's journal, *Abstracts of Nuclear Science*, and 55,000 catalog cards. The portion of the reference library at the Geneva Conference contributed by the scientific and technical societies and the commercial publishers includes more than 300 books, displays of 46 United States journals dealing with atomic energy subjects, and 54 publications by agencies of the United States Government other than AEC. The contributions to this portion of the library are listed in Appendix 6.

After the conference, the technical reference library will be presented by the United States Delegation to the library of the United Nations center at the Palais des Nations, to become a permanent part of its collection.

Film Program

To portray atomic science and technology in film, the United States delegation is providing to the UN management of the conference a collection of 7 technical films voiced in each of the four official languages. The showing of the films will be scheduled by the UN management for the conference. There will be an hour and a half of United States films on various technical reactor subjects; and an hour on the applications of radioisotopes in general science, chemistry, metallurgy, and biology and medicine. The contributors to this portion of the United States program for the conference are listed in Appendix 8.

The delegation staff includes as Executive Officer, Mr. Harry S. Traynor, Assistant General Manager; as Technical Director, Dr. George L. Weil; as Director of Public Information, Mr. John P. McKnight, Deputy Public Affairs Officer, United States Embassy, Rome, Italy. Also Mrs. Laura Fermi, widow of the late Enrico Fermi, will serve as Historian of the delegation.

The conference will be, it is now apparent, the outstanding scientific and technical event up to this time in the years following World War II. It will gather together the largest and most representative group of the world's specialists in nuclear science and the arts of applying atomic energy to human welfare that has ever been assembled. Old lines of scientific communication will be renewed and new ones formed. The collective knowledge of mankind on how to put the atom to work for material progress in all lines will be shared among the technical representatives of the great majority of the people of the world.

Training Programs

School of Nuclear Science and Engineering, Argonne National Laboratory

Without the training of technical personnel in the theories and the skills involved in the operation of nuclear reactors, both for research and power, and in the handling of the radioisotopes used in peacetime applications, no nation will be able to make rapid progress with its Atoms-for-Peace program. Therefore, along with the other actions detailed above, the Atomic Energy Commission has developed an extensive and growing program of training in various lines of specialization open to qualified students sent by nations cooperating in Atoms-for-Peace programs.

To start the work of training in reactor engineering the Commission opened on March 14 a new School of Nuclear Science and Engineering at the Argonne National Laboratory with Dr. Norman Hilberry, Associate Director of the Laboratory, as Director for the school. The school has a full time faculty and is provided with its own laboratory facilities. Dr. J. Barton Hoag, on loan from the U. S. Coast Guard Academy, is serving as Associate Director at the school. The first session will run 7 months. It includes unclassified courses in design, construction and operation of reactors for nuclear research; principles of design of nuclear power reactors; handling of irradiated materials and other related peacetime applications of nuclear energy.

Enrolled for the first session are 30 scientists and engineers from 19 nations representing a cross section of applicants from Europe, Central and South America and the Near, Middle and Far East. There are also 9 United States students in the class of 39.

The nations represented in the first class are: Argentina, Australia, Belgium, Brazil, Egypt, France, Greece, Guatemala, Indonesia, Israel, Japan, Mexico, Pakistan, the Philippines, Portugal, Spain, Sweden, Switzerland, and Thailand.

A second session is scheduled to begin in November and a third next March.

Present plans for expanding the training facilities—subject to Congressional approval—will bring the capacity of the school for each session to 120 students. When these men return to their own nations after completing the courses of the future, they will form a nucleus around which may develop their own country's group of specialists in reactor technology.

Courses in Radioisotope Techniques, Oak Ridge Institute of Nuclear Studies

For the past 6 years the Oak Ridge Institute of Nuclear Studies has conducted each year six 4-week courses in the safe and efficient handling of radioisotopes. Whenever possible, without excluding any United States candidates for enrollment, students from other countries have been admitted to these courses. However, so great has been the demand from the United States that very few students from other nations could be accommodated. To provide for training for students of other nations, the Commission held a special course for them starting May 2. Enrolled were 30 scientists and technicians from the following 21 nations: Australia, Canada, Chile, Colombia, Cuba, Egypt, Finland, Germany, Greece, Guatemala, India, Italy, Japan, Mexico, Netherlands, Pakistan, Peru, Philippines, Spain, Thailand, and Venezuela.

The training given to these students was identical with that given to American students at earlier sessions. In the future to make certain that training is readily available to people from all lands, up to 15 percent of the total enrollment in the radioisotopes handling courses at Oak Ridge will be reserved for students from other countries. In addition a second special course will be offered in October 1955.

Training in Biological and Medical Applications

An extensive program for conveying new knowledge available in the United States to special groups of doctors, surgeons and biological scientists from abroad was inaugurated June 20 when a group of 23 leading doctors and surgeons from 11 nations started a 37-day tour of hospitals, research centers, universities, and AEC installations in the United States. This tour was sponsored by the Department of State and the American Council on Education as well as by the Atomic Energy Commission. The medical program prepared for the group centered on the use of isotopes, reactors, and other atomic devices and techniques in medicine, with emphasis on their application to research and treatment in the field of cancer. The general medical applications of atomic energy also were covered.

The tour group included physicians and surgeons from Australia, Brazil, Denmark, Egypt, France, Italy, Japan, Philippines, Portugal, Spain, Turkey, and the United Kingdom.

Over and above such tours are the many training courses offered year in and year out in the United States dealing with the utilization of atomic energy in the fields of biology, medicine, and agriculture. Such courses are open to students from all over the world. The AEC is preparing a brochure listing these courses for world-wide distribution so that their availability may be known wherever training in these lines is desired. As some examples, pre- and post-doctoral training will be provided henceforth at Brookhaven National Laboratory, Argonne National Laboratory, Argonne Cancer Research Hospital, and the U. S. Atomic Energy Projects at the University of California, the University of California at Los Angeles, and the University of Rochester. Courses in the medical applications of atomic energy are available at the Harvard University Medical Physics Laboratory, the New England Deaconess Hospital Cancer Research Laboratory, and the Western Reserve University School of Medicine.

Technical Libraries

Since late in 1954, the Atomic Energy Commission has been prepared to make available to each foreign country upon request a library carrying all of the unclassified atomic energy publications of the AEC. This offer was announced by Ambassador Henry Cabot Lodge of the United States Mission to the United Nations on November 5, 1954. Ambassador Lodge stated:

"Always mindful of the day when it might be beneficial to present this material in package form despite the fact that it has always been available in individual items, we have accumulated 10 complete libraries of our own material, which we are prepared to give to the principal technical libraries of cooperating nations. And we will provide more than 10 if there is a demand for more."

The response has been widespread. In November 1954 a library was presented to Japan. Since then, the AEC has approved requests from the following nations: Argentina, Australia, Austria, Burma, Denmark, Egypt, Finland, France, Greece, India, Israel, Italy, Netherlands, New Zealand, Norway, Peru, Philippines, Portugal, South Africa, Spain, Sweden, and Turkey. In addition, the library on display at the Geneva conference will be presented to the United Nations library at Geneva and a partial library will be given to CERN.

The composition of these libraries was described in connection with the typical Atoms-for-Peace library which will be set up at the conference in Geneva and later presented to the library of the United Nations Center at Geneva. As new material is published by the AEC, periodical additions are made to these libraries—and to the 42 identical libraries maintained in the United States by the AEC and cooperating institutions. The United States asks only that the nations receiving AEC libraries reciprocate by providing their collections of similar official unclassified papers.

Other Projects

Atomic-Powered Ship. On April 25, speaking at the annual luncheon of the Associated Press, President Eisenhower proposed adding to the Atoms-for-Peace program a demonstration atomic-powered ship. "This new ship," the President said, "powered with an atomic reactor, will not require refueling for scores of thousands of miles of operation. Visiting the ports of the world, it will demonstrate to people everywhere this peacetime use of atomic energy, harnessed for the improvement of human living. In part, this ship will be an atomic exhibit, carrying to all people practical knowledge of the usefulness of this new science in medicine, agriculture and power production."

On May 9, the Commission transmitted to the Joint Committee a request for authorization of $21,000,000 to proceed with the building of the reactor and power system for the proposed ship. On May 26, in a request for supplemental appropriations for the Commerce Department, the White House included $12,650,000 for the Maritime Commission for "design and construction of the hull, crew training, and administration of its part of the program."

As of June 30, Congressional action had not been completed.

Atoms-For-Peace Stamp. The Post Office Department was scheduled to put on sale on July 28 a special three-cent commemorative "Atoms-

For-Peace" stamp. The design was chosen from more than 40 drawings and ideas submitted by the AEC and its contractors.

Assistance to USIA. The Commission and its contractors continued to furnish technical assistance to the USIA's growing atomic exhibits program whose showings have been viewed by more than 5,000,000 persons in other nations. AEC contractors and other firms and organizations have been most generous in supplying materials for these exhibits. The close liaison with USIA's other projects in support of the atoms-for-peace program has been maintained and strengthened.

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Raw Materials

Uranium concentrate production continued to increase during the first half of 1955. The production increase in the United States was substantial. Further sharp increases over the next 18 months are assured as a result of construction programs now under way or about to start. Domestic prospecting, exploration, and processing trends continued on the upswing. Foreign sources continued to supply a substantial quantity of concentrates, with South Africa assuming a more significant role. Research and process development studies on economic methods for the recovery of uranium from its ores continued.

Domestic Production

Domestic production of uranium ore and concentrates during the first 6 months of 1955 reached record levels—making the United States one of the world's leading uranium producers. The expansion of existing processing facilities and construction of new mills due for completion before the end of the year will add substantially to the present production rate. Private prospecting and exploration activity continued at a high level.

Ore Production

In June 1955, the number of producing mines in the United States was estimated at 850 as compared with some 795 in June 1954.

The potential uranium production area continued to expand with new discoveries in eastern Washington, North Dakota, and south-central Texas.

Ore Processing

Ore production continued to exceed present processing capacity with a resultant buildup of ore stockpile inventories at certain locations. However, stockpiles in excess of normal plant requirements are at mills just completed or at locations where new mills are being constructed or are planned.

A contract was completed between the Uranium Reduction Co. and the AEC for the construction of a large mill at Moab, Utah and the plant is now under construction. Negotiations are in progress for construction of a plant in the Cameron area of the Navajo Indian Reservation in Arizona. The Commission also completed a concentrate procurement contract with Mines Development, Inc. for the construction and operation of a processing plant at Edgemont, S. Dak. The plant is presently under construction. The U. S. Vanadium Co. and the Commission have reached an agreement on a major expansion of the present Uravan, Colo. mill, which is now under construction.

The Shiprock, N. Mex., mill of Kerr-McGee Oil Industries, Inc., now operating at rated capacity, is serving the mining areas of northeastern Arizona and also treating some of the high-grade ores of the Big Indian Wash area of Utah. Expansion of the Naturita, Colo. mill of the Vanadium Corp. of America was completed in March with full capacity operation in April. Expansion of Climax Uranium Co.'s Grand Junction, Colo. plant is completed. The plant of the Bluewater, N. Mex. mill of Anaconda Copper Mining Co. began full-capacity operation in April. Construction of another plant is proceeding rapidly with completion expected later in 1955. Vanadium Corp. of America's Durango, and Naturita, Colo. plants are operating above their rated capacities.

New Ore-Buying Stations

The new uranium ore-buying and sampling stations at Moab, Utah and Riverton, Wyo. were officially opened on February 1 and March 1, 1955, respectively. The Globe, Ariz. plant opened for receipt of ores in June, while plants at Greenriver, Utah and in the Tuba City, Ariz. area are expected to be in operation this year. The addition of Greenriver, Utah and Tuba City, Ariz. will bring to 17 the number of locations where producers may sell uranium ores.

Uranium From Phosphates

Three uranium recovery facilities are now producing and shipping small tonnages of uranium concentrates as a byproduct of the recovery of phosphate chemicals and fertilizers from Florida phosphate rock. These facilities are Blockson Chemical Co., Joliet, Ill.; International Minerals and Chemical Corp., Bartow, Fla.; and Virginia-Carolina Chemical Corp., Nichols, Fla. A fourth facility, the U. S. Phosphoric Products, Division Tennessee Corp. plant at East Tampa, Fla. is presently under construction.

FOREIGN ACTIVITIES

Belgian Congo

The Shinkolobwe mine in the Belgian Congo continued to be an important producer of uranium concentrates.

South Africa

Production from South Africa again increased over the previous 6-months period, with a total of 11 uranium processing plants now in operation.

Canada

In the Beaverlodge area of northern Saskatchewan the new, enlarged Eldorado Mining and Refining Co., Ltd. mill is now operating at full capacity. In addition to treating ore from the Ace Mine of Eldorado, the mill is accepting ores from several nearby mines. Construction of the large mill of Gunnar Mines, Ltd. in the Lake Athabaska area in northern Saskatchewan proceeded on schedule with mill startup expected in October 1955.

An underground development program is being carried on by Eldorado Uranium Mines, Ltd. in the Beaverlodge area of northern Saskatchewan, where surface drilling, completed in 1954, indicated extensive mineralization. National Exploration is also carrying out extensive underground development near the Beaverlodge plant. At the Verna property, which includes ground under lease to Eldorado, underground work continued on four levels with encouraging results. The entire Blind River area was the center of intensive prospecting and exploration activity by many companies. Construction of the Pronto Uranium Mines, Ltd. mill is scheduled for completion in September, 1955. The Quirke Lake and Nordic properties (Algom Uranium Mines) each has a large milling plant under construction. Drilling on Consolidated Denison property indicated substantial ore tonnages, and an underground development program is underway.

Considerable drilling and exploration activity continues in the Bancroft area of eastern Ontario, where large low-grade ore bodies were found.

Normal production was maintained at the Port Radium operation of Eldorado on Great Bear Lake.

Shipments from the Port Hope refinery were suspended during April, May and June in preparation for production of metal-grade uranium oxide.

Australia

The Radium Hill mine and treatment plant was officially opened on November 10, 1954, and low-grade mechanical concentrate is being stockpiled there until the Port Pirie chemical plant opens in July.

First shipments from the Rum Jungle ore processing plant, officially started up on December 19, 1954, arrived in the United States.

Widespread exploration continued in northern Australia, with two new areas—the Alligator River district in the Northern Territory and the Mt. Isa district in Queensland—appearing as potential producers.

Portugal

Portuguese operations continued at the normal rate during the past 6 months.

Combined Development Agency

The Combined Development Agency is a joint United Kingdom-United States-Canadian organization established in Washington in 1944 to develop the production and to undertake the procurement of uranium and thorium supplies in certain areas. The present membership is as follows: United States, Lewis L. Strauss, Dr. C. K. Leith, and Jesse C. Johnson; United Kingdom, Sir Edwin Plowden, and J. G. Bower; Canada, G. C. Bateman. Mr. Strauss is the Chairman of the CDA and Sir Edwin Plowden is the Deputy Chairman.

The agency at the present time has production contracts with the Belgian Congo, the Union of South Africa, Australia and Portugal.

Domestic Exploration

Greatly accelerated exploration activity by private industry resulted in the discovery of potentially large depósits of uranium ore in presently non-producing areas off the Colorado Plateau. The first large deposit of ore in a contact-metamorphic geologic environment was discovered in Stevens County, eastern Washington. Promising deposits were found in Gunnison and Fremont Counties, Colorado and private ground and airborne exploration located an area of significant uranium mineralization in Karnes County in south-central Texas.

The continually increasing number of prospectors and mining companies engaged in exploration and airborne surveying, coupled with a noticeable expansion of private geological consultant services, has permitted the Commission to emphasize the development of geologic information and criteria for finding new mineralized areas and new favorable stratigraphic horizons. Results of this work are made public to assist private interests in the exploration and development of favorable ground. (Technical reports on exploration, geology, and mineralogy are on sale at the Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.)

Drilling

Total drilling by the Government was approximately 350,000 feet during the first half of 1955, as compared to a rate of over a million feet a year in the past 2 years. The Commission's drilling was largely conducted on withdrawn lands which, upon completion of drilling, are leased to private companies or restored to the public domain. The rate of private drilling was accelerated and is now estimated at more than six times that of the Government. Continued increase of ore reserves was due largely to the discovery of new deposits and development of known deposits by private drilling.

Process Development

The U. S. Bureau of Mines Experimental Station at Salt Lake City, Utah, the National Lead Co., Inc. operating the Raw Materials Development Laboratory at Winchester, Mass., Battelle Memorial Institute, the Dow Chemical Co., and Arthur D. Little, Inc. are continuing to work on the development of both new and improved recovery processes for Colorado Plateau uranium ores.

Chattanooga uraniferous shale process studies continued on a laboratory and bench scale at Columbia University.

New ore testing facilities for both acid and alkaline processes for western ores are now in operation at the pilot plant at Grand Junction, Colo. This pilot plant, operated by National Lead Co., Inc., now has four separate processing circuits.

Studies on the recovery of uranium as a single product from Florida phosphatic leached-zone materials were completed. Although it was demonstrated that uranium can be recovered from the leached-zone material, this process is not considered economical by present standards.

Production

Production of special nuclear materials exceeded that during the previous 6 months, and attained new high levels.

Facilities for Production

All of the new gaseous diffusion facilities authorized in 1952, except that at Portsmouth, Ohio, were completed and contributing to production. Construction at Portsmouth proceeded as scheduled. New facilities at the Hanford and Savannah River reactor sites began operation during this period.

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Design of additional feed materials processing facilities, authorized last year at Fernald, Ohio, St. Louis, Mo., and Paducah, Ky., progressed satisfactorily and construction at the three sites began during March.

AEC-MVGC Contract

On July 16, 1955, the Director of the Bureau of the Budget, confirming an earlier oral discussion, wrote the Chairman of the Commission that "The President has requested me to convey his direction to the Atomic Energy Commission to take immediately the necessary steps to bring to an end the relationship between the Mississippi Valley Generating Co. and the Commission." The Commission is taking action in accordance with this direction.

Source and Special Nuclear Materials Accountability

Since the Atomic Energy Act of 1954 provided that the Government retain ownership and control of special nuclear materials, at the same time encouraging the use of these materials in industrial applications of atomic energy, the necessary accountability controls were formalized. These controls developed by the Division of Source and Special Nuclear Materials Accountability are expected to follow standard practices of private industry. They require periodic reports of holdings of special nuclear materials and periodic review by the Commission to find out if the control measures used are adequate. In this respect AEC's function corresponds in some ways to those of internal auditing staffs in industry.

In keeping with the Commission's policy of accounting for source and special nuclear materials on the basis of their dollar value, a review of AEC's current material accounting practices is planned. This review would determine if accounting practices have kept pace with the increasing volume and scope of Commission activities.

A criterion was developed to permit operations offices to maintain a routine evaluation of contractors' activities on the basis of dollar value of materials handled. This criterion advanced to a point where it could be applied to routine operations on a trial basis. It employs simple techniques of mathematical statistics and elementary formulas. If successful, its use will provide the AEC with a valuable guide in determining an appropriate balance between the value of material assets and the cost of material accounting control.

Proposals are being studied of the best means of preparing and distributing standard materials, improving and developing measurement methods, and providing facilities for verification of inventories of Government-owned source and special nuclear materials, in helping the Commission to carry out its responsibilities in retaining the Government's title to and control of such materials.

The fifth annual meeting of AEC's accountability representatives was held in Washington on June 22–24. Such annual discussions of mutual problems contribute significantly to improvements in materials accounting and provide a better understanding of overall Commission problems.

In conjunction with the June meeting an AEC and contractor meeting was held to discuss problems associated with the application of mathematical statistics to accountability goals. Papers were presented by AEC and contractor personnel describing techniques of mathematical statistics applied to the accountability program.

Construction and Supply

During the period January 1 through June 30, 1955, costs incurred for new plant and equipment were estimated to be $375 million, raising the total capital investment in atomic energy facilities to about $6.6 billion before depreciation reserves. Except for the Feed Material Expansion program now under way construction of most of the AEC major production plant facilities has been completed or passed its peak, and construction activity is gradually tapering off.

Costs incurred for new plant and equipment amounted to approximately $870 million during fiscal year 1955—AEC costs accounting for 2.2 percent of the Nation's total construction dollars.

For the first half of 1955 monthly incurred costs averaged about $63 million, a decrease of almost 25 percent from the $83 million per month for the previous 6-month period. A further moderate decline in monthly construction costs is expected during the second half of the calendar year.

Review of Real Property

An estimated 3,900 acres of land were or will be declared excess as the result of a program for review of AEC real property holdings. Criteria for such action in this review and in future reviews are that real property not essential for minimum operating and program needs, minimum physical requirements, and health and safety standards be disposed of as excess.

Emergency Relocation Center

Consistent with the Administration's policy of planning for the continuity of essential Government operations during an emergency period resulting from enemy action affecting the Nation's capital, the AEC prepared a plan to provide for carrying out its essential activities during any such emergency period. As part of this plan, an alternative headquarters was established at a location outside the District of Columbia where key members of the Commission's staff can assemble and conduct the most urgent operations. This alternative headquarters (emergency relocation center) is fully operational, with the necessary office supplies, equipment and communications facilities available for immediate use. Test operations were held at this center during the Nation-wide Operation ALERT, June 15–17.

Auction Sales

The AEC continued to dispose of surplus property by the auction sale method whenever the amount, value, type, and location of the property warranted. Returns from 6 auctions at Paducah, Savannah River, Oak Ridge, Portsmouth and Hanford, during the past 6 months, grossed from 17 to 29 percent of the original cost of the property sold.

Small Business

The AEC small business program, established in conjunction with the procurement activities of the AEC operations offices and cost-type contractors, was explained at a hearing before Subcommittee No. 2 of the House Select Committee on Small Business on March 2, 1955, and the Procurement Subcommittee of the Senate Select Committee on Small Business on May 5, 1955. The testimony described the action taken by the Commission to assure that a fair proportion of total supplies and services are procured from small business concerns.

A substantial portion of AEC procurement dollars continued to go to small business. From July 1, 1951, to March 31, 1955, AEC cost-type contractors awarded $2.44 billion in subcontracts. Small business concerns received $941 million or 38.6 percent of the total amount. Direct contract awards to small business during the same period amounted to $172.8 million or 3 percent of the $5.6 billion in contracts awarded during the same period.

Military Application

Immediately following Operation CASTLE, the test series held at the AEC's Pacific Proving Ground in the spring of 1954, the weapons program was directed toward development of weapons whose design was based on results of those tests. During the first 6 months of 1955, weapons produced in accordance with the President's directive included types incorporating such designs.

Operation TEAPOT

Another prominent event in the weapons program during the period of this report was Operation TEAPOT, at the Nevada Test Site. This was a series of 14 nuclear tests conducted between February 18 and May 15. It took only 7 more days than the 11-shot, 80-day series conducted at the Nevada site in the spring of 1953 despite the heavier schedule.

Operation TEAPOT introduced a concept of "dual capability" permitting two nuclear devices to be ready for firing on several occasions—one "sensitive" and the other "nonsensitive" in terms of various test criteria including public safety. Under this concept it was sometimes possible to delay the most "sensitive" tests until conditions were more favorable—using the less ideal periods before or after these for a less sensitive test. On March 29 this dual readiness for testing allowed the firing of a sensitive test at 4:55 a. m. (Pacific Standard Time) and another less sensitive one at 10 a. m. (Pacific Standard Time), the first time that 2 nuclear tests were carried out in one day.

The firing of 2 more nuclear devices than originally planned for the series again demonstrated the unique advantages of a continental testing facility. Data developed in the weapons laboratories and from the tests themselves, indicated the need for two additional tests and it was possible to plan and fire them during Operation TEAPOT. This accomplishment would have been impossible without the special advantages offered by the Nevada site.

In conducting Operation TEAPOT the Commission again worked jointly with the Department of Defense, the Federal Civil Defense Administration, and other Government agencies. Private enterprises participated under Government contracts. The Commission, through its contractors, was responsible for the test devices and diagnostic measurements, while the associated military and civil tests were performed by the Department of Defense, FCDA, and other interested agencies. The Department of Defense also used several of the scheduled detonations for indoctrination of military personnel.

The Federal Civil Defense Administration conducted its "Operation Cue" in connection with the thirteenth nuclear test of the series on May 5. This was the most comprehensive FCDA exercise held in Nevada to date, and consisted of emergency feeding, radiological safety monitoring, and other disaster-related training exercises before and after the detonation.

One nuclear shot in the series and one non-nuclear test were specifically designed to determine effects of high altitude atomic detonations required in connection with development of nuclear warheads to be used against attacking enemy aircraft.

Operation WIGWAM

In addition to Operation TEAPOT, a joint AEC-Department of Defense test (Operation WIGWAM) was conducted in the Eastern Pacific ocean in mid-May. The principal purpose of the test was to study effects of a deep underwater detonation. The Commission participated in the test by furnishing the device, assisting in its final assembly and placement, and conducting diagnostic measurements. As forecast, indications are that the test involved no health hazard to mainland or island inhabitants or consumers of fish.

Contract with ACF

A definitive contract with ACF Industries, Inc., replaced the letter contract under which certain engineering, design, fabrication, testing, and operating work have been carried on by ACF at Buffalo, N. Y., for more than a year. The new contract extends from February 1954 to June 1959.

Community Operations

Community Disposal

Revised proposed legislation to facilitate the establishment of local self-government, and to provide for disposal of Federally owned properties at Oak Ridge, Tenn. and Richland, Wash. was introduced on April 26, 1955, by members of the Joint Committee on Atomic Energy. In the House of Representatives, Representative Carl T. Durham introduced H. R. 5845 and an identical bill, S. 1824, was introduced in the Senate by Senator Clinton P. Anderson. Hearings were held on these bills at Oak Ridge on June 10, 1955, by a Subcommittee of the Joint Committee on Atomic Energy.

The principal change in the present bill as compared with the bill submitted last year, concerns the basis for Federal contributions to the municipalities, schools and hospitals at the communities. Under last year's proposal, such contributions would have been paid on the basis of a formula under which any entity to which municipal facilities were transferred would receive the difference between the Commission's cost of operating such facilities for fiscal year 1955, and the revenue which that entity actually received. These payments would have been subject to review after 5 years and would have terminated after 10 years.

The revised legislation proposes the payment of fixed dollar amounts for schools at Oak Ridge, and for the municipality, schools and hospital at Richland—which payments after transfer of facilities, would decline annually on a straight line basis and terminate at the end of 5 years at Richland, and at the end of 15 years at Oak Ridge.

The revisions in the bill were made in the light of the Richland hearings last June, of numerous helpful comments and suggestions received from various interested groups at both Oak Ridge and Richland, and of further study by the Commission.

Later hearings were held by the Subcommittee of the Joint Committee on Atomic Energy at Hanford on July 5.

Housing and Community Facilities

Oak Ridge

Construction of the new commercial center, to be known as the "downtown" area, was started January 19, 1955, when Oak Ridge Properties, Inc. held a groundbreaking ceremony. It is anticipated that the first segment of 287,500 square feet of commercial space will be available for occupancy by October 1, 1955.

In preparation for general disposal, a boundary survey of the minimum geographic area for the municipality of Oak Ridge was completed. In addition, all lot lines were surveyed.

As of June 30 the program of leasing lots for private residential construction progressed to the point where 126 individual lots were leased, 25 houses were completed, and 10 houses were under construction.

North Richland

North Richland, used principally as a construction camp, was transferred from custody of the AEC to the Department of the Army on July 1, 1955. Prior to transfer the AEC had curtailed its construction activities to the extent that remaining construction employees could be housed satisfactorily in privately owned housing in the surrounding area.

Los Alamos

The program to replace substandard housing at Los Alamos, N. Mex. continued. The first phase of this program, 120 replacement units, was completed in February, while the second phase, calling for completion of 96 units by March 9, 1956, began on March 31.

Several times in the past consideration was given to making changes in the system of community access controls at Los Alamos. Recently this plan was fully considered in terms of security of technical facilities and information, economy of operations, and community relationships, and it was decided that existing controls should not be changed at this time.

Other Areas

Occupancy control by the AEC of all privately owned permanent-type Title IX dwelling units at Portsmouth area was released during January and the units were made available for sale or rental to the general public. However, in no event was an eligible defense worker occupying a rental unit required to vacate in order that such unit could be sold. As of June 30 there were 221 vacancies in the 400 temporary housing units and 496 vacancies in the 900 trailers furnished by PHA under Title III of the National Housing Act. One hundred of these trailers were released by AEC. The Public Housing Administration will discontinue operation of the 250 temporary housing units at the Waverly project by September 30, 1955.

At Paducah 58 Title IX housing units were sold, and others are being advertised for sale. As of June 30 there were 137 vacancies in the remaining 390 Title IX units, and 243 vacancies in the 500 Title VIII units.

Reactor Development

The Commission's program of developing reactors for industrial and military power and for naval and aircraft propulsion made greater strides during the first 6 months of 1955 than in any earlier half-year.

Expenditures of nearly $151 million were made for reactor development during the fiscal year ending June 30.

During the period of this report emphasis was placed on the development of advanced reactor technology through projects involving the building of experimental reactors. These reactors were chosen in February 1954 under a 5-year program to represent five ideas of power reactor designs that seemed potentially capable of producing economic nuclear power and at the same time could be built and tried out because the technology had recently advanced sufficiently. (The program was covered in detail in the Sixteenth Semiannual Report, January–June 1954, pp. 20–26.)

Each of these five concepts selected continued to show promise of ultimate production of civilian power at competitive costs in future nuclear powerplants. Some changes were made in the program while others are under active consideration. Meanwhile studies of other promising reactor concepts have reached a point where experimental reactor projects are being considered.

The Navy gave preliminary acceptance to the nuclear-propelled submarine *Nautilus*. A 100-hour full power test of the Submarine Intermediate Reactor (SIR) Mark A—the land-based prototype of the engine designed to propel the second nuclear submarine, the *Seawolf*—was successfully completed (p. 44). Development work continued on a reactor for a high performance submarine and on a reactor suitable for large ship propulsion. The first phase of the Army's Package Power Reactor program was completed and the Aircraft Nuclear Propulsion program accelerated, with the promise of nuclear-powered flight considerably brightened.

The AEC moved toward greater participation by industry in advancing the development of competitive nuclear power. Toward this end, the Commission set up an expanded program for making classified information available to industry, established a classified schedule of charges for materials furnished by the AEC, and prices for special nuclear material produced in power reactors. Four industrial proposals were received for the power demonstration reactor program. The number of industrial study groups was increased from 18 to 25, bringing the number of individual organizations now in the program to 81.

Implementing the President's "Atoms-for-Peace" plan, a training school was established at Argonne National Laboratory primarily for the training of foreign students in nuclear technology, as noted earlier in this report (pp. 18–19).

Civilian Power Reactor Program

Pressurized Water Reactor

The Pressurized Water Reactor (PWR) will be the Nation's first civilian nuclear powerplant. This nuclear powerplant is to produce at least 60,000 kilowatts of electricity net and is the only large-scale reactor in the original civilian power development program. Major construction work is in progress at the PWR site at Shippingport, Pa. Excavation for the entire plant was well advanced in recent weeks. Contracts were awarded for concrete and for furnishing and erecting the steel structures to house the reactor portion of the plant. Procurement of major components for the nuclear portion of the plant was put under way and final design of auxiliary equipment was nearly complete.

In February, the Duquesne Light Co. entered into a contract with Burns & Roe Inc. (J. Rich Steers, Inc., and Hatzel & Buehler, Inc. as associates) to act as Duquesne's agent-constructor for the turbine-generator portion of the plant and as supervisor of construction of those portions of the nuclear plant which may be assigned for construction to Duquesne.

Design of the turbine-generator portion of the plant was well advanced. Duquesne placed purchase orders for all major equipment to be installed in this part of the plant.

On May 7, 1955, the Commission held the third of a series of PWR classified technical seminars at Bettis Plant, Pittsburgh, Pa. This seminar was planned to acquaint representatives of private and public utilities, industrial study groups, major AEC contractors, and appropriate Government agencies with the details of PWR progress. It was attended by about 300 individuals.

Boiling Water Reactors

Investigation of the concept of boiling water reactors continued under the direction of the Argonne National Laboratory. This concept—basically a variation of the pressurized water reactor concept—differs in that pressure in the boiling design's coolant system is lowered and steam generation allowed to take place in the core.

There are three experimental reactors in the overall project. The first boiling reactor experiment (Borax I) was operated at the National Reactor Testing Station in 1953 and described in the Sixteenth Semiannual Report (January-June 1954, pp. 22–23). A second boiling reactor experiment (Borax II) was constructed last summer on a site close to Borax I. The reactor became critical on October 19, 1954, and since then has operated successfully. During the past 6 months experiments were conducted to study both the steady state and transient behavior of the reactor and to define the limits of stable operation as a function of variables such as pressure and specific power.

The ultimate goal of the boiling reactor project is the construction and operation of the Experimental Boiling Water Reactor powerplant (EBWR) designed to produce 20 megawatts of heat and 5,000 kilowatts of electricity. This plant was conceived as a minimum capacity, enabling sound extrapolation to large size central station powerplants. Bids for the construction of the reactor building were invited and a lump-sum contract was awarded to the Sumner Sollitt Co. of Chicago, Ill. Construction at Argonne began in June 1955. This reactor plant should be generating power during the latter part of 1956.

In the meantime plans were made to install a 3,700-kilowatt (electrical) turbogenerator at Borax II to be driven by the steam from this temporary boiling experiment. One object of this experiment is to provide data on the carryover of radioactivity from the boiling reactor to the turbine, condenser and feed water pumps which can be utilized in the design of the EBWR. Another objective is to create a pilot plant of package power type for possible further development. Specifications for the turbogenerator addition were prepared by Sargent & Lundy Co. architect-engineers for the EBWR.

Sodium Graphite Reactors

Nuclear powerplants with sodium-cooled, graphite-moderated reactors continued to look promising for production of competitive power. North American Aviation, Inc., is pursuing this concept under contract with the AEC. Fabrication of the small experimental reactor designated SRE (Sodium Reactor Experiment) proceeded on schedule.

During the past 6 months detailed design work on the Sodium Reactor Experiment and site preparation were essentially completed and an engineering test building erected. In addition to being used for engineering experimental work, the final fabrication and assembly of the fuel elements for the first core of the SRE is being carried out in the engineering test building.

Original plans did not include the generation of steam or the conversion of heat energy from this experiment. The reactor heat was to be dissipated to the atmosphere. However, the Southern California Edison Co. proposed to the Commission to purchase the SRE heat and install, at its own expense, all equipment necessary to convert the heat to electricity. Proposals from other utility organizations were solicited but no others have been received. It is expected the decision to utilize the SRE heat will be made in the near future.

Consistent with its policy of making technical information developed under its civilian nuclear power program available to authorized groups and individuals, the Commission sponsored a classified seminar on the Sodium Reactor Experiment at Los Angeles, Calif., on February 3 and 4. This seminar was attended by some 200 representatives of private and public utilities, industrial study groups and Government agencies.

Fast Breeder Reactors

The project for the construction and operation of the Experimental Breeder Reactor powerplant (EBR No. 2) continued under the direction of Argonne National Laboratory. The EBR No. 2 is to be sodium cooled, generate 62.5 megawatts of heat, and produce 15,000 kilowatts of electricity (Sixteenth Semiannual Report, January–June 1954, pp. 25–26).

The development program for the EBR No. 2 was well underway during the period of this report. Complex problems in physics, characteristic of such fast reactors, were solved on the UNIVAC electronic computer at New York University. Reactor physics measurements required for the program were made at ANL with a subcritical core assembly using the neutron source reactor. Such exponential experiments neared completion and data were analyzed by the AVIDAC electronic computer at Argonne. The construction of a zero power fast critical assembly was essentially completed at the National Reactor Testing Station. It will provide accurate data for the detailed design of the core of EBR No. 2.

Construction of EBR No. 2 is scheduled to start in 1956, while the reactor is scheduled to be in operation early in calendar year 1958.

A facility for the development, manufacture, and reprocessing of fuel elements containing plutonium is essential to the development and operation of fast breeder reactor powerplants. The architect-engineering for such a facility, to be located at Argonne, was completed and the building will be erected this year.

Homogeneous Reactors

Reactors may be defined as *heterogeneous*, meaning the core is composed of different materials separated one from the other, or *homogeneous*, signifying a uniform core material of fuel and moderator in solution. The Commission's homogeneous reactor project is directed toward solving problems whose solution will permit construction of reactors of an engineering type different from others being investigated on a project basis.

The Oak Ridge National Laboratory continued its investigation of the homogeneous reactor. ORNL designed, built, and operated the Homogeneous Reactor Experiment No. 1 in 1952. The present program is centered on assembling a second Homogeneous Reactor Experiment (HRE No. 2).

During the past 6 months this reactor concept was modified rather significantly as the design progressed, so that a much more useful reactor will be provided than was originally planned. The reactor will be more powerful than the HRE No. 1. It is believed that power levels of 10 megawatts may be attained, at least intermittently, compared with the 3 megawatts originally planned. It also will be more versatile and, by fiscal year 1957, will include a blanket system with chemical processing equipment as part of the reactor. These modifications made it appear unnecessary to construct an intermediate-scale homogeneous power reactor, as reported in the Seventeenth Semiannual Report (July-December, 1954), since it is expected that the modified HRE No. 2 will provide most of the technology originally intended to be obtained from the intermediate-size reactor.

Construction of the HRE No. 2, housed in the original HRE No. 1 building, was started in July 1954, after HRE No. 1 was shut down and dismantled. Erection of the underground steel-lined reactor cell was completed in May 1955. Contracts were awarded and fabrication started on all major equipment, including the heat exchangers, core tank, pressure vessel, and circulating pumps. In view of the fact that the scope of the HRE No. 2 project was enlarged since January, the startup date was changed from 1955 to early 1956.

Other Reactor Concepts

General research and development work is essential to the power reactor development program. Most of the promising new reactor concepts are the results of such work, and from these beginnings advance to a state of technology which permits the planning of reactor construction. Among promising concepts are a liquid metal-fueled reactor, an organic-moderated reactor experiment and a small homogeneous type reactor. During the past 6 months work on these concepts has progressed to the point where experimental reactor projects which would test these concepts are being considered.

Liquid metal-fueled reactor. A reactor in which the fuel is carried in a liquid metal system has the potential advantages of simplified fuel processing, as in the homogeneous reactors, plus the advantage of high temperatures at low pressure. During the past 6 months one such reactor concept, using graphite as moderator and a uranium solution in bismuth as fuel, was carried to a reasonably advanced state of component development primarily by Brookhaven National Laboratory.

Babcock & Wilcox entered into a contract to study the BNL data and calculations with a team of highly trained technical personnel on loan from several other organizations. They are: Air Reduction Co., American Smelting & Refining Co., Atomic Power Development Associates, the Bailey Meter Co., Carbide & Carbon Chemicals Co., Dow Chemical Co., Electro Metallurgical Co., Ethyl Corp., the International Nickel Co., Inc., Merck & Co., Inc., National Carbon Co., Nuclear Power Group, Oak Ridge National Laboratory, Rensselaer Polytechnic Institute, Tennessee Valley Authority, and Vanadium Corp. of America. The objective is to determine technical feasibility and identify important areas for additional investigation. A final report on this study is expected in July or August 1955.

Future plans for development of this type of reactor technology will depend upon the results of this study and upon investigations of other fuel systems offering comparable advantages.

Organic-moderated reactor experiment. Several advantages of some organic compounds as possible reactor moderator-coolants were evident from investigations of these materials. Low induced radioactivity, low corrosion of fuel elements, and high boiling point were among these advantages. Thus, they would afford the possibility of reactors of the small size of water-moderated units operating at higher temperature with lower vessel pressure and practically no problems of corrosion.

The major unknown in systems under investigation is the mechanism of deposition on heat transfer surfaces under reactor conditions. Experiments in progress are expected to develop the facts about this mechanism. It is believed that the next step in determining the value of this technology, if radiation-loop test results are satisfactory, should be a simple, inexpensive reactor experiment somewhat similar to the boiling water reactor experiments at the National Reactor Testing Station. This experiment with the organic-moderated reactor principle would simulate conditions of heat flux, temperature, and coolant velocities practical for a power reactor of this type.

In May the North American Aviation Inc., began an engineering design for such an organic-moderated reactor experiment. The design will be completed by the end of 1955.

Los Alamos Scientific Laboratory reactor. While not included as part of the original civilian power reactor program, nonmilitary application work involving reactors at LASL was integrated with the civilian reactor power program. LASL continued development of a power reactor experiment of the homogeneous type using an enriched uranium compound as fuel. The fuel composition, operating temperatures and pressures as well as other engineering aspects differ somewhat from the ORNL–HRE No. 2 approach. LASL also made plans for another homogeneous reactor to be used in "hot" loop experiments.

Small-sized civilian reactors. The Army Reactor Program (p. 45–46) is the only one currently studying and developing small reactor powerplants. This small, package powerplant concept, designed to meet military requirements, is also well suited to many other nonmilitary power needs. For example, package powerplants may fulfill needs in outlying, high power cost areas. Indications are that a large foreign market lies in the range below 30 megawatts of electrical capacity. Applications to mining operations and outlying industrial plants also appear likely for package power reactors.

Industrial Participation

The Commission under the provisions of the Atomic Energy Act of 1954, took steps to accelerate the domestic industrial development of nuclear power. AEC procedures for providing access to classified data were modified making such data available to a larger segment of industry. Schedules of charges for available materials and services needed by private atomic energy developers and users in the United States were issued, and fair prices were established for certain products from privately operated atomic reactors. Proposals were received under the power demonstration reactor program.

Access Permits

In April of this year the Commission announced a simplified program under which organizations or individuals may be given access to certain confidential and secret restricted data relating to civilian applications of atomic energy technology, and not primarily of military significance, for their own private purposes. (This program is discussed in detail under "Civilian Application," pp. 102–103.)

Power Demonstration Reactor Program

In January, the Commission established a program planned to encourage industry to develop, fabricate, construct, and operate experimental nuclear power reactors. The aim of the program is to bring private resources into the development of engineering information on the performance of nuclear power reactors and thus advance the time when nuclear power will become economically competitive.

Under the program the Commission stated that it would consider providing the following kinds of cooperation and assistance in effectuating proposals for power reactors submitted by April 1, 1955 by applicants who were willing to assume the risk of construction, ownership, and operation of such facilities:

1. Waiving the established Commission charges for loan of source and special nuclear materials up to an agreed upon amount for a period of up to 7 years from July 1, 1955. The proposers would nevertheless pay for all material consumed and for services performed for them by the AEC;
2. Performing in AEC laboratories without charge or at reduced charges to the proposers certain mutually-agreed upon research and development work; and
3. Making payment, to be fixed in advance, for technical and economic information resulting from the project. This information would then be made available by the Commission to the technical public working on reactor development.

Proposals for large central station reactors. By April 1, 19 proposals were received for large-sized reactors at sites sul Commission approval. The proposals are:

1. Boiling water reactor plant in Illinois of 180,000 kilowatts el capacity, to be completed in 1960. This plant is proposed Nuclear Power Group, composed of: American Gas & Service Corp., New York; Bechtel Corp., San Fransicso, Commonwealth Edison Co., Chicago, Ill.; Pacific Gas & Co., San Francisco, Calif.; Union Electric Co., St. Lou
2. Light water-moderated and -cooled reactor plant in no Massachusetts of 100,000 kilowatt capacity, to be compl late 1957, proposed by the Yankee Atomic Electric Co. of members of which are: New England Power Co., Boston, Connecticut Light & Power Co., Hartford, Conn.; Boston Co., Boston, Mass.; Central Maine Power Co., Augusta, Hartford Electric Light Co., Hartford, Conn.; Connecticut Co., Hartford, Conn.; Western Massachusetts Electri Greenfield, Mass.; Public Service Co. of New Hampshire chester, N. H.; Montaup Electric Co., Fall River, Mass Bedford Gas & Edison Light Co., New Bedford, Mass.; Can Electric Light Co., Cambridge, Mass.; Central Vermont Service Corp., Rutland, Vt.
3. Fast breeder reactor plant at Monroe, Mich., with 100,0 watts capacity, to be completed in late 1958, proposed by Hudson Gas & Electric Corp., Poughkeepsie, N. Y.; Cin Gas & Electric Corp., Cincinnati, Ohio; Consumers Pow West Jackson, Mich.; Delaware Power & Light Co., Wilm Del.; Detroit Edison Co., Detroit, Mich.; Long Island L Co., Mineola, N. Y.; Philadelphia Electric Co., Philadelph Rochester Gas & Electric Corp., Rochester, N. Y.; Toledo Co., Toledo, Ohio. (By mid-June the following addition panies had joined this group: Alabama Power Co.; Allis-C Manufacturing Co.; the Babcock & Wilcox Co.; Burroughs Georgia Power Co.; Gulf Power Co.; Holley Carburet Mississippi Power Co.; Potomac Electric Power Co.; the S Co.; Wisconsin Electric Power Co.)
4. Sodium graphite reactor plant of 75,000 kilowatts capacity completed in 1959; proposed by the Consumers Public District of Columbus, Nebr.

In evaluating the proposals, the Commission will consider:

a. Probable contribution of the proposed project achieving economic nuclear power;
b. Cost to AEC in funds and material;
c. Risk to be assumed by the maker of the proposal;

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d. Competence and responsibility of the maker of the proposal; and

e. Assurance given by the maker of the proposal against abandonment of the project.

New Study Groups

The Commission approved seven new study group agreements prior to announcement of the new access program in April. This brings the total number of participating study teams to 25 and the total number of organizations under the program to 81. Study agreements now in effect will be converted to the new access permits on expiration of current contracts or sooner if the groups desire. (A list of industrial study groups was published in the Seventeenth Semiannual Report, July–December 1954, pp. 26–27.)

The seven new industrial study groups are:

Baldwin-Lima Hamilton Corp. and the Denver & Rio Grande Western Railroad Co., which will study the engineering, technical, and economic aspects of a reciprocating atomic-powered engine.

Combustion Engineering, Inc., which will conduct a study of reactors of all sizes for central station and special uses, and also study fuel element design and fabrication processes.

Ford Motor Co., which will study fuel element fabrication for present reactor designs.

General Dynamics Corp., which will make a study of small power reactors and components of reactor systems and also study such auxiliary areas as decontamination services, byproduct radiation, instrumentation, waste disposal and related developments required for materials and equipment.

National Rural Electric Cooperative Association, which will study the engineering and economic practicability of nuclear power reactors for the rural electric systems' specialized wholesale power needs and problems.

Puget Sound Utilities Council, which will make a survey of nuclear power systems for the most practical and technically and economically feasible type for future construction and operation in the areas served by the Council's member utilities.

Seminole Electric Cooperative Association, which will study the possibility of achieving economic nuclear power in the Florida area and also examine the suitability of a 10,000-kilowatt electrical capacity reactor as a source of supply.

Naval Reactors Program

The Naval Reactors program is aimed at the dev
reactors suitable for the propulsion of naval vessels in a ra
ratings covering all feasible applications.

The initial Naval Reactors program consisted of two p
Submarine Thermal Reactor and the *Submarine Intermedi*
The program now includes work on the development
nuclear powerplant suitable for a high performance sub
Submarine Advanced Reactor (*SAR*), and a reactor suitab
ship propulsion, the *Large Ship Reactor* (*LSR*).

Submarine Reactors

Experimental operation of the prototype *Submarin*
Reactor (*STR*), Mark I, at the National Reactor Testing
Idaho was continued by the Westinghouse Electric Corp. a
the program for testing this type of reactor. Work on mo
which will change Mark I from a prototype of the *Nautil*
powerplant to a test facility for investigating new develo
technology, design and operation of improved water coole
powerplants, was scheduled to begin in July and will co
approximately 3 months. Electric Boat Division of General
Corp. will assist Westinghouse Electric Corp. with shipbuil
required for the modification.

The USS *Nautilus*, powered by the STR Mark II, got
on nuclear power on January 17, 1955; following successful
she was given preliminary acceptance by the Navy on April

The second nuclear-powered submarine the USS *Seawolf*, w
be propelled by the *Submarine Intermediate Reactor* (*SIR*)
was launched on July 21, 1955, at the Electric Boat Division
Dynamics Corp., Groton, Conn. A 100-hour full power tes
Mark A, the land-based prototype of the engine designed t
the *Seawolf*, was successfully completed. *SIR* Mark A wa
oped at the Knolls Atomic Power Laboratory, Schenectady
which is operated for the AEC by the General Electric Co. T
are being conducted at a site at West Milton, N. Y. *SIR*
first went "critical" (successfully sustained a nuclear chain r
on March 20.

Surplus steam from the *SIR* Mark A will be channeled into a
kilowatt turbine generator installed and operated by the G
Electric Co. at no cost to the Government. The resulting el
output is being sold by AEC in the first commercial usage of a
powered electricity.

The first delivery of power was made to Niagara-Mohawk Po
on July 18 and the occasion was signalized by a ceremony at th

a which General Electric, Legi
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Milton plant in which General Electric, Legislative Branch and Executive Branch spokesman took part. The arrangement with Niagara-Mohawk is temporary, pending determination by the three public power organizations or cooperatives within a 100-mile radius of West Milton which have expressed a desire to purchase the power on arrangements for transmission to their systems.

Under the Atomic Energy Act of 1954, the Commission is directed to "give preference and priority to public bodies and cooperatives . . ." in contracting for the disposal of electrical energy. The public power organizations or cooperatives which desire it will be sold the power when they can make arrangements to transmit it to their systems.

Production of *SIR* Mark B continues at KAPL.

Design and development work on the nuclear powerplant, *Submarine Advanced Reactor* (*SAR*) continued at the Knolls Atomic Power Laboratory by the General Electric Co. under AEC contract. Authorizing legislation was enacted permitting the construction of a land prototype of the SAR. This plant will consist of a section of a submarine hull containing one reactor with primary coolant system including related control and auxiliary systems and steam-producing equipment.

Large Ship Reactor

Design and development work on the nuclear powerplant, *Large Ship Reactor* (*LSR*), continued at the Bettis Plant by the Westinghouse Electric Corp. under AEC contract. The ship design studies by the Newport News Shipbuilding and Dry Dock Co., and Bethlehem Steel Co., Shipbuilding Division, under contract to the Navy Department, continued. Under the AEC prime contract Westinghouse has subcontracted with Newport News Shipbuilding and Dry Dock Co. for assistance in arrangement, shielding and systems studies at the LSR prototype plant.

Authorization was obtained to construct a prototype Large Ship Reactor at the National Reactor Testing Station, Idaho, at an estimated cost of $25 million, $6 million to be spent for test facilities, and $19 million for engineering, design and construction of the reactor and the propulsion equipment. The Rust Engineering Co. of Pittsburgh, Pa., was selected to perform the architect-engineering work for this prototype.

Army Reactors Program

The Army Reactors program has as its objective the development of land based systems suitable for meeting heat and power requirements of the three military services.

The first project under the Army program is the Army Package Power Reactor (APPR–1). Preliminary efforts are in progress which may lead to establishment of additional projects.

Army Package Power Reactor (APPR–1)

ALCO Products, Inc. (formerly the American Locomotive Co.) continued work under lump-sum contract to design, construct and test operate at Fort Belvoir, Va., a prototype of a plant for furnishing heat and electricity at remote bases. Operation of the APPR-1, employing a pressurized water reactor system with enriched uranium fuel and producing 1,825 kilowatts of electricity, is scheduled for December 1957.

Developments supporting military pressurized water reactor systems include heat transfer tests under contract with Columbia University, and experiments at the Oak Ridge National Laboratory and the National Reactor Testing Station in Idaho.

Advanced Military Package Power Reactors

Study projects were initiated to prepare conceptual designs of advanced reactor systems to meet additional requirements in the overall military range of interest. The most promising types will be selected for further development. Organizations engaged in these study projects are: General Electric Co., Schenectady, N. Y.; Babcock & Wilcox Co., New York City; Westinghouse Air Brake Co., Pittsburgh, Pa.; Fluor Corp., Los Angeles, Calif.; Walter Kidde Nuclear Laboratories, Garden City, N. Y.; Glenn L. Martin Co., Baltimore, Md.; Sanderson & Porter, New York City; Argonne National Laboratory, Lemont, Ill.; Oak Ridge National Laboratory, Oak Ridge, Tenn.; and the Army Engineer Research and Development Laboratories, Fort Belvoir, Va.

Aircraft Reactors Program

The Commission continued to push forward the frontiers of reactor technology in the effort to develop a successful nuclear-powered aircraft reactor. By its very nature the aircraft reactor requires, among other characteristics, the optimum in shielding, high temperature materials, high temperature fuel media, and high power-weight ratio.

Construction of the aircraft nuclear propulsion test area for testing aircraft reactors and associated components at the National Reactor Testing Station is nearing completion. These facilities include an administrative and service area, an assembly and maintenance area and an initial engine test area.

In addition to its reactor research facilities the Carbide and Carbon Chemicals Co. at the Oak Ridge National Laboratory has a tower facility for shielding research. The company employs many of the other test facilities, such as the Bulk Shielding Facility, in research for nuclear-powered aircraft.

The facilities at the General Electric Co. at Evendale, Ohio, while provided by the Air Force, are used jointly by the AEC and the Air Force to carry on their respective parts of the Aircraft Nuclear Propulsion program.

Work is presently underway to construct facilities at Middletown, Conn. to implement further the Pratt & Whitney effort in the program. These, too, are Air Force facilities to be used jointly.

The Air Force also has research facilities for nuclear propulsion at the plant of the Consolidated Vultee Aircraft Corp. at Fort Worth, Tex.

General Engineering and Development

Sanitary Engineering

Through the cooperation of 20 public water supply systems in various parts of the Nation, water samples from their source to and through treatment plants were collected following certain detonations of nuclear devices during the spring test series at the Nevada Test Site. The water samples were examined for radioactivity by the Sanitary Engineering Laboratories at the Massachusetts Institute of Technology which is under contract to the Commission. The objective is to evaluate the effect, if any, of fall-out of bomb debris in public water systems and the extent to which standard water purification methods remove radioactive contaminants.

The economic and public health aspects of disposal of high level radioactive wastes were given special consideration. Because of increased interest in the construction of nuclear power reactors near populated areas, safe disposal of these wastes is a significant factor in development of the industry. The Oak Ridge National Laboratory emphasized research to determine the feasibility of disposal in special underground pits instead of costly storage in underground tanks. The Geological Survey cooperated in this program.

Under AEC contract, the Department of Sanitary Engineering and Water Resources of the Johns Hopkins University continued evaluation of environmental problems in transporting and disposing of radioactive wastes. The cooperation of a special committee of the Earth Sciences Division, National Research Council, was enlisted to investigate the potentialities of ground disposal of high level radioactive wastes.

Since controlled dilution in surface waterways offers economical possibilities in the disposal of large volumes of low level radioactive wastes from atomic energy operations, a contract was made with the Engineering Science Department, Harvard University, to study the potentialities and limitations of this disposal method. Under this program a controlled pilot stream in Massachusetts will be used [to d]evelop and evaluate significant data useful to industry and public officials in establishing the effects of release of radioactive wastes to surface waterways.

Reactor Safety

The Reactor Kinetics program continued to study the behavior of reactor systems under adverse operating conditions. The purpose of this study is to demonstrate experimentally safe top operating limits, to discover points of design weakness, and to learn what inherent safety mechanisms contribute most to self-safety so as to capitalize on them. A center was established at the National Reactor Testing Station for such tests, and the first reactor core consisting of aluminum-clad MTR-type fuel elements became critical on July 1, 1955.

A parallel program studying the kinetics of homogeneous reactors is underway at North American Aviation's field laboratory at Santa Susana, Calif. The Sodium Reactor Experiment there is scheduled to reach criticality either at the end of 1955 or the beginning of 1956.

The reaction between the water coolant and molten fuel element material in the event of high temperatures during a runaway were studied to determine the extent of pressure surges during such incidents.

Explosive studies were made by the Naval Ordnance Laboratory for the AEC to study the relation between power excursions and damage to reactor containers.

Engineering Test Reactor

In April the Commission invited industry to build and operate with private funds an Engineering Test Reactor which would provide radiation facilities the Commission will need early in 1957 for the development of reactor components for military and civilian nuclear power programs. Irradiation facilities now being used by the AEC are not suitable for engineering experiments which require relatively large spaces in areas with high neutron intensities.

During the period of this report the Commission received two proposals from industry to construct the ETR. These proposals were made by the Babcock and Wilcox Co., of New York, jointly with the Lockheed Aircraft Corp., of Burbank, Calif.; and the J. A. Jones Construction Co., of Charlotte, N. C. They are being evaluated by the Commission. The AEC estimates that it would cost about $15 million to build the ETR at the National Reactor Testing Station.

To assure meeting the date when irradiation services are required the Commission awarded a contract in June for architect engineer work for an Engineering Test Reactor to the Henry J. Kaiser Co., Oakland, Calif.

Pressure Vessel Studies

Three separate studies of pressure vessel design and technology made under the direction of the Engineering Development Branch of AEC's Reactor Development Division demonstrated the feasibility of constructing power reactor shells from conventional pressure vessel material with approved fabricating methods. The studies included forged vessels, vessels fabricated from heavy plate material, and vessels fabricated in layers. Comparative costs were prepared for the different methods of construction.

Materials and Fuel Elements

Electronically controlled remote manipulators were developed at the Argonne National Laboratory handling as much as 10-pound loads. These manipulators transmit "feel" back to the hands of the operator, which was possible previously only with mechanical models. They are an important contribution in the remote handling and study of alpha-active materials.

Corrosion testing and theoretical work led to development of aluminum alloys which may be used for cladding fuel elements used in very pure high temperature water, contrary to former experience. This information was used as a design basis for the boiling reactor in the Power Demonstration Reactor program.

Since higher temperatures in water or other coolants require materials of greater strength and corrosion resistance, AEC facilities continued study of the zirconium-base alloy systems. As a result of this study one new alloy composition will be adopted in the near future, and several others are very promising.

Uranium-base alloys are the subject of much work. The objective is to secure greater radiation stability and corrosion resistance, with minimum use of "poison" elements. Radiation stability is particularly important for reducing the cost of nuclear power.

New production methods for recovering uranium, thorium, zirconium, and beryllium are being developed as means of reducing costs. Those for thorium and beryllium appear to be especially promising. Argonne National Laboratory is installing equipment for plutonium fabrication development, which will also be used as a guide on other remote fabrication problems.

Brookhaven National Laboratory made further progress in fuel and container material problems. The solution of these problems is necessary for the contemplated "Liquid Metal Fuel Reactor." The bismuth solution of uranium was stabilized so that there will be little, if any, interaction with the steel piping or the graphite moderating material

An extrusion method of cladding rods and tubes of uranium and thorium was developed by Nuclear Metals, Inc.

Reactivity Measurement Facility

During the report period, a Reactivity Measurement Facility (RMF) was placed in operation at the Materials Testing Reactor operated at the National Reactor Testing Station in Idaho by Phillips Petroleum Co.

Basically, the RMF consists of a low power (1–100 watts) reactor using MTR–type fuel assemblies, constructed in the MTR canal with ordinary water serving as moderator, coolant, and shield. The RMF is a sensitive device for measuring neutron-absorption qualities of various materials, both before and after irradiation. Among its other uses, it provides a quicker and less expensive means of determining in advance the effects an experiment will have on the neutron flux of the MTR.

Reactor Training Schools

Oak Ridge School of Reactor Technology

In August 85 students will be graduated from the 1954–55 session of the Commission's Oak Ridge School of Reactor Technology, a 1-year graduate-level course run at the Oak Ridge National Laboratory. Of those graduating 52 will return to their sponsoring industrial organizations, 20 to AEC and military contractors, and 13 to the military and other Government agencies. Of the 80 new students enrolled in the 1955–56 class, 60 are experienced men from Government and industry and the remainder are recent college graduates. On completion of the present course, the school will have graduated 300 men.

Beginning with the 1956 session more scientists and engineers from industry will be accommodated at the school. By 1958 attendance of the nonexperienced recent college graduates is expected to be eliminated. This year, for the first time, the Government will charge a tuition fee for students sponsored from private industry. The fee of $2,500 is intended to reduce the Government's operation cost and is consistent with its general policy of charging for services rendered.

Argonne School of Nuclear Science and Engineering

On March 14, 1955, a training school in reactor technology was officially begun. The first class consisted of 31 students from 19 foreign countries and 9 students from the United States. The 7-month course of instruction will cover only unclassified fields of nuclear reactor technology. A second course with a similar enrollment is planned to start in the late fall.

Physical Research

Emphasis in this report is given to university participation in the physical research program of the Commission. The leading role of our academic institutions in the training of scientists is cited, and university contributions in physics, chemistry, and metallurgy are described. At this point, however, there are outlined a few outstanding research accomplishments of the past 6 months at Commission laboratories.

Discovery of Element 101

Since the beginning of the atomic energy project eight elements heavier than uranium have been created artificially. Preparation and identification of the last of these—elements numbered 99 and 100—were described in the Sixteenth Semiannual Report (January–June 1954, p. 41).

Recently scientists working under Dr. Glenn T. Seaborg at the University of California Radiation Laboratory identified element 101. The newly discovered element contains 101 protons and 155 neutrons in its nucleus (atomic number of 101 and mass number of 256).

To form the new atomic species, element 99 of mass number 253 was bombarded with 41 Mev helium ions from a cyclotron. A neutron released in the ensuing nuclear reaction yielded the observed isotope of element 101. Seventeen atoms of the isotope were identified. They are radioactive, with a half-life of one-half hour. It was proposed by the discoverers to name the element Mendelevium (Mv) in honor of a pioneer in chemistry—the Russian scientist Dmitri Mendeleev. The identified isotope would be represented as $_{101}Mv^{256}$.

Thorium Production

Thorium metal is the starting material from which uranium 233, a fissionable isotope of uranium, is made. Reactor cores containing uranium 235 can be surrounded with a blanket of thorium metal, which absorbs the stray neutrons leaving the core and with the added neutrons becomes uranium 233. Thorium is now produced by batch processes requiring expensive reagents. At Oak Ridge National

Laboratory, a promising new, semicontinuous process for thorium production was worked out. Appreciable savings are expected from the process, which uses inexpensive reagents.

Low-Temperature Nuclear Alinement

Nucleons (protons and neutrons) like the earth rotate about their axes and have magnetic poles at the two ends of the axes. In a beam of nucleons, the axes of the particles are usually randomly oriented. However, methods have been developed whereby nucleons in a beam can be oriented with their axes all parallel and their spins in one direction. Such a beam of nucleons is said to be "polarized." In studying the funadmental properties of neutrons and their interactions with atomic nuclei, additional information can be gained when experiments are carried out with polarized beams of neutrons. However, such experiments must deal with nuclei whose orientations have been alined by a magnetic field and a low temperature.

The lowest temperature attainable is −460° F. At this temperature (absolute zero) all substances or particles reach a state of frozen immobility.

At Oak Ridge National Laboratory indium metal was placed between the poles of a magnet and kept at a temperature between −459 and −460° F. Under these conditions the nuclei became preferentially oriented in the direction of the applied magnetic field, and the effect could be observed by passing polarized neutrons through the sample.

According to theory when polarized nuclei revert to a random arrangement, they should absorb energy from the motion of the atoms. Accordingly, if advances in technique can increase the degree of polarization, then by simply cutting off the magnetic field, the indium should be cooled by temperatures perhaps one hundredth as great as those realized previously in low-temperature research.

Hydrogen Bubble Chamber

Cloud chambers and photographic emulsions have provided conventional methods for studying the mass, energy, and reactions of high energy nuclear particles. More recently, a technique was developed by Donald A. Glaser of the University of Michigan that offers significant advantages over cloud chambers and emulsions in nuclear research. Glaser succeeded in photographing bubbles of vapor formed along the tracks of cosmic ray particles passing through super heated ether. His success encouraged scientists working at other laboratories to explore the advantages of bubble chambers, especially for studying reactions of mesons and protons.

Through the use of a special liquid hydrogen bubble chamber, meson tracks were observed during operation of the bevatron at the University of California Radiation Laboratory. The density of the liquid hydrogen in the chamber is equivalent to that which would be obtained if an ordinary cloud chamber were operated at about 700 atmospheres. Consequently, the large amount of material in the path of the speeding mesons permits observation of rare particle interactions. Also, the target nucleus can be positively identified, since the liquid hydrogen nucleus consists solely of protons.

Research in University Laboratories

The physical research program is the source of many of the new ideas contributing to the Nation's progress in atomic energy. Here too, is where the atomic scientists of the future first become interested in the Commission's problems and begin their work in the program. Naturally, the universities play an essential role because of their traditional responsibilities for advancing fundamental knowledge and teaching students.

Fortunately, the areas of science where advancement most benefits the atomic energy program are also of great interest to the academic scientists. For this reason it is possible to enlist the assistance of professors and their students in university departments of physics, chemistry, and metallurgy for research which advances atomic technology and, at the same time, strengthens the universities in their efforts to keep pace with the rapidly increasing demand for qualified scientists. The record shows that the great majority of those who are now entering careers in the laboratories where atomic weapons or atomic powerplants are being developed began as assistants on research projects conducted for AEC by the universities. Moreover, it is clear that the rate at which these projects are able to introduce new manpower is a limiting factor as America advances toward full-scale utilization of atomic power and in her efforts to keep the peace through superiority in atomic armaments.

The Atomic Energy Act of 1954, like that of 1946, directs the Commission to conduct research and development in support of the atomic energy program, both in its own facilities and through contracts or other arrangements with independent institutions. In response to this directive, and in recognition of the unique service the educational institutions can render the program, the Commission is currently contracting with 90 different universities, colleges, and research institutions for fundamental research in the physical sciences. The university contractors and the type of work they perform are listed in Appendix 5, pp. 128-136. These consist of 135 studies in chemistry, [illegible] in physics, and 46 in metallurgy.

Universities have traditionally supported research to expand the frontiers of human knowledge, and in those areas bearing on atomic energy they have a common interest with the Commission. Normally contracts between the Commission and a university for basic scientific research are based upon proposals made by the university scientists, and the results of the research are generally made available to the scientific community through publication in the open literature. The Commission believes that giving free latitude to individual initiative is the surest way to insure that significant new ideas are conceived and rapidly developed.

A type of arrangement which the Commission has adopted for assisting research in universities and colleges is the lump-sum joint participation contract. These contracts may be used when the annual cost to the AEC is less than $100,000, when the cost can be estimated with reasonable accuracy in advance, and when the contractor and the AEC both contribute to the costs. In consideration for the work undertaken and the submission of a satisfactory report, the AEC pays a lump-sum based upon a part of the estimated total cost. These contracts involve a minimum of supervision and auditing. Projects requiring the AEC to pay substantially all of the costs, or those for which the costs cannot be estimated with reasonable accuracy, are financed under cost-type contracts under which the AEC controls expenditures and audits the accounts.

Irrespective of contract type, the payments assist the institution to meet the expenses of the project, which usually include summer salaries of the investigators, supplies and equipment, and part-time employment of graduate students who partake in the work and often use the results as material for a dissertation.

Since the inception of the Commission's university research program in 1948, these institutions have made many contributions to the advancement of the atomic energy program. Investigations in which they have had a leading role are those designed to develop a better fundamental understanding of the nuclear processes involved in the release and use of atomic energy. They have also made substantial contributions to knowledge in chemistry and metallurgy basic to the development of new processes for the manufacture and use of nuclear and other special materials.

In carrying out investigations for the Commission the educational institutions are also substantially strengthened for their primary task of training the manpower which flows in an increasing, but still insufficient stream, from university classrooms and laboratories into the plants and other establishments where the end products of the program are being developed or manufactured.

Nuclear Processes

The story of the university's role in atomic research is an important and interesting chapter in the history of our time.

As a result of a century and a half of research, mostly in university laboratories, the atomic theory of matter was developed. This theory led in 1939 to the discovery of a method of releasing atomic energy. The theory was tested and proved beyond all doubts. Extensive laboratory experiments invariably check its predictions, but all of its consequences will not be realized before another generation or two. According to this theory all substances are made up of minute and indivisible units called *atoms* of which 101 different varieties are known. Each variety corresponds to one of the chemical elements—oxygen, iron, silver, uranium, or any of 97 others found in nature. (Actually only 88 elements occur in nature, 13 have been produced artificially.)

The Atom and Its Energy

The atom is a very small unit of matter. For example, the number of silver atoms in a dime is expressed by the digit 1 followed by 22 zeros. Small as it is each atom is in itself a complex structure, containing at its center a minute but relatively massive nucleus surrounded by a cloud of light weight particles called *electrons*. The nucleus bears a positive charge of electricity which attracts and holds the negatively charged electrons. According to the atomic theory, all of the reactions of chemistry—like the burning of coal or the fermentation of sugar—are to be explained by the forces between electric charges on the electrons and nuclei of interacting atoms. Atomic energy, on the other hand, arises from forces deep within the nucleus between the still tinier particles of which it is composed, for the nucleus is also a surprisingly complex structure, and one occurring in even greater variety than the atoms.

Atomic Nuclei

Nuclei are now known to be made up of two still smaller units of matter—*protons* and *neutrons*—bound together by strange newly recognized forces which are neither electrical nor gravitational in nature. (Because they are the essential constituents of atomic nuclei, neutrons and protons are often referred to by the general name of *nucleons*.) Nuclei are characterized by the numbers of neutrons and protons contained in them. These numbers range from [illegible] to 101 protons, and from zero to 157 neutrons. More than [illegible]0 different nuclear species have been identified.

A fundamental problem of nuclear science—toward the solution of which the universities are assuming major responsibility—is to devise a theory of the forces between neutrons and protons which will explain all of the observed properties of the 1,000 or more nuclear species. Not until such a theory is devised and tested can all of the possibilities of releasing atomic energy be conceived.

The attack on this problem is going on from two sides, the experimental and the theoretical. Experimentalists must first discover as many of the facts as will yield to their observations and measurement. Then the theorists try to interpret the facts as they fit into the picture of structure of neutrons and protrons interacting according to a hypothetical law of force. The idea is to learn the nature of that force and understand how it operates. In this phase of the work the possible practical use of the information is undetermined, since experience shows that uses cannot be fully determined until the facts of nature are understood.

Facts about the nucleus are obtained by observing the radiations which it emits as it changes from one energy state to another, or from the scattering or absorption of high energy particles used in experiments to bombard materials containing the nuclei under investigation. The modern experimentalist is equipped with instruments which count both radiations and particles and measure their energies. Both types of experiments usually involve the use of either an accelerator which supplies a beam of charged particles with high energy—such as protons or electrons—or a reactor, which is the best source of neutrons. Even at the low energy with which they emerge from a reactor, neutrons are able to enter a nucleus and make changes in it. Protons or other charged particles cannot enter a nucleus unless they have a sufficiently high velocity to overcome the electrical repulsion which extends beyond the range of the attracting nuclear force.

Particle Accelerators

Most of the university laboratories engaged in nuclear research for the Commission use a particle accelerator of one sort or other to supply high velocity particles. Reactors are less common on the university campus, although several universities are now acquiring them and one is already in operation at the North Carolina State College. The accompanying table lists the educational institutions where particle accelerators are being used for Commission research. This table also includes institutions where projects in nuclear physics are jointly supported by the AEC and the Navy. As shown in the table, several kinds of accelerators are in use—cyclotrons, electrostatic generators, synchrotrons for both electrons and protons, betatrons, and linear accelerators. These give various energies to a variety of particles.

The characteristics and principles of operation of the different types of accelerators are described in books on nuclear physics. It is sufficient here to realize that the nuclear physicist has the means for producing beams of several kinds of nuclear particles possessing a wide range of carefully controlled energies.

The particles accelerated for nuclear research include electrons, protons, or any of the simpler atomic nuclei.[1] The energies to which they are accelerated are commonly expressed in units of the electron volt. One such unit is the energy acquired by a particle carrying the charge of one electron (or of one proton, since it is of the same magnitude but opposite in sign) moving through a potential difference of one volt. Modern accelerators are able to produce all energies up to 6 billion electron volts (Bev.) A new machine being constructed at the Brookhaven National Laboratory is expected to accelerate protons to an energy of 25 Bev.

Nuclear Changes

Nuclear changes can be observed in target materials when they are bombarded by particles with an energy of a few hundred thousand electron volts or higher. In the range of energy between a third of a million and 250 million electron volts (Mev) the bombarding particle may do one of three things. It may knock one or more neutrons or protons out of the nucleus; the bombarding particle may be captured to form a heavier nucleus; or it may agitate the particles of which the bombarded nucleus is made up so that the nucleus goes into a state of higher internal energy, called an *excited state.* The last usually happens to the residual nucleus in any event, causing it to emit electromagnetic (or gamma) radiation as it returns to its normal, or stable state.

Nuclear Structure and Forces

Nuclear reactions are complex problems for the typical university research project. For example, even in the relatively simple nucleus of ordinary carbon, containing 6 protons and 6 neutrons, 32 different levels of internal energy were identified.

In the nucleus of uranium [2] containing 92 protons and 143 neutrons, it might seem hopeless to try to understand the complex modes

[1] Machines that use the heavier nuclei, such as lithium, beryllium, boron, etc., as projectiles are called heavy ion accelerators.

[2] This is the species of uranium that contains 235 nucleons, uranium of mass number 235. Like other elements, uranium exists in several forms that have different mass numbers. These varieties of the same element are known as *isotopes.*

of internal motion and countless energy levels. However, it is already becoming clear that protons and neutrons are not thrown into a nucleus at random like apples into a basket. Evidently nuclear particles fall into subgroups, or shells, in which their motions have simple regularity. From the work already done in university laboratories, there appears to be definite hope that we may be able to understand the law of force between neutrons and protons well enough to be able to calculate their interactions and modes of motion and arrive at energy levels which agree with the observations. These results may lead to generalizations of deep significance and practical value. Our knowledge of nuclear reactions and nuclear structure is being advanced by the work of 22 universities in this field (see table).

The problem is formidable but definite progress is being made. Whether the riddle of the nucleus is solved or not, it is of the greatest significance that scientists are concerning themselves with these problems. In attacking them they are gaining an understanding and a facility which prepares them to deal with technical problems arising throughout the Commission's program.

To study forces between protons and neutrons by observing the energy states of the nucleus is like watching two football teams in action in order to study human nature. One would learn more by observing an individual player. It has long been realized that the study of collisions between proton and proton, or proton and neutron, would be expected to give the most readily interpretable information on the elementary nuclear force.

Experiments of this nature are possible with accelerators used by the university contractors of the Commission, and they have long engaged the attention of several such investigating groups. In one instance a beam of protons is scattered by a target containing hydrogen atoms, the nuclei of which are protons, and the angles through which particles of the beam are scattered are recorded by suitable detecting instruments. The observed distributions in angle of scattered particles are found to depend upon the energy of the incident beam. It is possible to interpret the results obtained with beam energies up to 200 million electron volts (Mev) by assuming that the force between two protons varies in a regular way with the distance between the colliding particles, when account is also taken of the directions in space of the axes about which the protons spin. Similar experiments were also done with heavy hydrogen targets, the nuclei of whose atoms contain one proton and one neutron and are called *deuterons*. From the latter it is possible to infer the nature of the forces between neutron and proton.

Mesons

Although the results for collisions at energies up to 200 Mev are relatively easy to interpret, protons behave in a very confusing manner when they collide at higher energy. In addition to neutrons and protons other strange new particles emerge from the impact and appear to be created by the force of the blow. These particles, called *mesons*,[3] because their mass is intermediate between that of the electron and the proton, are not fragments of the original protons, since those particles survive the impact undamaged. On the contrary they are entirely new pieces of matter created out of the energy of the bombarding proton beam.

Although in some respects similar to ordinary matter, mesonic matter is of extremely short duration. Soon after their creation these particles disappear and their mass reverts to energy. Moreover, several kinds of mesons have been observed, differing from one another in mass, in electric charge, and in the time that they exist as matter. These particles are apparently embodiments of atomic energy in its purest essence. Their fundamental significance has aroused the interests of the pure scientists on a broad scale. Several of the Commission's institutional contractors, as indicated in the table, have facilities for producing mesons and for studying their manifold properties. Ten machines have been put to use by nine universities investigating these phenomena. Investigations of this type are aimed at the heart of the problem of understanding the true nature of atomic energy.

Neutron Spectroscopy

Processes of immediate practical interest in the reactor and weapons programs are those in which neutrons are scattered (p. 60), slowed down, or captured by atomic nuclei of the various materials used in these devices. The design engineer must know how far, on the average, a neutron goes through the material in question before it is affected in each of these ways. Moreover, the distance depends upon the speed of the neutron as well as upon the kind of material. At certain critical speeds the neutrons interact strongly with the nucleus, whereas at others they are only weakly scattered or absorbed. Because of the similarity to the absorption of light in certain regions of the spectrum, these studies are called *neutron spectroscopy*. Each material is characterized by a neutron absorption spectrum. In fact, since neutron absorption is a nuclear property, each different nuclear species, of which there are more than 1,000, has its own characteristic spectrum.

[3] Meson is from the Greek *mesos*, meaning intermediate.

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At five universities (listed in the table), special emphasis is given to research on neutron spectroscopy. Under these projects great advances have been made in the techniques for accurately determining the energies of the highly absorbed neutrons. The almost limitless task of studying the various nuclei is also underway on several campuses as well as in AEC laboratories. The results are of great value for nuclear engineering, and of interest to the student of nuclear structure.

Nuclear spectroscopy is a general term covering the study of spectra resulting from internal changes in a nucleus brought about spontaneously or stimulated by a bombarding nuclear particle. Nineteen accelerators are being operated by 14 university contractors engaged in these studies apart from those working on problems of neutron spectroscopy (see table). These studies are also closely related to those on nuclear reactions and nuclear structure.

Scattering

Particles such as protons raised to high velocities, and hence high energies, in accelerators undergo collisions with nuclei when they strike a target. A common type of interaction that the protons experience is simple *scattering.* (Proton scattering reactions were mentioned in connection with studies of nuclear forces.) Scattered protons may rebound, be deflected, or simply be slowed down. In any event they are removed from the proton beam of which they were initially a part. In the scattering process energy may be transferred from the energetic protons to the target atoms.

Two kinds of scattering occur, *inelastic* scattering and *elastic* scattering. In an inelastic scattering process part of the energy of motion (kinetic energy) of the proton serves to excite the struck nucleus, and kinetic energy is transformed to internal or potential energy of the nucleus. On the other hand, in elastic scattering the proton imparts only kinetic energy to the struck nucleus, but none of the proton's kinetic energy is converted into other energy forms. Thus, the kinetic energy of the system comprising both particles remains unchanged as in billiard ball collisions. For a target nucleus having a given mass, the amount of energy transferred will depend on the angle through which the proton is scattered. Much can be learned about nuclear forces from the energies and angles of scattered particles.

Although protons were used as the example in discussing scattering, all the other particles such as neutrons, electrons, alpha particles, etc., can also be scattered on collision with nuclei. The following table lists 22 universities performing a wide variety of scattering experiments and 26 accelerators employed in these studies.

Excitation Functions

When deuterons or heavy hydrogen nuclei are accelerated and used to bombard nuclei, the reaction frequently results in the neutron from the deuteron being captured by the nucleus and the proton being emitted as a free particle. In such reactions it was found that a higher percentage of target nuclei undergo change as the energy of the deuteron projectile is increased. In this connection, the dependence of the yield of a nuclear reaction on the energy of the incident particle is called the *excitation function* of the particular process. Excitation functions are being worked out in several university laboratories, particularly at the University of Washington where research is performed with a 60-inch cyclotron (see table).

Summary

In summarizing, there are 33 universities at work on 62 accelerators. Each group contributes new data or improvements of older data and at the same time provides training for the nuclear physicists of the future. The new facts being brought to light continue to fill in the spaces of a giant jigsaw puzzle. When all the pieces are put together in the right order man will have attained a more complete understanding of the source of atomic energy and, possibly, a greater facility in its use.

PARTICLE ACCELERATORS USED FOR AEC RESEARCH BY UNIVERSITIES

Institution	Particle	Energy (Mev)	Year of completion	Type of research
SYNCHROTRONS:				
California Institute of Technology.	Electron	1,000	1953	Meson production.
University of California Radiation Laboratory.	Electron	335	1948	Nuclear structure.
	Proton	6,100	1953	Meson production and scattering, neutron and proton interactions.
Cornell University	Electron	1,500	1955	Meson physics.
Iowa State College	do	80	1951	Nuclear structure.
Massachusetts Institute of Technology.	do	330	1950	Do.
Michigan, University of	do	300	1953	Electron scattering and nuclear structure.
Purdue University	do	300	1953	Nuclear forces.
SYNCHRO-CYCLOTRONS (accelerator diameter shown in parentheses):				
University of California Radiation Laboratory (184″).	Deuteron	195	1946	Meson production and scattering, high energy nuclear reactions.
	Proton	350		
	Alpha	390		
Carnegie Institute of Technology (142″).	Proton	440	1952	Do.
Chicago, University of (170″)	do	400	1951	Do.
Columbia University (170″)	do	400	1950	Meson production and scattering, high energy nuclear reactions, high resolution slow neutron spectroscopy.
Rochester, University of	do	240	1948	Do.
CYCLOTRONS (accelerator diameter shown in parentheses):				
University of California (Los Angeles) (37″).	do	18	1934	Nuclear reactions, proton group studies.

PARTICLE ACCELERATORS USED FOR AEC RESEARCH BY UNIVERSITIES—Continued

Institution	Particle	Energy (Mev)	Year of completion	Type of research
CYCLOTRONS—Continued				
University of California Radiation Laboratory, (60").	Proton Deuteron Alpha	9 18 36	1939	Heavy ion acceleration, production of radioisotopes, nuclear reactions.
Columbia University (36")	Protons Deuteron	4 8	1939	Slow neutron spectroscopy.
Harvard University (92")	Proton	125	1949	Nuclear reactions and nuclear scattering.
Illinois, University of (41")	Deuteron	10	1940	Nuclear reactions, scattering.
Indiana University (45")	do	22	1941	Do.
Michigan, University of (42")	Deuteron Proton	10 20	1950	Fast neutron spectroscopy.
Ohio State University (42")	Proton Deuteron Alpha	5–7 10 20	1951	Nuclear reactions, nuclear scattering.
Pittsburgh, University of (47")	Deuteron	16	1940	Do.
Princeton University (35")	Proton	18	1951	Precision nuclear reactions and scattering.
Purdue University (37")	Deuteron Alpha	11 21	1936	Nuclear reactions and structure.
Rochester, University of (27")	Proton	7	1936	Nuclear structure, nuclear scattering.
Washington, University of (60").	Deuteron Alpha	20 40	1951	Excitation functions and alpha particle scattering.
Yale University (28")	Proton	4	1940	Nuclear structure.
BETATRONS:				
Case Institute of Technology	Electron	30	1949	Nuclear reactions, electron scattering.
Chicago, University of	do	100	1950	Nuclear reactions.
Illinois, University of	Electron do do	22 80 300	1949 1949 1950	Do. Do. Meson production, electron scattering.
Pennsylvania, University of	Electron	22	1949	Nuclear reactions.
INEAR ACCELERATORS:				
University of California Radiation Laboratory.	Proton	32	1947	Nuclear spectroscopy, nuclear scattering.
	Heavy ion	10/nucleon	1957	Under construction (nuclear chemistry).
Massachusetts Institute of Technology.	Electron	16	1950	Nuclear reactions.
Minnesota, University of	Proton	40	1952	Scattering, nuclear reactions.
Purdue University	Electron	10	1952	Nuclear reactions, low energy electron scattering.
Stanford University	Electron	70	1955	Under construction (accelerator development).
	do	680	1956	Under construction—now in partial operation (meson production, electron scattering).
Yale University	Heavy ion	10/nucleon	1957	Under construction (nuclear physics).
	Electron		1955	Slow neutron spectroscopy.
ELECTROSTATIC GENERATORS:				
Bartol Research Foundation	Proton	2	1951	Fast neutron scattering.
California Institute of Technology.	do	1.5 3 4.5	1946 1948 1950	Nuclear spectroscopy. Do. Do.
Columbia University	do	5.5	1955	Fast neutron and nuclear spectroscopy.
Duke University	do	4	1951	Do.
Iowa, State University of	Proton Deuteron	4 4	1950	Nuclear spectroscopy.
Johns Hopkins University	Proton	3	1953	Nuclear spectroscopy, fast neutron reactions.
Massachusetts Institute of Technology.	do	1 5 8	1938 1947 1952	Nuclear spectroscopy. Do. Do.
Minnesota, University of	Proton Deuteron	3.75 3.75	1940	Do.
Notre Dame, University of	Electron	2	1940	Electron scattering.
Ohio State University	Proton	2	1950	Nuclear spectroscopy.
Pennsylvania, University of	do	1.5	1951	Do.
Rice Institute	do	2 6	1946 1952	Nuclear spectroscopy, fast neutron scattering. Do.
Texas, University of	do	4	1952	Nuclear spectroscopy, fast neutron interactions.
Virginia, University of	do	1	1955	Do.
Wisconsin, University of	do	4.5	1939	Nuclear spectroscopy, fast neutron scattering.

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Chemical Research by Universities

The release of atomic energy for military or for peacetime applications requires preparation and processing of many new materials, some on an enormous scale. The subsequent use of these materials is often under conditions far more difficult than those encountered in normal industrial operations. At every stage of this complex undertaking one must be concerned with how materials react to or resist the effects of other substances in contact with them, or what are the effects of temperature and pressure, and of the radiation which is frequently present. In the preparation of special materials to be put into a reactor for irradiation or where products of reactor irradiation are to be recovered, many of the processes are entirely chemical in nature.

The manifold impact of chemical problems on utilization of nuclear energy requires that the chemists working on atomic energy projects shall be continuously involved on many fronts in the struggle for better processes at lower cost. The long-term assurance of supplies of raw materials is based on progress in understanding the processes by which ore deposits are formed, and in the improvement of processes for recovering uranium and thorium from these sources. Conversion of ore concentrates to fuel for reactors and recovery of the valuable constituents from used fuel are expensive operations which must be further improved. Materials must be developed that can resist the severe conditions of use in a reactor. Chemical methods have provided powerful tools in the interpretation of the nuclear processes involved in the release of atomic energy and project chemists are continually using such methods and developing better techniques to extend knowledge of nuclear reactions.

Underlying the specific chemical problems is the need for better and more extensive knowledge of the fundamental properties of chemical substances and of basic chemical principles. Advances here will result in a more effective attack upon the difficult practical problems that will arise as the Nation moves into a nuclear power economy. The fundamental problems are emphasized in all parts of the chemistry program. It is here that the universities are clearly suited, by their academic background and unconcern with immediate technical problems, to make their most important contributions. In discussing the contributions to the Commission's program of university research in chemistry, examples are given of work bearing on some of the current technical developments.

Raw Materials

Atomic energy is based on the chemical element uranium. Thorium is also potentially useful in power systems. These elements combine in nature with other elements as minerals. Among the many varieties known the content of the useful elements vary widely.

In the search for uranium to support a continuing large-scale atomic industry, research is required to develop methods for locating useful minerals, to learn how ores were deposited, and to discover their origin. The results may assist in locating new deposits. The concentration of the valuable mineral components of the ores, the isolation of the metals, their purification, and a host of other problems arise in connection with the processing. The method of attack on these problems varies with the particular ore. A method of chemical treatment that is entirely satisfactory for high-grade ore, such as pitchblende, is not suitable for relatively low-grade carnotite. The universities are making valuable contributions to the solution of all these problems through 15 separate research projects carried out for the AEC in their own laboratories.

For example, at California Institute of Technology the problems of ore formation and occurrence are under investigation through measurements indicating the temperature of the rock in the geologic era when the uranium ore was formed. The ratio of abundance of the light and heavy isotopes of oxygen in the "ore minerals" is an indication of that temperature. The measurements indicate that minerals containing uranium and thorium were formed at a considerably lower temperature than the quartz and feldspars in which these minerals are imbedded. This is regarded as an important clue to the method of formation, but its full significance is not yet known. The geochemistry of radioactive elements in granites is being investigated with the hope of more definitive conclusions, since these rocks are related in origin to the uranium minerals. Evidence strongly indicates that uranium was deposited between the grains of feldspar and quartz where it is more accessible than previously supposed.

Some of the uranium atoms originally present in minerals, such as pitchblende, have already undergone fission either spontaneously or by absorption of neutrons. The number of neutron-induced fissions were estimated by scientists at the University of Chicago and at the University of Arkansas. Both studies indicate that about 25 to 30 percent of the fission in pitchblende is neutron-induced. The Arkansas group has also undertaken analysis for radioactive chlorine 36 as an indicator of total neutron flux in minerals, with the objective of evaluating the overall importance of neutron reactions in geologic history.

At the University of Chicago measurements are being made of temperatures that existed in the oceans during past geologic ages. It was found that the bottom temperature of the Pacific Ocean has fallen by about 9° C. during the last 35 million years, and the temperature is apparently still decreasing. Measurements depend on the variations in the amounts of heavy oxygen (O^{18}) in the calcareous shells of marine animals. Temperature determinations are being correlated with radioactive carbon dating methods to broaden our understanding of the age and method of deposition of ocean sediments.

Knowledge of the history of ground water yields a better understanding of processes that deposit mineral substances, and may be helpful in finding useful ore bodies. Although the possibility that some of the water issuing from hot springs has originated from the earth's interior cannot be entirely excluded, it was found by scientists of the University of Chicago that hot springs are fed mostly by surface water that has traveled deep into the earth and become heated and returned to the surface.

In all of these studies new knowledge of the nucleus has increased our understanding of the geological history of the earth's crust.

Nuclear Chemistry

When a nucleus fissions or is struck by an accelerated particle, so that it breaks up into smaller pieces, one asks what new nuclei are formed and what properties they possess. Such products of nuclear disintegration are often best identified through their chemical properties. In fact chemical methods were used for identifying the artificially produced heavy elements and their isotopes, including plutonium one of the important sources of nuclear energy. It is also necessary to know both chemical and nuclear properties of the elements in order to understand and improve the design of nuclear machines and weapons.

When medium high-energy protons, deuterons, helium ions, etc., are used to bombard the nuclei of the common stable elements, a wide variety of different nuclei is produced. A study of the nature and the yields of the nuclei contributes to our understanding of the nucleus and what happens to it when struck by a high energy particle.

The elements, cobalt, vanadium, cesium, and yttrium, among others, were subjected to proton bombardment at energies up to 240 Mev (million electron volts) in the University of Rochester synchrocyclotron, in order to study the nature and yields of the various kinds of nuclear fragments produced and thereby add to our understanding of the nucleus.

The total yields decrease with increasing proton energy, amounting at 240 Mev to about 25 percent of the amount obtained at 60 Mev, thus indicating a change in the nature of the process occurring. At low energies, the proton projectile amalgamates with the target nucleus to form a neutron-deficient nucleus that subsequently disintegrates to a stable form of lower atomic number. At high energies, the bombarded nucleus becomes somewhat transparent, and a large percentage of the protons pass through without striking neutrons or protons. As a byproduct of these studies, previously unknown nuclei are formed. At the University of Rochester alone more than a dozen new nuclei were found and studied.

A new isotope of manganese (Mn^{53}) was recently produced at Florida State University. In this instance chromium 53 (Cr^{53}) was bombarded with 9.5 Mev protons to produce Mn^{53} which has a half-life of about 140 years.

Radiochemistry

A minute amount of a radioactive isotope of an element, when placed in a sample of the element, makes possible observation of the sample's course during a chemical, biological, or physical process. Movement of the element can then readily be followed by radioactivity measurements without disturbing the process in any way. Isotopes that are so used are called *isotopic tracers*. Radiochemistry includes the preparation and isolation of the radioisotopes as well as their adaption to these studies. Isotopic tracers are generally produced by means of reactor or accelerator irradiation of suitable targets. Although the uses of isotopic tracers are already numerous, they are constantly increasing.

A year ago the technique of isotopic tracing was possible with all of the 100 chemical elements then known except aluminum. The naturally occurring form of this element contains only the stable isotope Al^{27}. The longest lived radioisotope then known (Al^{29}) has a half-life of only seven minutes, too short for tracer work. Several lines of theoretical and experimental work suggested that the known 6-second Al^{26} might be only one of a pair of nuclear isomers (nuclei of the same element having the same mass number, but existing in different energy states) and that the other might be long-lived.

At Carnegie Institute of Technology, a feebly radioactive sample of aluminum was isolated from a magnesium target bombarded with deuterons in the University of Pittsburgh cyclotron. The half-life of the new aluminum isotope, designated Al^{26g} to indicate that it is in the ground or stable state, is about 1 million years. It emits both beta and gamma radiations—easily measurable with standard equipment, making Al^{26g} suitable for tracer work.

At Florida State University, a search was made for new radioactive isotopes that might be particularly applicable as tracers. The most interesting isotope uncovered appears to be magnesium 28 (Mg^{28}). It is particularly useful, since its half-life of 21.3 hours is more than 100 times longer than that of the longest-lived previously known magnesium activity. For this reason, it should prove particularly useful in the study of photosynthesis, the metallurgy of magnesium animal and plant metabolism involving magnesium, and perhaps the mechanism of the Grignard reaction in organic chemistry. Not only is magnesium 28 useful as a magnesium tracer, but because it has an aluminum activity in equilibrium with it, a second isotope of aluminum (Al^{28}) is available for tracer experiments.

The preparation and use of tracers is another example in which research provides the means for further investigations that are essential in solving important and difficult problems. Isotopic tracers are powerful research tools for learning how processes occur. In addition to the universities named, a half dozen others are making significant contributions to this program.

Radiation Chemistry

High energy radiations are destructive to most solids, liquids, and gases, and to living matter. On the other hand, they are potentially useful in medical treatment, in chemical synthesis, and in modifying chemical properties. For example, the materials in a reactor are always exposed to high energy radiations as a result of the fission process. These include neutrons, beta particles, and gamma rays. When the detrimental effects of radiations on engineering materials are better understood, it will be possible to select materials that will stand up under exposure. A beneficial effect is also observed in the plastic *polyethylene* whereby hardness, tensile strength, and density are increased by irradiation. This points to the possibilities that may be realized from research in this field.

Work in radiation chemistry once required an expensive source of radiation. However, the radiation project at the University of Notre Dame, in collaboration with Oak Ridge National Laboratory, developed a versatile cobalt 60 radiation source that is not too expensive for a small college laboratory or research institution.

Hot Atom Chemistry

The term *hot atom chemistry* refers to the properties of atoms which are in a high state of excitation (p. 57) or possess high kinetic energy as a result of nuclear processes. Also, processes in which a radioactive atom emits a particle and "kicks back" or recoils from its position are "hot" processes. It is apparent that, through such reactions, new compounds can be formed in a reactor and also in solutions being processed to recover material after pile irradiation. Knowledge of these reactions will help improve atomic energy operations.

A study was carried out at the University of Arkansas on the variation in chemical form of certain fission products, as affected by the environment of the fission process. This study could be a source of fundamental information on the chemical effects of energetic nuclear processes, and be valuable in planning chemical processes in reactor technology.

To date, the work was largely concentrated on one of the fission products—iodine. Iodine was fractionated into oxidized and reduced forms (varieties representing a difference in the number of hydrogen atoms with which each form will combine) following the irradiation of uranium in various chemical environments. The distribution of iodine activity among its oxidation states was determined as a function of solution composition, length and intensity of irradiation, and the separation method. The following results were obtained: (1) increasing the irradiation time led to a decrease in the fraction of reduced iodine, (2) when the irradiation period was held constant, the more alkaline solutions yielded a smaller fraction of reduced products, and (3) greater radiation intensities increased the production of oxidized forms.

At the University of Illinois crystalline ammonium compounds are being irradiated with pile neutrons in a study of the chemical processes taking place when an energetic recoil atom is projected into a crystalline material. The chemical compounds containing radioactive carbon that are produced, following the N^{14} (n, p) C^{14} reaction, were determined for the case of irradiated ammonium sulfate crystals dissolved in water.

High Temperature Chemistry

The most efficient power reactors operate at high temperatures. Accordingly, it is important to develop materials that will be stable and resist corrosion at such temperatures. In the processing of spent reactor fuels there is need for more economical methods; high temperature metallurgical or chemical methods may prove advantageous for this purpose. Both could be explored more effectively if the properties of chemical substances at high temperatures were better known. Studies to broaden knowledge in this area are underway at six different universities.

At high temperatures atoms in the solid state can move throughout the solid structure at appreciable rates. When a metal is exposed to a corrosive gas, such as oxygen or chlorine, it becomes covered with a layer of metallic oxide or chloride. Further reaction takes place only if the metal atoms or the atoms of the attacking gas can diffuse through the layer of corrosion product. At Indiana University, the rates at which atoms move through such solid layers are being studied. These rates determine the resistance of the metal to attack by gases at high temperatures.

In the case of an oxide film on copper—by using oxygen 18 as a tracer—it was found that the copper migrates about 30 times faster than the oxygen at 1,000° C. An understanding of these rate processes should aid the development of alloys suitable for exposure at high temperatures to reactive gases.

The nature of gases and solids at high temperature is also under study. Titanium, a metal useful for high temperature application, has several oxides, one of which, TiO, was identified in gaseous form by astronomers in many stars. At the University of Kansas this oxide has received particular attention, and the stability of gaseous TiO was measured. It was found that solid TiO evaporates as molecular TiO predominantly, rather than decomposing into atoms.

Chemical Kinetics and the "Isotope Effect"

The rates of reactions that are desired in a chemical process or the corrosion that one would like to avoid in a reactor structure are related to the nature, the mechanism, and the energy changes of the reaction taking place. Study of such effects is of fundamental importance in all chemical systems. The difference in reaction rates between isotopes of the same element—that is between atoms that differ only in weight and not in chemical identity—provides a significant tool for the understanding of *kinetic processes*. For some time after the discovery that many elements have different isotopes, it was thought that isotopes of the same element should have identical chemical properties. However, careful work showed the existence of differences both in rates of reaction and in degree of reaction to equilibrium—the latter providing the basis for isotope separation methods that are discussed under "Isotope Separation" (pp. 70–71).

A molecule containing a heavier isotope is more stable than one containing a lighter one. Such molecules react at slightly different rates. Studies of this "isotope effect" carried out at Illinois Institute of Technology and at the University of Michigan have shed light on reaction mechanisms, and have served to corroborate the theory of the isotope effect.

The greatest differences in reaction rates are found between the isotopes of hydrogen. The speed of reactions involving rupture of light hydrogen bonds is often 5 times or more faster than the speed of reactions involving heavy hydrogen (deuterium). A recent study showed that at 400° C. light water (H_2O) reacted with zinc 60 percent faster than did water containing deuterium (HDO). Thus, in the reduction of water vapor by zinc, the portion of the hydrogen evolved first was depleted in deuterium by a factor of 1.6, whereas the last portion of hydrogen produced was substantially enriched in deuterium.

Another investigation was concerned with the rates of thermal decomposition of chloroform containing hydrogen and chloroform containing deuterium at elevated temperatures. The difference in rates was small, showing that the initial step in the pyrolysis is not the direct scission of a C–H (or C–D) bond, but rather involves a C–Cl bond rupture, a fact which was demonstrated by a different method.

In another study the C^{13} isotope effect was measured in the thermal decomposition of gaseous ethyl bromide. The initial portion of ethylene produced has a slightly lower C^{13} abundance. The small magnitude of the isotope effect suggested that the first step in the reaction does not involve the simple rupture of the C–Br bond, for which a larger carbon isotope effect would be expected on theoretical grounds, but that the reaction proceeds by the direct intramolecular elimination of HBr.

The hydrogen isotope effect on different organic reactions was studied at the Massachusetts Institute of Technology, and the results obtained have contributed to an understanding of reaction mechanisms. Investigations in which tritium was used as a tracer have extended understanding of the exchange of hydrogen between oxygen atoms—a process of the most widespread occurrence.

Isotope Separation

Although different isotopes of an element have very similar chemical properties, their nuclear properties may differ greatly. Accordingly, when materials are for nuclear use, one isotope is frequently preferred to the others found with it and there is a need to separate it from the others. Thus, uranium 235 is useful in power reactors when separated from the preponderant uranium 238, and deuterium or heavy hydrogen in the form of heavy water is useful for slowing down neutrons in thermal reactors.

One of the more interesting methods of isotope separation is *chemical exchange.* When two suitable compounds containing a mixture of isotopes are brought together under proper conditions, a chemical exchange, or transfer, occurs, and the isotope of interest becomes concentrated in one of the compounds. Although the single contact, or single stage, separation is normally rather small, the procedure can be repeated many times to give significant concentrations. Production of heavy water usually depends upon this principle.

Chemical exchange methods provide efficient and versatile means for separating the isotopes of many of the lighter elements. These isotopes find many uses in the sciences and in engineering, especially as tracers. At Columbia University, investigations of the separation of nitrogen 15 from nitrogen 14 showed that the exchange of nitrogen

15 from nitric oxide gas to a solution of nitric acid appears favorable for a large-scale separation plant. Similar studies initiated at New York State College for Teachers indicate that the exchange between nitric oxide gas and liquid oxides of nitrogen may also be useful.

An economical method for the production of nitrogen 15 is of interest, since it would make possible the use of thorium nitrate in homogeneous breeder reactors where thorium should be converted to uranium 233 by absorption of neutrons at a high efficiency. Ordinary nitrogen which consists of 99.72 percent nitrogen 14 is not suitable for this application because it absorbs too many neutrons, whereas nitrogen 15 absorbs relatively few neutrons.

Metallurgical Research by Universities

More than 70 of the 101 recorded elements are metals, but only a relatively few of these are now developed as materials of industry. The uncovering of additional useful materials was speeded up by the exacting requirements of the atomic energy program, which makes it necessary to examine carefully all of the elements in the periodic table to determine their nuclear, chemical, and physical properties. Some metals produced commercially prove satisfactory for use in reactors, accelerators, and weapons, but this is the exception. More commonly, treatment, processing, and mixing of metals as alloys are required to provide a suitable material. Ceramics prove useful for some high temperature applications where conventional metals and alloys fail.

The metallurgist is concerned with the extraction of metals from ores, and their subsequent purification, the heat treatment of metals to obtain suitable properties, the correlation of the properties of alloys with their compositions, the reduction or elimination of corrosion, the effects of radiation on materials and many other problems.

The AEC has about 50 university contracts for research of long-range interest in metallurgy. These deal with (1) production, treatment, and properties of materials of AEC interest—such as uranium, thorium, zirconium, etc., (2) the structural nature of solids, including alloys, and (3) the effects of various kinds of radiation on materials. Examples of fundamental metallurgical research—programs on crystal structure, diffusion (movement of atoms in metals), and sintering (bonding of metal powders)—in which several laboratories are cooperating, follow.

Crystal Structure of Metals

One of the characteristics of solid metals is the arrangement of their atoms in a periodic array of *crystal lattice*. In the very simplest case, the lattice is made up of cubical cells stacked face to face. Atoms are located at each of the eight corners of every cube. Some metals are built as variations of this simple structure, whereby an additional atom is located at the center of the cube (body-centered cubic) or further atoms occupy the cube faces (face-centered cubic). Other metals have still more complicated structures.

The distance between atoms in a unit cell varies with the metal but is on the order of one-hundred-millionth of an inch. Single crystals in which the lattice structure is continuous throughout can be produced in pencil size, or larger, but the usual metal is an aggregate of many small crystals or grains, randomly oriented. In these, the adhesive forces between grains are of special interest in determining the strength of the metal. Bicrystal specimens are frequently used for research purposes, since these consist of two single crystals separated by a single grain boundary. Crystal dislocations are regions of misfit in which one section of the crystal contains an extra plane of atoms relative to the adjacent section. Regions of misfit thus give rise to an alignment of lattice defects known as *dislocation pipes* or *channels*. For example, these defects can occur when one portion of a crystal is caused to slide or slip over the remaining portion.

Studies of crystal structure and its influence on the properties of solids are under way at the University of Virginia, New York University, Massachusetts Institute of Technology, and the State University of Iowa.

Diffusion in Metals

Metals, as they are known in most aspects of everyday usage, are rather stable and dormant materials. The position of the atoms in the metal, however, is far from rigid, since atoms are constantly changing their positions from one lattice site to another. Furthermore, the rate of change is increased by increasing the temperature. For example, in a piece of solid lead at a temperature of a few hundred degrees, each atom changes its location about a billion times a second. If two blocks of lead are placed together with good contact between the smoothed sides of each, and the assembly is heated to high temperature (but below the melting point), the two pieces will be bonded together. The effect results from the movement of lead atoms in both directions across the boundary between the two pieces. Such movement of atoms in a single metal is known as *self-diffusion*. When two different metals, such as lead and tin, are involved, the phenomenon is known as *interdiffusion*.

The diffusion phenomenon is of extensive scientific and technological importance, since atom movements are involved in practically all metallurgical reactions and processes. For example, diffusion plays an important role in the homogenization of alloys, the heat-treatment and tempering of metals and alloys, the sintering or heat-bonding of metal powders, the coating and cladding of metals to improve or protect the surface, and in a host of other operations. The use and understanding of the diffusion process is essential in the fabrication and cladding of reactor fuel elements, in the processing of the irradiated elements for fuel recovery, and in other problems of vital interest to the AEC. University laboratories that have assumed an active role in this program, under AEC contracts, are the University of Illinois, Carnegie Institute of Technology, and Rensselaer Polytechnic Institute.

Mechanisms. Experimental and theoretical studies on the basic mechanisms of diffusion in metallic systems are being made at the University of Illinois, where a special type of alloy system is under study. These alloys are mixtures of two metals (*binary alloys*) in which the minor constituent is dissolved in the major component, just as sugar dissolves in water. The resulting solution of one metal in another is known as a *solid solution.* Only the crystals of the predominant metal are observable in the alloy. The dissolved metal is termed the *solute* and the dissolving metal, or major component, is the *solvent.* The binary alloys under study are further distinguished in that they are a special kind of solid solution known as a *substitutional solid solution,* because the solute atoms replace, or substitute for, solvent atoms in the crystal lattice.

Particular attention is being devoted to precise radioactive tracer measurements of the migration of solvent and solute atoms in these alloys. With solid solutions of metals in silver, the new work showed that the solute atoms diffuse faster than the silver atoms in those cases where the former are heavier than silver, i. e., lie to the right of silver in the periodic table of the elements (e. g., cadmium, indium, tin, and antimony). On the other hand the metals diffuse slower when they are lighter than silver. The effect depends upon the difference in atomic number (number of protons in the nucleus) between the solvent and the solute.

The Illinois investigators developed a theory of the dependence of the diffusion mechanism upon atomic number, giving a good explanation of many of the experimental facts.

Grain boundary diffusion. At the Carnegie Institute of Technology, the problem of grain boundary diffusion in solid solutions is being extent on the direction of the movement. In a parallel study of self-diffusion along grain boundaries in bicrystals of the body-centered cubic lattice (i. e., iron containing about 3 percent silicon), it was shown that there is a good correlation between the density of dislocations in grain boundaries and the depth of diffusion penetration.

This aspect of the program is continuing to clarify the role of atomic size in grain-boundary diffusion and also the diffusion behavior along grain boundaries made out of various types and combinations of dislocations.

Anisotropy. It is well known that many metal crystals exhibit different diffusion rates in the various lattice directions. This problem of *anisotropy of diffusion* is being vigorously investigated at the Rensselaer Polytechnic Institute. Measurements of the diffusion coefficients (numbers indicating the rate of diffusion) and energies required for diffusion in different lattice directions in zinc, cadmium, and thallium have been completed. Similar studies on antimony, arsenic, and bismuth—members of a different crystal system—are in progress.

Moreover, it is intended to study the anisotropy of diffusion in iridium and uranium. Knowledge of the diffusion rates in uranium in the different lattice directions is of vital importance in understanding many of its peculiar characteristics.

Liquids. Besides atom movements in solids, the diffusion of atoms in the liquid state is also of great interest and concern. Not only does a study of diffusion in liquids contribute to an understanding of the liquid state, but such data are useful in dealing with problems associated with heat-transfer liquids, mass transfer, and corrosion in nuclear reactors.

A study has been completed at the Carnegie Institute of Technology on the diffusion of atoms in liquid lead-bismuth alloys. The program for investigating various diffusion phenomena in liquid metals is now being expanded to include other academic institutions.

Sintering of Metals and Oxides

The process of bonding metal or other powders by heating below the melting temperature to form a strong cohesive body is called *sintering.* In this process the powders are usually first pressed into the desired shape when cold. Metal-cutting tools, bearings, machine parts, insulators, and many other items can be fabricated by using the sintering process. The technique is often employed in making special materials required in the atomic energy program.

It was shown that atoms move within metals—especially at higher temperatures—and that bonding of metals can result from this process. Thus, diffusion is generally acknowledged to take place during the sintering process. Sintering in certain cases is believed to be partly due to the flow of the powdered material under the processing conditions—a phenomenon known as *plastic flow*. New cohesive bonds are thus formed both by diffusion and by plastic flow. Other mechanisms are also thought to contribute to the bonding of powders.

In the hot pressing of powder formed into a compact, or briquette by compression in a die, elevated temperature and pressure are used to increase the surface contacts through deformation of the powder particles. Diffusion can then proceed at a more rapid pace. The resulting metal is polycrystalline and resembles that obtained by conventional fabrication methods—melting, casting, and forming.

Plastic flow during sintering is related to the surface forces of the particles. Just as two drops of water will join together to form a larger droplet with a resulting decrease in surface area, solid particles will combine with a decrease in the area of exposed metal surface. The decrease in surface is accompanied by a decrease in surface energy, and a more stable condition is thus reached. The fact that temperature increases the reaction is directly related to the increase in surface energy attending the rise in temperature. When bonding is accomplished, surface energies are reduced, and only a grain boundary may remain as a reminder of the previous status.

To clarify the mechanism of sintering in metals and ceramic powders, AEC-financed experimental and theoretical studies are under way at various laboratories, including work at the Massachusetts Institute of Technology and the University of Utah.

At MIT, sintering studies were made for sodium chloride, glass, copper, aluminum oxide, zirconium dioxide, sodium fluoride, and calcium fluoride. It was shown that sodium chloride, glass, and copper sinter by a distinctly different mechanism. Investigations are planned for systems which have a limited quantity of material present in the liquid state. Surface energies will also be studied.

Metals rolled when cold, or otherwise cold worked, possess stressed and distorted grains. When the metal is heated to a sufficiently high temperature, which varies with the conditions, and then slowly cooled, the grains are rendered free of stress. This process is known as *recrystallization*. In a similar fashion, recrystallization is observed as a part of the sintering process.

At the University of Utah, research is being performed on the sintering characteristics of alumina (Al_2O_3), with special attention to recrystallization and the influence of impurities.

Since the sintering process is often accompanied by an increase in the grain size of the material (*grain growth*), relationships will be

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sought that link recrystallization, grain growth, and impurities. The Utah investigators have already found that impurities can increase or decrease the temperature at which recrystallization will occur and that the observed effect depends upon the particular impurity present. Measurements of plastic deformation under load are also being made in order to determine the effect of crystal structure on this property of materials.

Results of University Research

The ingenuity of university researchers led to the design and construction of a variety of particle accelerators that impart energies up to billions of electron volts in nuclear particles. In addition, North Carolina State University now owns and operates a nuclear reactor and many others are being planned by educational institutions. All of these are tools useful for basic studies of the structure of matter and forces at work in the nucleus. They are also useful in finding practical answers relating to the nature and properties of materials produced in production and power reactors, to the effects of irradiation in changing the character of materials, and to methods of separating the mixtures of radioactive materials that are the products of nuclear bombardment.

University research in sintering of metal powders and in the diffusion of atoms in metals proved useful in the fabrication and cladding of reactor elements and in fuel recovery studies. Such studies have shed light on the peculiar characteristics of uranium—the most important source of nuclear energy.

University studies of the age of minerals and of mineral deposits are making easier the location of thorium and uranium ores and their extraction from these ores. New nuclides are being prepared and identified, and novel uses for these are surely forthcoming. Research at educational institutions advanced the discovery and use of nuclides for isotopic tracing, and this technique can now be used with all of the 101 known chemical elements.

Studies of high-temperature corrosion of metals and alloys help in the selection of satisfactory materials for reactors and chemical-processing equipment.

Advances made in isotope separation methods, as in the isolation of nitrogen 15 by chemical exchange, have served the atomic energy program in many ways.

Only a few of the university accomplishments in the Commission's research program could be outlined here. Contributions from our educational institutions have accounted for major breakthroughs in science and technology, resulting in the investment of substantial sums of money in successful processes used in reactor and weapons programs.

Biology and Medicine

The biology and medicine program of the Commission includes research relating to the establishment of control measures against harmful exposure to radiation for the protection of atomic energy workers and the public. Laboratory and field investigations continued in the past 6 months to be projected toward studies of the effects of radiation on living things, understanding the mechanisms by which these effects are produced, and developing controls for and methods of protection against damaging effects. Current progress is reported here on research projects indicative of the broad scope of this program.

Funds allocated for the 1955 fiscal year for the biology and medicine research program totaled $27 million and financed investigations in such fields as cancer, medicine, biology, and biophysics. The budget for the work done at the national laboratories and major research installations represented $19,570,000 of this total. Approximately 415 separate "off-site" studies at colleges, universities, hospitals and other research centers throughout the Nation received support in the amount of $7,430,000. The results of these studies are published and disseminated widely to research groups under the unclassified technical information program of the AEC. Illustrative of the many ways in which experimental data can be put to use are the techniques used by the Commission in the application of radioactive isotopes in research, some of which are described in the following.

A report on the biological and medical phases of the 1955 atomic test series held at the Nevada Test Site is given in this report.

Weapons Test Activities

Various safeguards were in effect during Operation TEAPOT to hold to a minimum the exposure of the public to fall-out radioactivity. The Commission also maintained an extensive monitoring system to detect and measure levels of radioactivity near the test site and also at points throughout the Nation. In general, the radiological safeguards and the monitoring system were similar to those for previous Nevada test series, but past experience made it possible to improve controls and procedures in several respects. As a result, fall-out outside the controlled area was less than that resulting from the preceding Nevada test series in the spring of 1953. Off-site levels of radioactivity were well below those which would impair the health of human beings or animals or cause damage to crops.

Improved Controls and Procedures

Improved weather prediction techniques and methods of forecasting fall-out intensity and location were utilized. For the first time, towers as high as 500 feet were built, and their use aided in keeping fall-out to a minimum. As in the past, all factors relating to health and safety were carefully considered by an Advisory Panel before the detonation of each device.

The system of radiological monitoring around the test site was strengthened by reorganization of procedures and the addition of two additional monitoring programs. The area within 150 miles of the test site was divided into 12 zones, each of which was staffed by a joint AEC-Public Health Service team. These personnel lived in communities within their zones during the test series, and acted both as monitors and as liaison between the residents and the test organization. There were also six mobile teams which moved to areas where additional monitoring was desired.

In addition to the monitoring teams, about 30 automatic recording instruments and the same number of telemetering units were in operation in localities within about 350 miles of the test site. The telemetering units were part of a unique system which made it possible for an operator at a control point to place a long distance telephone call to each unit, and to receive signals which could be translated into radiation readings in a few seconds.

As in the past, aerial surveys were conducted to provide for monitoring over large areas in a relatively short time.

National Monitoring System

The monitoring systems described above were used to obtain information on radiation levels within a few hundred miles of the test site, where more fall-out would be expected. To provide a continuous record of the lower level fall-out in more distant areas, samples were collected at 89 U. S. Weather Bureau Stations across the Nation as part of the Commission's National Monitoring System. This system has operated during previous Nevada series, and is maintained on a partial basis between testing periods.

Weather Bureau personnel at the stations cooperate with the Commission by serving as fall-out collection agents. A one-foot square gummed film, spread on a three-foot high stand, provides a simple but excellent device for catching and retaining fall-out particles. The films are changed each day. After being exposed, the film is mailed to the Health and Safety Laboratory at the Commission's New York Operations Office, where it is ashed in a vacuum furnace and the radioactivity in the ashes is measured. Through production line techniques, it is possible for the laboratory to count 400 to 600 such samples per day.

Fall-out Measurements in Test Site Area

In the area surrounding the test site, monitors made measurements of external gamma radiation, of airborne radioactivity, and of radioactivity in water. The results were as follows:

External gamma radiation. The highest measurements of external gamma radiation experienced in populated areas off the test site during Operation TEAPOT are given in the table below. The exposure is expressed in units of "Effective Biological Dose," which represents the best estimate of radiation dosage in terms of its biological effects. In calculating the effective biological dose, account is taken of reduction in exposure as a result of weathering and shielding by walls and buildings.

The operational guide established by the test organization in terms of the effective biological dosage for exposure of the public to radiation was 3.9 roentgens in any one year. This limit was not exceeded at any community nor at any place where people were living.

EFFECTIVE BIOLOGICAL DOSES

Location	*Approximate Population*	*Effective Biological Dose (roentgens)*
1. Elgin, Nev	40	2.90
2. Alamo, Nev. (and environs)	1,000	1.35
3. Moapa, Nev	150	.84
4. Glendale, Nev	17	.68
5. Beryl Junction, Utah	10	.61
6. Lockes, Nev	5	.51
7. Warm Springs Ranch, Nev	50	.51
8. Lund, Nev	300	.41
9. Caliente, Nev	970	.39
10. Logandale, Nev	300	.35
11. Warm Springs, Nev	12	.32
12. Beaver, Utah	1,700	.27
13. Currant, Nev	75	.25
14. Adaven, Nev	25	.21
15. Overton, Nev	600	.20
16. North Las Vegas, Nev	4,000	.19
17. Ely, Nev	7,000	.18
18. Enterprise, Utah	620	.18
19. New Castle, Utah	100	.18
20. Santa Clara, Utah	320	.18
21. Minersville, Utah	600	.17
22. Crystal Springs Junction, Nev	4	.16
23. Kanarraville, Utah	260	.15
24. Panaca, Nev	500	.13
25. Ash Springs, Nev	12	.13
26. St. George, Utah	5,000	.10

Airborne radioactivity. Although past experience indicated that the concentration of radioactive fall-out materials in the air is of secondary importance to the external gamma radiation, the air monitoring program was continued. The highest concentration of radioactivity in the air following any one detonation was at Ely, Nev. This amounted to about 6/100 of a microcurie per cubic meter averaged over the 28 hours that the material was present in significant quantities. The highest concentrations in air, averaged for the entire series, occurred at Ely, Nev. and Alamo, Nev., where the total additional radiation doses to the lungs from inhaling fall-out material were estimated to be about equivalent to that expected from breathing air containing normal amounts of naturally radioactive materials, for a period of several days.

Radioactivity in water. The highest concentrations of radioactivity in water measured during the spring of 1955 are shown below.

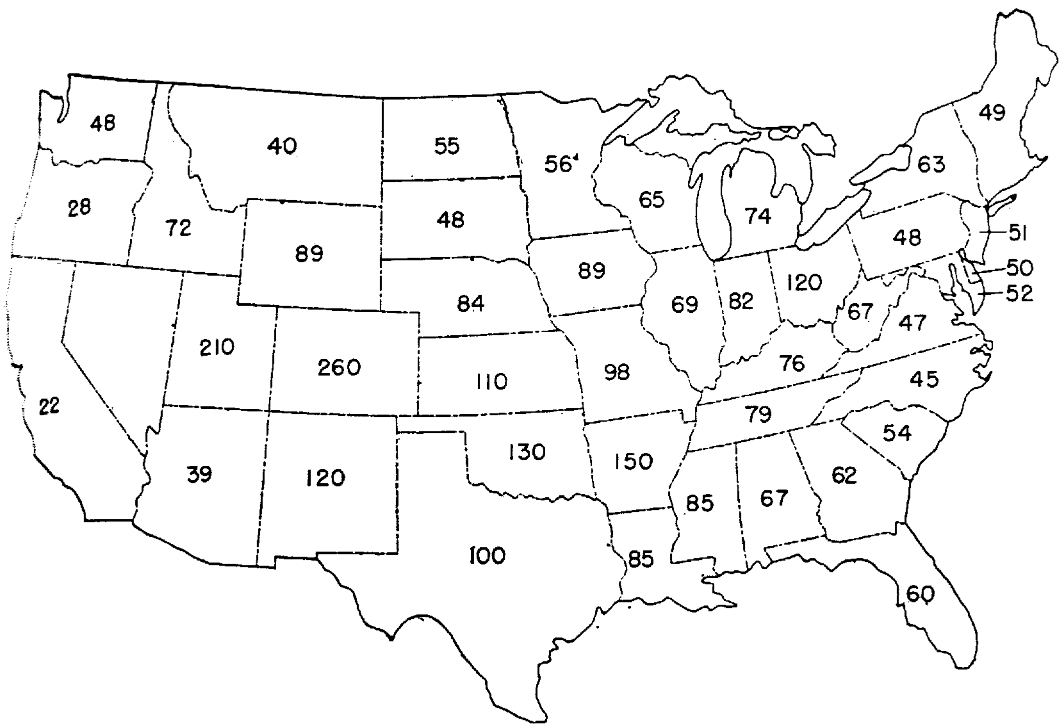
Locality	*Concentration (Microcuries per milliliter extrapolated to 3 days after detonation)*
Upper Pahranagat Lake, Nev	1.4×10^{-4}
Waterhole near State (Nevada) Highway 25	9.2×10^{-5}
Meadow Valley (Nevada) Wash	3.3×10^{-5}

The highest concentration noted in the table is about 1/36 of the operational guide—an amount that is still considered safe even if the water were to be stored and used as the sole source of supply for a lifetime.

Fall-out Measurements Across the Nation

The National Monitoring System consists of a network of stations which collect and measure fall-out over the entire United States. Fall-out levels at distances away from the test site have been low, and generally have not exceeded more than one milliroentgen per hour. The collection stations in the network do not provide information on immediate dose rates, as do the monitoring units operating in the test site area. However, the information collected has varied scientific uses. It is needed by the AEC to compute and record the overall accumulation of radioactivity in the Nation as a result of tests. It is needed by the photographic industry and by scientists conducting experiments with low-level radiation, since these activities can be affected by even a very slight increase over the normal background radiation. The data also are used by meteorologists to trace air masses and check predicted trajectories.

CUMULATIVE FALLOUT IN U.S. FROM BEGINNING OF WEAPONS TESTS TO 5/20/55 BETA ACTIVITY, MILLICURIES PER SQUARE MILE EXTRAPOLATED TO 1/1/56



More than 17,000 samples were processed by the Health and Safety Laboratory from mid-February to the end of May 1955 and analyzed to determine the overall distribution of fall-out resulting from the 1955 test series.

Since 1951, more than 200,000 samples have been processed to provide cumulative figures on fall-out in the United States resulting from all known tests conducted to date. The data are shown on the above map.

It will be noted that the figures vary from 22 millicuries per square mile in California to 260 millicuries per square mile in Colorado. In its natural composition, the upper foot of soil in the United States contains about 1,000 millicuries of radium per square mile.

Civil Effects Experiments

During the current test series, the Civil Effects Test Group under the test organization conducted extensive field experiments to obtain needed information for civil defense. This was the largest civil effects program ever undertaken during test operations. The program comprised 10 scientific and technical experiments broken down into 47 projects involving 160 separate tests. Agencies participating with the AEC included the Federal Civil Defense Administration;

the Department of Health, Education and Welfare; the Department of Agriculture; the Department of Commerce and the General Services Administration. Scientific and technical personnel actively engaged included a total of some 200 medical doctors, physicists, biologists, geneticists, veterinarians, chemists, architects, engineers and other specialists.

The experiments in the Civil Effects Test Group are described under the following categories:

1. The evaluation and documentation of radiological fall-out data: This included use of the radiation telemetering system as described in the Sixteenth Semiannual Report of the Commission (January–June, 1954). Airborne radioactivity and meteorological data were recorded through the use of land lines and radio links from points up to 350 miles distant to a central point at the test site headquarters. In addition, a number of automatic radiation measuring and recording devices was placed in populated areas out to 350 miles in potential fall-out locations. Data were collected of radioactivity deposited over other off-site and on-site areas by employing aerial survey techniques.

Utilizing the data from earlier tests, a study was set up to determine the function of distance as related to fall-out exposure. Five arcs were extended from the Nevada Test Site out to a distance of 160 miles. Rabbits were placed at several distances and radiation inhaled by the rabbits was measured.

A field exercise was held to train and orient on-site and off-site radiological personnel in monitoring procedures during atomic explosions. The groups participating in this training were drawn generally from State radiological organizations. The programs included monitoring techniques of radioactive fall-out with survey instruments, mobile laboratory equipment, light aircraft, evaluation of a number of commercially produced radiation detection instruments, and investigations of gamma radiation intensities in various parts of residences constructed for the tests in probable fall-out areas.

2. Biological and medical experiments: In this category, investigations were made to evaluate the effects of nuclear explosions on foods and foodstuffs. Bulk staples, canned foods, meat and meat products, semi-perishable foods and frozen food packages were exposed to develop information on immediate and long-range radiation effects. This study will be supplemented by a 2-year feeding program, in which the exposed food will be fed to experimental animals. The results will be used to develop permissible limits of nuclear radiations in food used under emergency conditions, and for the commercial market in peacetime. Resistance of glass, metal, plastic,

wood, paper, and other packaging materials to radiation, thermal and blast effects was also tested.

A number of biomedical experiments were designed to evaluate current medical data on blast phenomena, and to verify laboratory experiments. In a related project, a pilot test was developed in which rats were trained to move in certain maze patterns. These animals were again tested after exposure to determine the effect of noise shock on the efficiency of the animals to perform their learned routines in the maze patterns.

Biomedical and engineering experiments were combined to determine the design of physically resistant and biologically acceptable shelters and structures. Another phase of this work involved the distribution and density of missiles from explosion effects. Missile traps made of cork and plastic materials were placed both inside and outside the shelters and residences to determine the size, number and velocity of fragments per unit area produced from explosions.

3. Materials, utilities, structural and functional design projects: Tests were planned to study nuclear effects on residential, commercial and industrial structures and materials, shelters, utilities, services and associated equipment, mobile housing and emergency vehicles. Construction entailed completion of 4 two-story and 6 one-story residences, 7 commercial and industrial structures, and a number of special projects involving certain structural components. There were 15 to 20 indoor-type and 9 to 12 outdoor-type home shelters designed to test protection from blast loadings. Other tests included electrical installations, communications equipment, such as a standard commercial 250-watt AM radio broadcasting station, underground and surface installations of natural liquified petroleum gas and representative types of large machine tools, as well as a wide variety of safes and other record storage equipment.

Analysis of the results of these experiments is in preparation, and will contribute significantly to the knowledge necessary to work safely with nuclear energy in peacetime, and to improve techniques employed for self-protection against enemy action in the event of war.

Research Investigations

Results of current experimental work offer a certain measure of optimism, not possible a few years ago, on the possibility of protection against and recovery from radiation. However, vital problems of the effects of radiation on living things are still unsolved, and extensive research continues at the Commission's major laboratories and at the participating universities, hospitals, and other institutions.

Advanced methods and procedures employing radiation as a tool have helped to increase fundamental knowledge of the biological and chemical processes that take place in living things. A review of some of the important advances follows.

Protection Against Radiation

Experiments conducted for several years in laboratories throughout the world as well as in Commission and private laboratories, showed that reducing the supply of oxygen reduced the sensitivity of living cells to damage by X- and gamma rays. Similar effects were produced by using reducing compounds; that is, chemicals which use up oxygen during the process of their metabolism. One of the outstanding chemical compounds in this field was cysteamine (Bacq, University of Liege). More recently a derivative of cysteamine (S,B-aminoethylisothiuronium.Br.HBr.) was found to have a wider range of protective ability, and also to be less toxic than the original compound (Doherty et al., Oak Ridge National Laboratory). However, these protective effects resulted only from treatment given before or during radiation exposure. No protection was afforded by treatment given after exposure.

An approach relating to treatment after exposure was developed by transplanting spleens from nonirradiated mice to irradiated mice (Jacobson, Argonne National Laboratory). A considerable number of mice supplied with spleen transplants recovered from radiation damage. The basic action of the treatment is the prevention of radiation injury, hemorrhage, and anemia by causing damaged tissues to recover.

Similar results were obtained with mouse bone marrow transplantations (Lorenz, National Cancer Institute). Rat bone marrow was shown to prevent death of the irradiated mice. Some of these marrow tissues not only caused recovery from radiation damage, but also prevented leukemia induction by radiation (Kaplan, Stanford University). Rat bone marrow also was found to prevent spontaneous leukemia in mice (Lorenz, National Cancer Institute).

Attempts to isolate specific chemical substances which will produce the same effects in mammals as spleen or bone marrow have not been successful as yet. Experiments at Oak Ridge National Laboratory have shown that it is possible to produce recovery of bacteria from damaging effects of radiation by means of yeast or spleen extract.

For one strain of bacteria (*Escherichia coli*) it was found that the chemical substances glutamic acid, uracil and guanine are almost as effective as the yeast or spleen extracts. By combining chemical protection before irradiation and these recovery chemicals afterward, it was possible to make a very high percentage of bacteria resist large quantities of radiation. Experiments with this strain of bacteria under proper conditions of nutrition and temperature showed a reduction of 50 percent or more of the potentially lethal damage produced by radiation.

It also was indicated that the recovered bacterial cells had a lower mutation rate than might be expected from the amount of radiation exposure. This suggests that there may be a relation between the reduction in mutation rate and the increase in survival produced by these compounds, and that both effects are produced through the same protective mechanism. The low mutation rate is an interesting finding, since previous experiments had indicated that mutation production depends solely on the amount of radiation to which the cell is exposed. Further studies are now under way to see if these findings with bacteria can be applied to mammals.

By treating mice with some of these newly-found chemical compounds before exposure, giving bone marrow after irradiation, and streptomycin to reduce bacterial infection, investigators found that it was possible to more than double the amount of radiation which a mouse can survive.

Soil-Plant Relations in Fission Products Uptake

Knowledge of the effects of fission products on plant growth and reproduction is important in evaluating health and safety aspects of atomic tests and production operations of nuclear reactors. For present and future operations, it is necessary to understand their distribution in the soil, their uptake and concentration by plants, and their effect upon animals which might eat the plants. This information also is valuable for civil defense planning. (See appendix 7, "The Effects of High-Yield Nuclear Explosions," pp. 147–154.)

Investigators at the AEC–University of California project (Los Angeles), in collaboration with the U. S. Department of Agriculture Research Service, have acquired data on the distribution in the soil of various elements found in fission products that may enter the food-chain year after year.

When materials are transported or placed in the soil, many dynamic reactions follow. These reactions are very complex and the solution of single specific case effects is difficult. A solid particle that may come from radioactive fall-out, or result from the discharge of a nuclear reactor plant stack, may contain a number of different elements, each reacting in its own characteristic pattern. Among these are strontium, ruthenium, cerium, cesium and iodine. Current research indicates that most of these elements have distribution and uptake patterns resembling those of common soil elements with similar chemical properties. For example, the behavior of strontium is quite similar to that of calcium and like calcium and magnesium, diffuses slowly and has little solubility in water. Cesium, in the same chemical group as sodium and potassium, moves quite readily under the influence of water.

Diffusion processes in the soil and in the plant disperse soluble material away from the source, making more of the material available to the plants. Each element has its own diffusion rate. The rate of uptake of any material differs according to the presence of other chemical substances during the diffusion process. Field and laboratory studies, such as the work being done at North Carolina State College, have supplied data on these diffusion processes permitting certain predictions of the fate of the various elements and confirming others. However, complete analysis of fission products dispersal through these numerous processes is not yet clearly defined.

Studies at the University of California (Los Angeles) and the University of Arizona indicate other important factors, such as the presence of actively growing microorganisms which tie up appreciable amounts of such elements and slow down their uptake by plants. This is indicated by the fact that reduced uptake was observed when readily decomposable organic materials were added to soils. The reduction was found to be directly related to the ease of decomposition and the quantity of material added.

The rate at which fission products spread through soils depends somewhat on the quantity of rainfall (leaching process); somewhat on solubility of the compound formed by the elements; and somewhat on materials in the soil which may speed or hamper diffusion.

Another phase of these studies included comparison of the total chemical reactions among various species of plants and between varieties within the species. In addition to the chemical transformations or ion distribution processes, the root distribution pattern of each plant must be considered. For example, the nutrient uptake of a deep-rooted plant will differ from that of a shallow-rooted plant. Fission product distribution is not uniform throughout the soil; therefore, the uptake of each species would vary depending on root characteristics. This fact was pointed out by recent studies at North Carolina State College. It was found that corn obtained about 70 percent of its total nutrient from the upper 10 inches of soil, while peanuts obtained about 87 percent from the same layer of soil.

Experiments undertaken by the U. S. Department of Agriculture Research Service used soybeans and blue grass to test the region of maximum uptake. Blue grass showed relatively more uptake of strontium from the surface regions and less from those deeper in the soil. Soybeans, on the other hand, obtained relatively more strontium from 6 inches or more below the soil surface.

The root distribution pattern of a plant also involves the density or number of root tips per unit soil volume. The nutrients in most plants enter from the soil through the root tip. Knowing the density of root tips indicates how thoroughly the plant forages the soil. This foraging is considered to range from values of a few percent to about 10 percent. Recent data on strontium uptake show that these values may be high by as much as tenfold.

Calibration Standards for Measuring Thyroid Uptake of Iodine 131

The Oak Ridge Institute of Nuclear Studies directs a research program employing radioactive isotopes in the study, treatment and diagnosis of cancer and allied diseases. This work also encompasses the development of therapeutic devices and equipment employing atomic energy byproducts and the advancement of techniques and procedures to measure radiation energies. A study was designed to unify methods of measuring and calibrating results of tests of iodine-uptake by the thyroid. For a number of years, it was realized that iodine-uptake measurements, as performed by different techniques over the country, are highly variable. It is important, especially with the increasing use of radioisotopes, to correct unnecessary errors in techniques, and to establish standardized and accurate calibration methods.

A Thyroid Uptake Calibration Committee was formed of medical representatives throughout the country, including members from AEC and the Oak Ridge Institute of Nuclear Studies. The committee initiated a study to survey methods and procedures presently being used to measure thyroid uptake. The plan calls for shipping accurate models of human patients to physicans first in one area under the sponsorship of members of the committee, and then shipping them in turn to adjacent areas.

The models were designed with head, torso, and thigh sections, and are suitable for making all essential physical measurements. This gives the physician or clinic a full scale standard of measurement for amounts of uptake of radioiodine in the thyroid. It is useful for calibration studies as well as for teaching. Simulated radioiodine, which was developed from a mixture of radiobarium (Ba-133) and radiocesium (Cs–137), will be used. This mixture matches the spectrum of radioiodine remarkably well and has a useful life of 5 to 10 years.

Models sent out will be supplied with a series of standard dose levels from small to large doses which are in common use for uptake studies. The physicians will conduct calibration practice studies on the models, applying their own routine methods of measurement at the various dose levels. Studies may be made to simulate patients with normal, hyperthyroid or hypothyroid conditions. It is expected that some 60 sets of independent measurements may be obtained from each model, and these measurements will be sent to the Calibration Committee for evaluation.

Pituitary Radiation Therapy

A group at the University of California Radiation Laboratory is actively engaged in research on the hormonal aspects of the pituitary gland as related to the treatment of cancer. The hormones produced by the pituitary regulate growth of all body tissues and control development and functions of the thyroid.

In experimental work at the University of California Radiation Laboratory and at the University's Institute of Experimental Biology, it was found that the pituitary gland of sheep contains very small amounts of a specific material which increases red cell formation, and hence iron uptake, by the bone marrow.

This development will be an important factor in the care of patients in which the pituitary was therapeutically destroyed by radiation. In such patients anemia may be a serious complication.

Radioactive Dye-Solution Tests for Liver Diseases

Various dyes have been used for many years in clinical medicine to evaluate liver functions. In classical tests designed to measure liver function, dyes injected into the circulation were removed from the blood by the liver cells and then excreted into the intestine via the bile. Their rate of removal from the blood is known to be slower in patients with liver disease. It is not always safe to employ the classical dye solutions in patients with jaundice resulting from obstruction of the bile passages. However, by using Rose Bengal dye tagged with radioactive iodine 131 only very small amounts are needed, the tests are easy to perform, and early diagnosis is possible. This technique was developed at the AEC project at the University of California (Los Angeles).

The new test was demonstrated to be at least 100 times more sensitive than standard dye-excretion tests in detecting liver damage in rabbits. To perform the tests in man a small dose of tagged dye is given to the patient intravenously. The rates of liver uptake and excretion are measured externally by placing a sensitive gamma ray counting device over the liver area. The results are read on an automatic recorder.

Since liver diseases are fairly common, this new method of measuring liver function is important. It is rapid, taking only about an hour to complete including evaluation of the results, and is an improvement over some of the lengthy laboratory procedures and diagnostic tests now used. Also, tests can be repeated at frequent intervals with a minimum of discomfort to the patients.

Role of Fatty Acids in Radiation Injury

Earlier experiments reported by the University of Southern California showed that low fat diets decrease resistance to X-irradiation injury in rats subjected to repeated sublethal doses of X-rays. The material responsible for this action was found to be largely in the essential fatty acids.

Tracer studies on the metabolic pathways of these essential acids are also in progress at the AEC project at the University of California (Los Angeles). Emphasis was placed on the role of arachidonic acid produced in animals, and linoleic acid derived from plant food. Animals deficient in the essential fatty acids are more susceptible to the effects of ionizing radiation. This probably is associated with the functions of these substances in growth promotion and wound healing.

Feeding experiments with a high fat diet showed that these fatty acids appear to be required for certain metabolic reactions. The mechanisms of these reactions are being investigated using pure vitamins, fatty acids, and crude body lipids—neutral fats, waxes, etc.

Labeling Antibodies

The use of radioactive isotopes in treating human disease will be greatly broadened when further methods are developed for localizing these isotopes in the body tissues to be treated with radiation therapy. At the University of Rochester Atomic Energy Project, research is underway to develop methods of attaching radioactive elements to antibodies that will localize specifically in certain tissues and body organs. (Antibodies are substances in the blood, etc., that destroy or weaken bacteria.)

In experiments with rabbits, it was found that the animals could be induced to manufacture antibodies against certain tissues when injected with tissue fractions and organ extracts from other animals. By labeling with radioisotopes, antibodies were shown to localize very specifically in certain tissues or organs. For example, labeled anti-kidney antibodies were produced that localized in the kidney in a higher concentration than in any other organ.

It is hoped that continued research along this line will eventually lead to the production of antibodies against different human tumors, specific enough to carry therapeutically useful doses of radioactive isotopes direct to them. This technology has important applications also in brain tumor studies, such as are carried on at Brookhaven National Laboratory and several of the off-site installations.

Columbia River Survey

River areas lying within the vicinity of the Hanford Works Project of AEC are continually monitored for radioactivity to determine if any radiation effects from plant operations produce changes in life forms or the environment.

Crustacea (crayfish) and other small arthropods in the Columbia River are easily accessible for such studies, and a 14-month survey was made of their life activities to determine if radioactivity produced any changes in growth or productivity.

None of the levels of radioactivity reported in the areas downstream from the Hanford reactors indicated any injurious effects or changes on growth or productivity of these aquatic life forms. It was found that in the crayfish, as well as in the smaller arthropods, the levels of radioactivity measured in the young, rapidly growing forms were higher than those found in the adult specimens.

Ecological Surveys of Coral Reef Communities

Surveys are being made at the Eniwetok Marine Biological Laboratory of the effects of nuclear explosions on whole plant-animal populations and ecological systems in the Central Pacific island areas used in atomic test operations. The laboratory, recently established by the Commission, is located within the Eniwetok Atoll of the Marshall Islands. The atoll lies 2,500 miles southwest of Hawaii and is made up of a circle of coral islands approximately 20 miles in diameter. Many of these islands are covered with tropical vegetation and possess coral reefs making an excellent experimental ground for biological field studies. Work completed in 1954 for the AEC under arrangements with Duke University and the University of Georgia provides interesting data on coral reef activities.

Coral reefs represent the ultimate in stable natural communities with a history of thousands of years of constant adjustment between organisms and environment. Effects of radiation on these reefs cannot be evaluated unless the structure and function under normal conditions are known. Thus, the initial work included experimental assaying methods in order to measure the "basal metabolism" and the overall trophic or "food-chain" structure of a coral reef community as a whole not affected by nuclear explosions. This was similar to assaying the metabolism of animals or humans under normal conditions. For example, it was found that a healthy Eniwetok reef had a production rate of about 74,000 pounds of glucose (a sugar) per acre per year. This exceeds man's best agricultural efforts in most parts of the world. The critical assay methods devised can be completed in a few weeks. The significant changes in this measurable "basal community production rate" can readily be observed if important effects are produced.

These assays revealed that corals and the algae growing in the skeleton of the coral colony live together to their mutual advantage (symbiosis). Although observations of skeletal algae were made previously, this is the first study to determine quantitatively the amount of algae present in different species of corals. A very definite ratio between algal (plant) and coral (animal) tissue was found. The amount of plant tissue was greater than the amount of animal tissue per unit of surface area. This marked development of symbiosis between plant and animal components achieves excellent "conservation" and cyclic use and reuse of critical nutrients. This enables the coral reef to achieve a high rate of productivity in waters which in themselves have a very low fertility.

These results are significant in physiological applications to other plants and animals which man requires for food. They provide a fertile field for scientific study of nuclear radiation effects on the "metabolism" of highly integrated systems.

The biological assays will be extended for related research investigations carried on by the AEC. College or university biologists, and the Commission contractors interested in radiological data of this type are invited to participate, using the facilities of the Marine Biological Laboratory.

Panel Discussion on Radiation Health Problems

The Commission organized a panel discussion on "The Impact of the Atomic Energy Industry on Community Health". Held under the sponsorship of the American Medical Association Council on Industrial Health on January 25–26, in Washington, D. C., the meeting was attended by about 250 representatives from industry.

The purpose of the discussion was to explore the health problems associated with the placement of a nuclear power reactor in a community. Papers were presented on the organization and function of the radiological protection and medical groups in reactor facilities as well as the control of hazards in normal operations. Part of the meeting was devoted to the types of possible reactor accidents and their potential effect on the plant and community. The conference marked the first public presentation of much of this material.

New Radioisotopes Pricing Policy

In April the Commission announced that it will make radioisotopes for all biomedical and agricultural research, and research in medical therapy and diagnosis available to domestic users at 20 percent of the AEC established price, effective July 1, 1955.

Since 1948, the AEC has supported the distribution of radioisotopes used in cancer research and therapy. Initially, radioisotopes for use against cancer were made available without charge for production costs. Since 1952, a charge of 20 percent of the AEC established price has been made.

Under the new policy, reduced prices are extended for all biomedical and agricultural research. The discount will not be available for radioisotopes used for routine clinical treatment nor for radioisotopes in fixed sources. The program is being administered by the Commission under the Division of Biology and Medicine, Washington, D. C. Domestic users who are interested and fulfill the requirements may submit application for authorization to make discount purchases. Upon approval of the application, the Division will authorize the applicant to purchase radioisotopes at 20 percent of AEC established price. The investigator or institution receiving the discount must agree to publish the results of the research, or report the results to the Commission.

National Academy of Sciences Radiation Project

The Commission will cooperate in a broad study on radiation effects recently undertaken by the National Academy of Sciences by providing information and consultation services. The Rockefeller Foundation made an initial grant for financial support of the project in its planning stages.

The project will consist of an appraisal of present knowledge on the effects of atomic radiations on living organisms. Extensive research work completed by the AEC will be available for the new study. The Academy will appoint a committee of eminent scientists and staff to deal with the project. From this study should come the necessary facts to clarify opinions in this important field of effects of radiation on human beings and their environments. Further, all the work in this general area may be reviewed to identify those areas needing increased effort. The study may evaluate the state of medical knowledge regarding therapy and protection; and the availability of information to scientists, physicians, and the general public.

AEC Scientific Expedition to Pacific

Scientists from the AEC, the Scripps Institute of Oceanography and the Institute of Applied Fisheries, University of Washington, in April completed a 6-week survey of the Pacific to measure the amounts of radioactivity, natural or introduced, present in sea water and marine life. The expedition is an extension of the marine biological studies carried on by the AEC and cooperating agencies for some years in the Marshall Islands area, and included major ocean currents of the Western Pacific not previously studied.

The expedition left the West Coast aboard the U. S. Coast Guard Cutter *Taney* on February 26, 1955. It reached Tokyo on April 12, after traversing wide reaches of the Equatorial and North Equatorial currents, and of the Kuroshio current east of Japan.

Measurements of temperatures, current characteristics, salinity, and radioactivity were taken at various ocean depths. Specimens of marine life and plankton were collected and measured for radioactivity amounts.

The investigators found that minute traces of radioactivity existed in proportions initially predicted by the oceanographers. The analyses showed widespread low-level activity of sea water throughout the Pacific, with the level dropping to zero only in approaching the West Coast of the United States. The activity level in edible portions of fish was about one percent of the recognized health standards.

It is expected that data collected during the expedition will clear up a number of presently obscure points in oceanography. For example, the presence of traces of radioactivity from atomic tests is being utilized in mapping the course and rate of flow of the north equatorial current. The AEC plans to survey these waters as long as it is possible to detect identifying activity. Valuable information concerning the depth of mixing of surface waters and the rate of turnover of deeper waters should also result from these studies.

Analyses of the preliminary data collected by the expedition are consistent with such findings as were made available to United States scientists by members of the Japanese cruise of the *Shunkotsu Maru* made in June 1954.

The Japanese scientists found that residual radioactivity from the tests conducted in the Marshall Islands in the spring of 1954 were still detectable in June of that year. Since that time, this residual radioactivity has greatly diminished in intensity as a result of mixing with large volumes of ocean water, and the known laws of radioactive decay. The fission product activity was found by the *Taney* expedition to be only about one-tenth of that due to naturally radioactive potassium in sea water.

Organization and Personnel

Personnel and Organizational Changes

The following personnel and organizational changes took place in Washington Headquarters during the first 6 months of 1955:

Dr. John von Neumann took office as Commissioner on March 15 following his confirmation by the Senate.

Appointment of Brigadier General Kenneth E. Fields as General Manager was announced by the Commission, effective May 1. General Fields, former Director of the Division of Military Application, succeeds K. D. Nichols who resigned from the AEC on April 30 to become an engineering consultant. General Fields retired from the Army to accept the General Manager assignment.

David F. Shaw was appointed Assistant General Manager for Manufacturing on June 6. R. W. Cook had been serving in an acting capacity in this position since his appointment as Deputy General Manager. Mr. Shaw had been manager of the Hanford Operations Office since June 1950.

The Division of Licensing was established in March to administer the Commission's licensing function and related responsibilities pertaining to the civilian use of atomic energy under the Atomic Energy Act of 1954. Harold L. Price, Deputy General Counsel, formerly designated Special Assistant to the General Manager for Licensing, was appointed director of the division, effective March 22 (see "Civilian Application," pp. 101–104). On June 29, the division was renamed the Division of Civilian Application, with Mr. Price as director. The new division takes the place and assumes the responsibilities of the former Division of Licensing and carries out AEC responsibilities relating to civilian uses of atomic energy under the Act of 1954. In establishing it, the Commission transferred to it the following staff functions previously assigned to other divisions: the activities of the Licensing Controls Branch, Division of Construction and Supply, and certain functions of the now abolished Industrial Liaison Branch, Division of Reactor Development.

W. Kenneth Davis who has been serving since January 1 as Acting Director, Division of Reactor Development, was appointed Director effective February 24.

Col. Alfred D. Starbird, USA, was appointed Director, Division of Military Application, effective July 1.

William C. Wampler was appointed Special Assistant to the General Manager (Congressional), effective January 31.

The Commission was assigned primary responsibility for technical planning and preparation for United States participation in the United Nations International Conference on Peaceful Uses of Atomic Energy to be held at Geneva, Switzerland, August 8–20. Dr. George L. Weil was named Technical Director for United States participation in the conference.

Organization and Management Studies

Although enactment of the Atomic Energy Act of 1954 did not result in major changes in AEC's organizational structure, it did have a substantial impact upon the operations of nearly all parts of the organization. In some cases existing organizations absorbed new functions without material increases in personnel; in others, new divisions have been established or some increases in personnel will be necessary to provide for the regulation of and services to civilian industry required by the Act. These needs arising out of this Act made it necessary for the Division of Organization and Personnel to undertake the following organization and management projects:

1. A study of the functions to be included in the Inspection Division established by Section 25 c of the Act, including definition of its duties, provision for staffing, and clarification of its functions with reference to those of other organization units.
2. A study of the organization necessary to administer the licensing and related provisions of the Act, which has resulted in establishment of the Division of Licensing (subsequently changed to the Division of Civilian Application) and in definition of its relationships to other parts of the organization.

A basic administrative document which states AEC organization policy, defines the roles of staff and line organizations, traces the line of authority from the Commission down through sub-offices in the field, and provides uniform nomenclature for organization units, was completed as part of the AEC Manual.

Continuing progress was made in codifying in the AEC Manual the directive material issued to subordinate units in the form of General Manager bulletins and a variety of correspondence.

Personnel Studies

In addition to the continuing staff work required in personnel matters, the following principal studies were completed:

1. Complete revision and incorporation in the AEC Manual of the policies and procedures on job evaluation and salary administration, including substantial expansion and refinement of job evaluation standards in the form of benchmark job descriptions.
2. The incentive awards program, authorized by the Government Employees' Incentive Awards Act, was formally established

March 1, 1955. Complete instructions under this program were issued, awards committees established, and a number of awards for constructive suggestions and for superior performance made.

3. The procedures for resolving employee grievances, handling of separations, suspensions, demotions and other disciplinary actions and others, were revised and improved.

Officials began reviews of important training needs of AEC employees which can be met under authority granted under Section 161 of the Atomic Energy Act of 1954. Such reviews are continuing, and employees are beginning to be sent to technical training courses under this authority.

Job Evaluation System

Benchmark jobs used as standards in evaluating AEC positions for salary purposes were revised, and a substantial number of additional ones developed. This will provide broader coverage by benchmarks in various occupational areas found in AEC. It will also contribute to a more effective application of the job evaluation system, and make possible a more consistent and equitable administration or salaries within statutory limitations.

Work Stoppages

Work continuity in atomic energy construction and design activities continued at a high level during the first 4 months of 1955. Lost time for the period was 0.5 percent of the scheduled working time—a notable decrease from the loss of 1.5 percent for the corresponding period of 1954. Construction work stoppages for the year 1954 amounted to [illegible] percent of the scheduled working time—a decrease of 28.2 percent over 1953.

Organized employees of Sandia Corp., Albuquerque, N. Mex. were on strike from April 26 through May 4 in a dispute over terms of renewal of labor agreements which expired on April 20. Striking workers were represented by an AFL Metal Trades Council and Office Employees International Union, AFL. Organized guards, whose agreement expired on April 21, did not stop work. Although they had at first refused to utilize its services, the employees returned to work with the understanding that the Atomic Energy Labor Management Relations Panel would hear the dispute.

As a result of the Sandia strike the percentage of scheduled time lost through work stoppages in the operations program was 0.11 for the first four months of 1955. There were no stoppages during the comparable period in 1954 and 0.08 percent for the entire year 1954.

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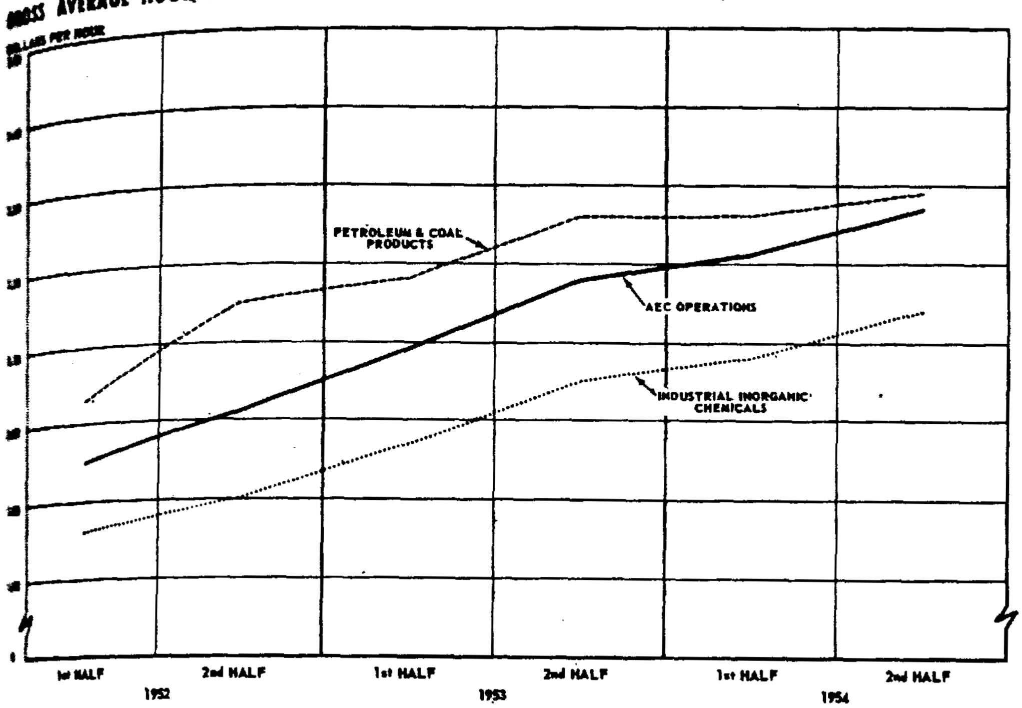
Hours and Earnings

Gross average earnings of production and related workers of AEC's operating contractors tended to level off during 1954, following a general trend in industry. The year-end average of $2.27 per hour represented an increase of 8½ cents during 1954, as compared with 15 cents during 1953.

Average hourly earnings of workers of AEC's operating contractors during the last 6 months of 1954 were 13 cents higher than the earnings of workers in the inorganic chemicals industry and 2 cents lower than those of the petroleum and coal products industry (industries most nearly comparable in process and equipment).



AEC and Contractor Employment Trends

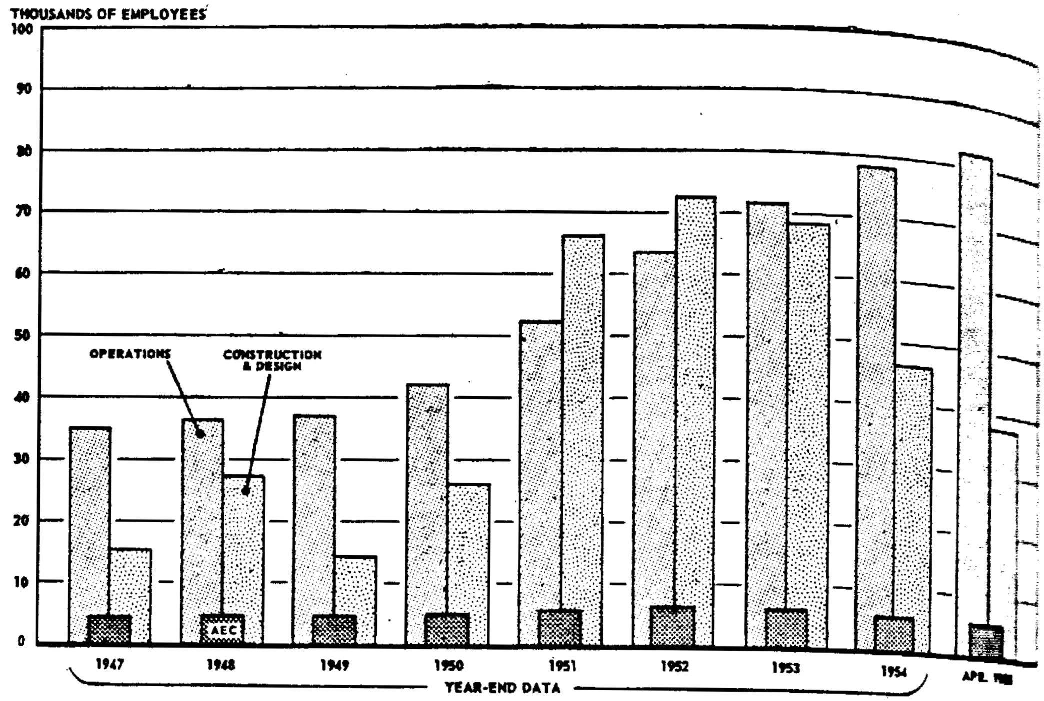
Employment by AEC and its contractors totaled 116,054 in April 1955. Of this total, 5,930 were AEC employees and 110,124 contractor employees—27,932 in construction and design, and 82,192 in operations.

AEC employment was relatively constant during the past 6 months—down from a high of 6,894 in June 1953 when total contractor employment also reached its peak.

Construction and design employment was about half the number reported 6 months ago. Large declines occurred at the Hanford, Paducah, and Savannah River projects where major construction was virtually completed, and at Portsmouth and Oak Ridge which were considerably under the peak levels reached in July and October, respectively. Current employment was the lowest since February 1951.

Operating contractor employment increased at the rate of about 1,000 per month during the past 6 months. The total in March more than doubled the number employed before the 5-year expansion program. During this 5-year period, production employment tripled while employment in research and development doubled.

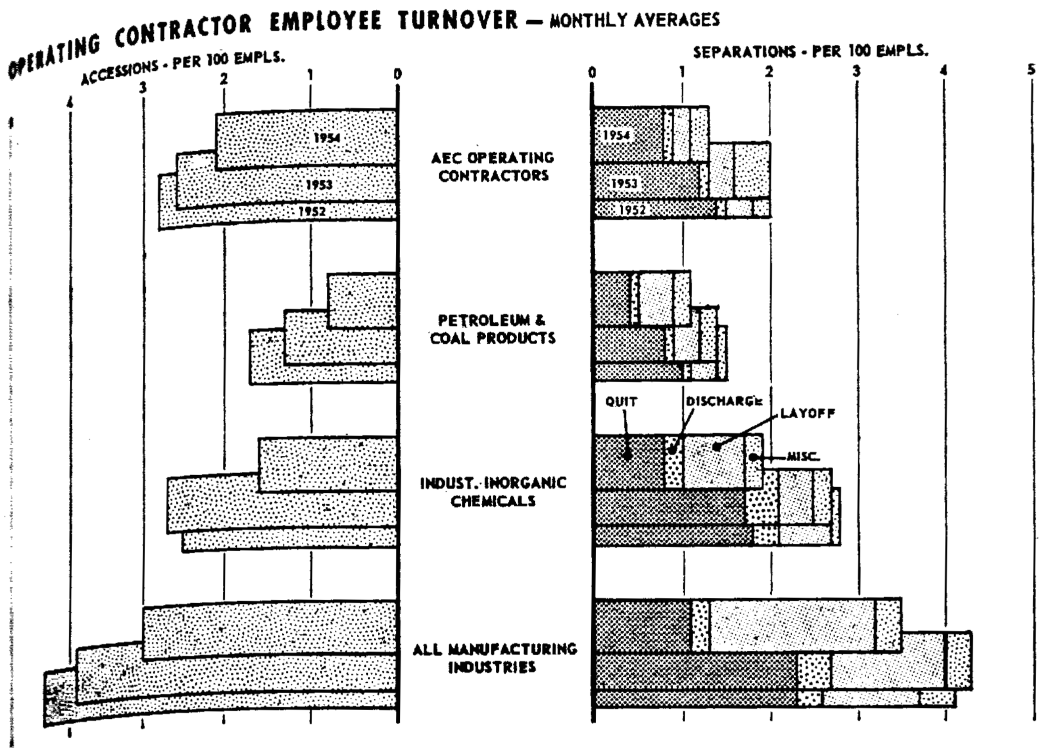
AEC & CONTRACTOR EMPLOYMENT



Labor Turnover

Turnover of employees of AEC operating contractors compared favorably with those of comparable industries—industrial inorganic chemicals and petroleum and coal products. AEC contractor separation rates fell between those of the two industries, all three being lower than the combined rate for all manufacturing industries. During 1954, employees of AEC contractors were separated at the rate of 1.3 per 100 employees per month. This was 35 percent lower than the two previous years and approached the 1.1 rate recorded for the petroleum and coal products industry—one of the few large industries experiencing a lower rate than AEC.

Unlike industries where accession rates nearly equal separation rates, accession rates of AEC operating contractors exceeded separation rates by 60 percent in 1954 and 35 percent in the previous 2 years, due to the placement of new and expanded facilities into operations. The effect of this difference is reflected in the upward trend in employment.



Inspection

On February 1 Curtis A. Nelson became the director of the Division of Inspection established in September 1954 (Seventeenth Semiannual Report, July–December 1954, pp. xiii, 58). A small staff was organized to carry out the functions assigned to the division in accordance with the provisions of Section 25 c of the Atomic Energy Act of 1954. This section provides in part that the division "shall be responsible for gathering information to show whether or not the contractors, licensees, and officers and employees of the Commission are complying with the provisions of this Act (except those provisions for which the FBI is responsible) and the appropriate rules and regulations of the Commission."

The director has three assistant directors: an Assistant Director for Management Appraisal to ascertain that management appraisals of the Commission's programs are developed and carried out by the staff and program divisions and that these appraisals are adequate in the areas they cover and do not involve any unnecessary duplication of activity; an Assistant Director for Compliance to inspect directly licensees for compliance with all license requirements; and an Assistant Director for Investigations to investigate directly all questions of employees' conduct, fraud, etc., in AEC and contractor organizations. In addition, when directed by the General Manager, the division will inquire into and report upon any other matters that are under the General Manager's authority.

Inspection Activities

During the first 6 months of 1955 studies were undertaken of existing inspection type activities by program and staff divisions. A preliminary inspection of some components of the Raleigh Research Reactor at North Carolina State College was conducted. Additional inspections of reactors at Oak Ridge—including the graphite reactor, the Low Intensity Test Reactor, the Tower Shielding Facility, and the Bulk Shielding Facility—and inspections of the General Electric Aircraft Nuclear Propulsion critical facility at Evendale, Ohio, and the Pennsylvania State Reactor at Pennsylvania State University were also scheduled.

The authorization and inspection program of the Isotopes Division, Oak Ridge Operations Office, was studied and a plan of inspection developed under the new licensing program—subject to further review as additional licensing experience is gained.

Patents

The Commission has approximately 775 patents available for licensing on a nonexclusive, royalty-free basis. It has issued approximately 481 such licenses under these patents.

The first patent issued to the Commission on a complete nuclear chain reactor was issued (after declassification) as patent No. 2,708,656 on May 17, 1955, by the U. S. Patent Office. The patent covers the inventions of Drs. Enrico Fermi and Leo Szilard on thermal neutron reactors. It includes the uranium-graphite moderated reactor constructed at the University of Chicago in 1942 in which the first controlled nuclear chain reaction was achieved.

During the past 6 months a considerable number of patents were issued on the electromagnetic method of separating isotopes. Included in this group is a patent on the overall electromagnetic method (the Calutron) developed by Dr. E. O. Lawrence—issued as patent No. 2,709,222 on May 24, 1955, and owned by the AEC.

After notice published in the Federal Register, the Commission amended its regulations establishing general rules of procedure in considering applications for reasonable royalty fees, just compensation and awards under the patent provisions of the Atomic Energy Act of 1954. The principal changes include a delegation of authority to the Patent Compensation Board to determine applications for just compensation under Section 173 of the Atomic Energy Act of 1954. There is also provision for the submission of interrogatories to any party to a proceeding before the board for the purpose of placing on record facts which the board deems relevant to its consideration of a patent application.

The Commission settled for $400,000 the application for an award made by Drs. Glenn T. Seaborg, Joseph W. Kennedy, Arthur C. Wahl, and Emilio Segre. Their application was based upon patent applications covering basic chemical separation processes developed prior to any Government contract. The settlement provided for the acquisition by the Government of all rights, both domestic and foreign, in the subject matter of the inventions and any patent applications and patents issuing therefrom and a release of all claims against the Government arising out of the inventions. The assignments were recorded in the U. S. Patent Office.

On January 11, 1955, the United States Court of Claims dismissed the action of Consolidated Engineering Corp. vs. United States, 104 U. S. P. Q. 111, who sued the Government in connection with certain specific line recorders associated with the diffusion processing plant at Oak Ridge. The plaintiff's petition to the United States Supreme Court for a review of the case was denied on May 23, 1955.

In accordance with the provisions of Section 156 of the Atomic Energy Act of 1954, standard specifications upon which the Commission may grant patent licenses for the use of Commission-owned patents and patents declared to be affected with the public interest are being promulgated.

Civilian Application

In order to discharge its regulatory responsibilities under the Atomic Energy Act of 1954, the Commission established a Division of Licensing [4] in March 1955 and took initial steps in setting up procedures under which private enterprise may assume the major responsibility in developing atomic energy for civilian uses.

Proposed regulations covering licensing of production and utilization facilities, distribution of special nuclear materials, and safeguarding of restricted data were published in the Federal Register (under Notice of Rule Making), so that the public might have an opportunity to comment on them prior to the time when they would become effective. Regulations on access to restricted data relating to civilian uses of atomic energy were similarly published.

Additional regulations covering operators' licenses, radiation protection, and rules of practice are currently being drafted by the Commission for future publication in the Federal Register.

In addition to the new regulations published, or soon to be published, there are already in effect regulations covering the distribution and possession of source and byproduct materials. These regulations,

[4] The Division of Licensing was renamed the Division of Civilian Application on June 29, 1955 (see "Personnel and Organizational Changes," p. 94).

promulgated under the authority of the Atomic Energy Act of 1946, are being revised to meet the requirements of the Act of 1954, and the proposed revisions will be published in the Federal Register.

Access Permits

In meeting the general objective of encouraging American industry to take an active and leading part in the development of future uses of atomic energy for nonmilitary purposes, it was necessary for AEC to institute a program under which information in this field could be made available to those outside of the Commission program. This was done previously on a limited scale by means of "study agreements" under which companies or groups of companies agreed to spend a certain amount of money on specific study projects and to submit reports to the Commission describing the results of these studies. Some 25 study groups, comprising a total of 81 companies, were granted access to restricted data under this program.

The study agreement program was replaced in April by a more simplified procedure under which restricted data relating to the civilian use of atomic energy, and classified as confidential, may be made available to any applicant who can evidence a potential use or application of the information in his business, profession, or trade. The other conditions to this access are that applicants obtain simplified security ("L") clearances and agree in writing to conform to all AEC security regulations. The Government will waive under Section 152 of the Atomic Energy Act of 1954 all rights to inventions and discoveries arising out of access to such information. Where an invention or discovery is made or conceived in the course of, in connection with, or under the terms of an *access permit* the applicant will be required to waive potential claims against the Government arising from the imposition of secrecy orders on patent applications and all claims for just compensation under Section 173 of the Atomic Energy Act of 1954.

Under similar conditions, limited access may also be granted to certain specific information classified as secret, if the applicant can demonstrate that such information has an immediate or significant effect on his business, profession, or trade. In such cases, applicants must obtain full security ("Q") clearances and the Government will retain royalty-free, nonexclusive rights for governmental purposes in inventions and discoveries which result from such access.

Applicants for access must also agree to pay all established charges for security clearances, publication, reproduction, and other services furnished by AEC in connection with access permits.

From the time the new access program was announced on April 20, 1955, to June 30, 214 applications for access permits were received. As of June 30, 148 of these were approved and the balance were in the process of being reviewed. The industries represented by these applications include aircraft, electric power, chemical, petroleum, shipbuilding, steel, and equipment manufacturers, as well as research and finance institutions, insurance underwriters, and engineering consultants.

Applications for licenses

During the period covered by this report, the following applications were received for licenses to construct facilities.[5]

1. *Consolidated Edison Co. of New York.* The company has applied for a license to construct and operate, for a period of 40 years, a nuclear power reactor of the pressurized water type, using fully enriched uranium 235 as a fuel and thorium as a blanket.
2. *Armour Research Foundation of the Illinois Institute of Technology.* This application contemplates a research reactor of the homogeneous solution type to be used for industrial research purposes. A construction permit was issued.
3. *Battelle Memorial Institute.* This proposed research facility is a modified "swimming-pool" reactor.
4. *Naval Research Laboratory.* This is an application for a license to construct and operate a modified "swimming-pool" type research reactor. A construction permit was issued.
5. *University of California at Los Angeles.* This is to be a low-power "water-boiler" type reactor for research in medical therapy.
6. *University of Michigan.* The application is for a license to construct and operate a "swimming-pool" type reactor for research purposes. A construction permit was issued.
7. *Metals and Controls Corp.* The Company's application is for a license to operate a facility for the fabrication of fuel elements.
8. *Pennsylvania State University.* The application is for a license to possess and operate a "swimming pool" type reactor for research and training purposes. A license was issued on July 8, 1955.
9. *Commonwealth Edison Co. of Chicago.* The company proposes to construct and operate a 180,000-kilowatt boiling water reactor for production of electric power to be integrated with the existing Commonwealth Edison transmission system.

Since 1953 North Carolina State College has operated a research reactor at North Carolina. This project was started prior to the 1954

[5] Proposals submitted under the Power Demonstration Reactor Program not listed.

Act and arrangements are being made to place the operation of the reactor under license.

In addition to applications involving construction of facilities, the following applications for possession of nuclear material were received.

1. *Battelle Memorial Institute.* For use in its anticipated research and development work with industry, the Institute has applied for a license to possess 3,000 grams of contained uranium 235 for use in preparing prototype fuel elements and subassemblies for in-pile testing and post irradiation inspection.
2. *Nuclear Science and Engineering Corp.* The corporation has applied for a license to possess 10 grams of enriched uranium oxide containing an uranium 235 concentration of up to 90 percent for use in fabricating flux monitors for the corporation's clients in connection with irradiation experiments.
3. *Sylvania Electric Products, Inc.* In April the company was granted a license to possess, fabricate and transfer 50 grams of uranium containing 10 percent uranium 235 for use in irradiation testing of material specimens. In June, at the company's request, the license was amended to double the quantity of material so that the company could fabricate an additional group of samples for irradiation testing.

Industrial Information

Passage of the Atomic Energy Act of 1954 stimulated industry's already considerable interest in the possibilities of the atom for peaceful purposes. Before enactment of the 1954 amendments, the Commission's information-for-industry programs were necessarily limited to unclassified areas. While these information programs contributed to scientific and industrial progress in many fields, they did not provide, because of classification problems, the technical information essential to the sustained growth of a normal, competitive atomic energy industry. To start this new industry, the Commission, under the authority granted by the new Act, will operate two information-for-industry programs—one unclassified and another classified.

As in the past, the AEC will continue, wherever possible to disseminate program-developed unclassified information through regular channels of communication. To assist in this function, the Commission has enlisted the advice and support of outstanding members of the industrial press and professional engineering societies. These men serve without compensation on the Advisory Committee on Industrial Information.

To assure availability of unpublished reports covering technical data of particular usefulness to persons participating in the civilian applications program, about 950 AEC reports were selected from the Technical Information Services master file, printed in full-size copy, and placed on sale at the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. These reports will bring the total of AEC reports on sale at OTS up to approximately 2,000. New reports as published will increase this number.

In addition to reports on sale, full collections of unclassified AEC reports are maintained at AEC Industrial Information depositories. These are: The Atomic Industrial Forum in New York; Stanford Research Institute in Stanford, Calif.; John Crerar Library in Chicago; and Georgia Institute of Technology in Atlanta. Each of these depositories is making available to industry, at charges normally assessed for such services, reference and photocopy service of all AEC unclassified research and development reports as well as unclassified mechanical drawings of AEC-developed equipment.

Each American business firm or industry will want eventually to conduct a self-evaluation in terms of all available information to determine its role in the development of the new atomic energy industry. To assist these firms the AEC has inaugurated a program for dissemination of classified information under the civilian applications program.

Some 16,000 existing AEC classified reports will eventually be made available under this program. About 3,000 of the most useful of these reports will be printed in full-size copy; the remainder will be available as micro-cards or photostats.

In addition to the report literature, special manuals evaluating and summarizing broad technical subject areas will be prepared and made available.

Charges will be made for the use of the classified information materials. To effect necessary accounting and security controls and to assure that persons holding access permits or licenses have equal opportunity to learn about, to obtain and to evaluate Commission developed classified technical information, all distribution of classified reports, drawings, or other documents will be made by or through the Technical Information Service.

In addition to the classified reports, handbooks, bibliographies, and periodicals to be made available under the classified program, the Commission will conduct periodic classified information briefings for access permit holders.

APPENDIX 1

ORGANIZATION AND PRINCIPAL STAFF OF U. S. ATOMIC ENERGY COMMISSION

Atomic Energy Commission	LEWIS L. STRAUSS, *Chairman*.
	WILLARD F. LIBBY
	THOMAS E. MURRAY.
	JOHN VON NEUMANN.
Assistant to the Chairman	JOHN MACKENZIE, Jr.
Assistant to the Chairman	MCKAY DONKIN.
Assistant to the Chairman	EVERETT HOLLES.
General Manager	K. E. FIELDS.
Deputy General Manager	R. W. COOK.
Special Assistant to General Manager (Liaison).	PAUL F. FOSTER.
Special Assistant to General Manager	CHARLES VANDEN BULCK.
Special Assistant to General Manager (Congressional).	WILLIAM C. WAMPLER.
Assistant General Manager	H. S. TRAYNOR
Assistant General Manager for Administration	J. L. KELEHAN.
Assistant General Manager for Manufacturing.	DAVID F. SHAW.
Assistant General Manager for Research and Industrial Development.	A. TAMMARO.
Controller	DON S. BURROWS.
General Counsel	WILLIAM MITCHELL.
Secretary to Commission	W. B. MCCOOL.
Chief, Office of Operations Analysis	C. D. W. THORNTON.
Director, Office of International Affairs	JOHN A. HALL.
Director, Division of Biology and Medicine.	Dr. JOHN C. BUGHER.
Director, Division of Civilian Application	HAROLD L. PRICE.
Director, Division of Classification	CHARLES D. LUKE.
Director, Division of Construction and Supply.	JOHN A. DERRY.
Director, Division of Information Services	MORSE SALISBURY.
Director, Division of Inspection	CURTIS A. NELSON.
Director, Division of Intelligence	C. H. REICHARDT.
Director, Division of Military Application.	Col. ALFRED D. STARBIRD, USA.

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Director, Division of Organization and Personnel.	OSCAR S. SMITH.
Director, Division of Production	E. J. BLOCH.
Director, Division of Raw Materials	JESSE C. JOHNSON.
Director, Division of Reactor Development.	W. KENNETH DAVIS.
Director, Division of Research	T. H. JOHNSON.
Director, Division of Security	JOHN A. WATERS, Jr.
Director, Division of Source and Special Nuclear Materials Accountability.	D. F. MUSSER
Managers of Operations Offices and Areas:	
Chicago (Ill.) Operations Office	J. J. FLAHERTY.
Lockland (Ohio) Area	E. M. VELTEN.
Pittsburgh (Pa.) Area	LAWTON D. GEIGER.
Grand Junction (Colo.) Operations Office.	SHELDON P. WIMPFEN.
Hanford (Wash.) Operations Office	JAMES E. TRAVIS, *Acting.*
Idaho (Idaho Falls) Operations Office	ALLAN C. JOHNSON.
New York (N. Y.) Operations Office	MERRIL EISENBUD.
Brookhaven (Long Island, N. Y.) Area.	E. L. VAN HORN.
Oak Ridge (Tenn.) Operations Office	S. R. SAPIRIE.
Dayton (Miamisburg, Ohio) Area	JOHN H. ROBERSON.
Fernald (Cincinnati, Ohio), Area	CLARENCE L. KARL.
New Brunswick (N. J.) Area	C. J. RODDEN.
Paducah (Ky.) Area	KENNEDY C. BROOKS.
Portsmouth (Ohio) Area	KENNETH A. DUNBAR.
St. Louis (Mo.) Area	FRED H. BELCHER.
San Francisco (Calif.) Operations Office	HAROLD A. FIDLER.
Santa Fe (Albuquerque, N. Mex.) Operations Office.	DONALD J. LEEHEY.
Eniwetok (Albuquerque, N. Mex.) Field Office.	PAUL W. SPAIN.
Kansas City (Mo.) Field Office	JAMES C. STOWERS.
Las Vegas (Nev.) Field Office	SETH R. WOODRUFF, Jr.
Los Alamos (N. Mex.) Field Office	FRANK C. DILUZIO.
Rocky Flats (Colo.) Field Office	GILBERT C. HOOVER.
Savannah River (Augusta, Ga.) Operations Office.	ROBERT C. BLAIR.
Dana (Terre Haute, Ind.) Area	CHARLES W. REILLY.
Schenectady (N. Y.) Operations Office	JON D. ANDERSON.

APPENDIX 2

MEMBERSHIP OF COMMITTEES

STATUTORY COMMITTEES

Joint Committee on Atomic Energy—Eighty-fourth Congress

This committee was established by the Atomic Energy Act of 1946, and continued under the Atomic Energy Act of 1954, to make "continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy." The committee is kept fully and currently informed with respect to the Commission's activities. Legislation relating primarily to the Commission or to atomic energy matters is referred to the committee. The committee's membership is composed of nine members of the Senate and nine members of the House of Representatives.

Senator CLINTON P. ANDERSON (New Mexico), *Chairman.*
Senator RICHARD B. RUSSELL (Georgia).
Senator JOHN O. PASTORE (Rhode Island).
Senator ALBERT GORE (Tennessee).
Senator HENRY M. JACKSON (Washington).
Senator BOURKE B. HICKENLOOPER (Iowa).
Senator EUGENE D. MILLIKIN (Colorado).
Senator WILLIAM F. KNOWLAND (California).
Senator JOHN W. BRICKER (Ohio).
Representative CARL T. DURHAM (North Carolina).
Representative CHET HOLIFIELD (California).
Representative MELVIN PRICE (Illinois).
Representative PAUL J. KILDAY (Texas).
Representative JOHN J. DEMPSEY (New Mexico).
Representative W. STERLING COLE (New York).
Representative CARL HINSHAW (California).
Representative JAMES E. VAN ZANDT (Pennsylvania).
Representative JAMES T. PATTERSON (Connecticut).
CORBIN ALLARDICE, *Executive Director.*

Military Liaison Committee

Under Sec. 27 of the Atomic Energy Act of 1954, "there is hereby established a Military Liaison Committee consisting of —a. A Chairman, who shall be the head thereof and who shall be appointed by the President, by and with the advice and consent of the Senate, who shall serve at the pleasure of the President, and who shall receive compensation at the rate prescribed for an Assistant Secretary of Defense; and b. a representative or representatives from each of the Departments of the Army, Navy, and Air Force, in equal numbers, as determined by the Secretary of Defense, to be assigned from each Department by the Secretary thereof, and who will serve without additional compensation. The Chairman of the Committee may designate one of the members of the Committee as Acting Chairman to act during his absence. The Commission shall advise and consult with the Department of Defense, through the Committee, on all atomic energy matters which the Department of Defense deems to relate to military applications of atomic weapons or atomic energy including the development, manufacture, use, and storage of atomic weapons, the allocation of special nuclear material for military research, and the control of information relating to the manufacture or utilization of atomic weapons; and shall keep the Department of Defense, through the Committee, fully and currently informed of all such matters before the Commission. The Department of Defense, through the Committee, shall keep the Commission fully and currently informed on all matters within the Department of Defense which the Commission deems to relate to the development or application of atomic energy. The Department of Defense, through the Committee, shall have the authority to make written recommendations to the Commission from time to time on matters relating to military applications of atomic energy as the Department of Defense may deem appropriate. If the Department of Defense at any time concludes that any request, action, proposed action, or failure to act on the part of the Commission is adverse to the responsibilities of the Department of Defense, the Secretary of Defense shall refer the matter to the President whose decision shall be final."

Hon. HERBERT B. LOPER, *Chairman.*
Brig. Gen. JOHN P. Daley, United States Army.
Maj. Gen. HARRY McK. ROPER, United States Army.
Rear Adm. GEORGE C. WRIGHT, United States Navy.
Rear Adm. PAUL H. RAMSEY, United States Navy.
Maj. Gen. HERBERT B. THATCHER, United States Air Force.
Brig. Gen. RICHARD T. COINER, Jr., United States Air Force.

General Advisory Committee

This committee was established by the Atomic Energy Act of 1946 (sec. 2 (b)), and is continued by Sec. 26 of the Atomic Energy Act of 1954. The nine civilian members are appointed by the President to advise the Commission on scientific and technical matters relating to materials, production, and research and development. Under the Atomic Energy Act, the committee shall meet at least four times in every calendar year.

Dr. I. I. RABI, chairman; professor of physics, Columbia University, New York, N. Y.

Dr. JESSE W. BEAMS, professor of physics, University of Virginia, Charlottesville, Va.

Dr. J. B. FISK, executive vice president, Bell Telephone Laboratories, Murray Hill, N. Y.

Dr. WARREN C. JOHNSON, chairman, department of chemistry, University of Chicago, Chicago, Ill.

Dr. EDWIN M. McMILLAN, professor of physics, UCRL, Berkeley, Calif.

EGER V. MURPHREE, president, ESSO Research and Engineering Co., New York, N. Y.

Dr. J. C. WARNER, president, Carnegie Institute of Technology, Pittsburgh, Pa.

WALTER G. WHITMAN, head, department of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. EUGENE P. WIGNER, professor of physics, Princeton University, Princeton, N. J.

Dr. RICHARD W. DODSON, secretary; chairman, department of chemistry, Brookhaven National Laboratory, Upton, Long Island, N. Y.

PATENT COMPENSATION BOARD

This board was established in April 1949 pursuant to section 11 of the Atomic Energy Act of 1946, and is the Board designated under Section 157a of the Atomic

Energy Act of 1954. Section 157 provides that upon application for just compensation or awards or for the determination of a reasonable royalty fee certain proceedings shall be held before such a board.

CASPER W. OOMS, chairman; firm of Casper W. Ooms, Chicago, Ill.
ISAAC HARTER, of Babcock & Wilcox Tube Co., Beaver Falls, Pa.
JOHN V. L. HOGAN, consulting engineer, Hogan Laboratories, Inc., New York, N. Y.

COMMITTEE OF SENIOR REVIEWERS

The Committee of Senior Reviewers studies the major technical activities of the Atomic Energy Commission program and advises the Commission on classification and declassification matters, making recommendations with respect to the rules and guides for the control of scientific and technical information. The committee consists of six members appointed for a term of 5 years on a rotating basis.

Dr. WARREN C. JOHNSON, chairman; associate dean of physical sciences, University of Chicago, Chicago, Ill.
Dr. THOMAS B. DREW, head, department of chemical engineering, Columbia University, New York, N. Y.
Dr. ALVIN C. GRAVES, J division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. JOHN P. HOWE, section chief, reactor materials, North American Aviation, Inc., Downey, Calif.
Dr. WINSTON M. MANNING, director, chemistry division, ANL, Lemont, Ill.
Dr. J. R. RICHARDSON, professor of physics, University of California, Los Angeles, Calif.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Advisory Committee on Biology and Medicine

The Advisory Committee on Biology and Medicine was created in September 1947, on the recommendation of the Commission's Medical Board of Review. The committee reviews the AEC programs in medical and biological research and health and recommends to the Commission general policies in these fields.

Dr. GIOACCHINO FAILLA, chairman; director, Radiological Research Laboratory, College of Physicians and Surgeons, Columbia University, New York, N. Y.
Dr. CHARLES H. BURNETT, professor of medicine, University of North Carolina, Chapel Hill, N. C.
Dr. SIMEON T. CANTRIL, director, Tumor Institute of Swedish Hospital, Seattle, Wash.
Dr. EDWARD A. DOISY, director, department of biochemistry, St. Louis University School of Medicine, St. Louis, Mo.
Dr. CURT STERN, professor of zoology, University of California, Berkeley, Calif.
Dr. SHIELDS WARREN, vice chairman; pathologist, New England Deaconess Hospital, Boston, Mass.

Advisory Board of Contract Appeals

This board was established in February 1950. One or more of its members hears contract appeals arising under the "disputes articles" of AEC contracts and subcontracts and makes recommendations to the General Manager concerning their disposition.

HENRY P. BRANDIS, Jr., dean of the law school, University of North Carolina, Chapel Hill, N. C.

SHELDON D. ELLIOTT, director of institute for judical administration, New York University, New York, N. Y.

ROBERT KINGSLEY, dean, school of law, University of Southern California, Los Angeles, Calif.

EDMUND R. PURVES, executive director, American Institute of Architects, Washington, D. C.

HERBERT F. TAGGART, dean, school of business administration, University of Michigan, Ann Arbor, Mich.

Advisory Committee on Brazing

This committee was formed at AEC request by the Welding Research Council of the Engineering Foundation to serve in an advisory capacity on problems involving fabrication by brazing.

F. W. DAVIS, chairman; U. S. Atomic Energy Commission, Washington, D. C.

CHARLES D. COXE, assistant manager, metallurgical department, Handy and Harman, Bridgeport, Conn.

A. E. FOCKE, manager, materials development, Aircraft Nuclear Propulsion Project, General Electric, Cincinnati, Ohio.

FRANK G. HARKINS, chief welding engineer, Solar Aircraft Co., San Diego, Calif.

Lt. T. HIKIDO, Wright Air Development Center, Wright Patterson Air Force Base, Dayton, Ohio.

G. O. HOGLUND, welding engineer, process and development laboratories, Aluminum Company of America, New Kensington, Pa.

T. E. KIHLGREN, welding section, research laboratory, International Nickel Co., Bayonne, N. J.

W. D. MANLY, head metallurgist, ANP division, ORNL, Oak Ridge, Tenn.

ROBERT L. PEASLEE, development engineer, Wall Colmonoy Corp., Detroit, Mich.

H. R. SPENDELOW, Jr., assistant director of research, Metals Research Laboratories, Electric Metallurgical Co., New York, N. Y.

W. SPRARAGEN, secretary; director, Welding Research Council, New York, N. Y.

LYALL ZICKRICK, supervisor, materials application unit, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Advisory Committee on Industrial Information

The committee, formed in 1949, appraises technological developments within the national atomic energy program and makes recommendations which serve as guides in the formulation of AEC information-for-industry policy.

SIDNEY D. KIRKPATRICK, chairman; vice president and director of editorial development, McGraw-Hill Book Co., Inc., New York, N. Y.

Dr. ALLAN G. GRAY, editor, Steel, Penton Publishing Co., Cleveland, Ohio.

EUGENE HARDY, National Association of Manufacturers, Washington, D. C.

KEITH HENNEY, editor, Nucleonics and Electronics, McGraw-Hill Publishing Co., Inc., American Institute of Radio Engineers, New York, N. Y.

Dr. ELMER HUTCHISSON, editor, Journal of Applied Physics, American Institute of Physics, New York, N. Y.

NORMAN H. JACOBSON, editor, market issue, Electric Light and Power, Haywood Publishing Co., New York, N. Y.

WALTER E. JESSUP, editor, Civil Engineering, The American Society of Civil Engineers, New York, N. Y.

ANDREW W. KRAMER, editor, Power Engineering, The Technical Publishing Co., Chicago, Ill.

EVERETT S. LEE, American Institute of Electrical Engineers, New York, N. Y.

Dr. WALTER J. MURPHY, editor, Chemical and Engineering News, American Chemical Society, Washington, D. C.

FREDERICK A. PAWLEY, research secretary, American Institute of Architects, Washington, D. C.

EDWARD H. ROBIE, secretary, American Institute of Mining and Metallurgical Engineers, New York, N. Y.

KARL T. SCHWARTZWALDER, The American Ceramic Society, Inc., Columbus, Ohio.

GEORGE F. SULLIVAN, managing editor, The Iron Age, Chilton Publication, Inc., New York, N. Y.

E. E. THUM, editor, Metal Progress, American Society for Metals, Cleveland, Ohio.

OLIVER H. TOWNSEND, secretary, Atomic Industrial Forum, Inc., New York, N. Y.

S. A. TUCKER, publications manager, American Society of Mechanical Engineers, New York, N. Y.

F. J. VAN ANTWERPEN, editor, Chemical Engineering Progress, American Institute of Chemical Engineers, New York, N. Y.

Dr. ALBERTO F. THOMPSON, secretary; chief, technical information service, division of information services, AEC, Washington, D. C.

Advisory Committee on Isotope Distribution

This committee was originally appointed by the Manhattan District to advise on the off-project distribution of isotopes. The Commission approved its continuation in December 1947 to aid in establishing new policies on distributing radioactive materials and to review existing policies. The committee reviews all initial applications for use of radioisotopes in human beings, and all other requests for their use in research, education, and industry which are referred to it by the Commission.

Dr. SAMUEL E. EATON, chairman; A. D. Little, Inc., Cambridge, Mass.

Dr. RICHARD CHAMBERLAIN, University of Pennsylvania Medical School, Philadelphia, Pa.

Dr. JOHN E. CHRISTIAN, associate professor, department of pharmaceutical chemistry, Purdue University, Lafayette, Ind.

Dr. LEON O. JACOBSON, associate dean, division of biological sciences, University of Chicago, Chicago, Ill.

Dr. EDITH H. QUIMBY, associate professor of radiology, College of Physicians and Surgeons, Columbia University, New York, N. Y.

Dr. HOWARD E. SKIPPER, associate director, Southern Research Institute, Birmingham, Ala.

Dr. JOHN E. WILLARD, professor of chemistry, University of Wisconsin, Madison, Wis.

Dr. PAUL C. AEBERSOLD, secretary; chief, isotopes division, AEC, Oak Ridge, Tenn.

Advisory Committee on Reactor Safeguards

The committee, formed in 1953 from the former Reactor Safeguard Committee and the Industrial Committee on Reactor Location Problems, serves in an advisory capacity to the AEC with regard to the hazards associated with the operation of reactor facilities. The committee reviews safety studies prepared by organizations planning to build or operate reactor facilities and appraises proposed reactor locations in terms of accepted industrial safety standards.

Dr. C. ROGERS MCCULLOUGH, chairman; general development department, Monsanto Chemical Co., St. Louis, Mo.

Dr. Manson Benedict, professor of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. Harvey Brooks, professor of physics, Harvard University, Cambridge, Mass.

Dr. Willard P. Conner, manager, physics division, research department, Hercules Powder Co., Wilmington, Del.

Dr. R. L. Doan, manager, atomic energy division, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. Hymer Friedell, director, department of radiology, Lakeside Hospital, Western Reserve University, Cleveland, Ohio.

Dr. I. B. Johns, Monsanto Chemical Co., Everett, Mass.

Dr. Mark M. Mills, radiation laboratory, University of California, Livermore, Calif.

K. R. Osborn, manager of industrial development, general chemical division, Allied Chemical and Dye Corp., New York, N. Y.

D. A. Rogers, manager, central engineering, Allied Chemical and Dye Corp., Morristown, N. J.

Reuel C. Stratton, supervising chemical engineer, engineering and loss control division, the Travelers Insurance Co., Hartford, Conn.

Dr. Edward Teller, professor of physics, University of California, Berkeley, Calif.

Dr. Abel Wolman, head, department of sanitary engineering and water resources, Johns Hopkins University, Baltimore, Md.

Advisory Committee on Stainless Steel

This committee, formed in 1950, by the Welding Research Council of the Engineering Foundation, in July 1951 at AEC request became advisory to the Commission in regard to research and development to improve the welding of type 347 stainless steel. All data resulting from these investigations are being made public. In October 1953 the scope of the committee's services was enlarged to include the manufacture, fabrication, and use of all stainless steels.

Dr. V. N. Krivobok, chairman; development and research division, International

Dr. ALSTON S. HOUSEHOLDER, mathematics panel, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. HENRY HURWITZ, Jr., supervisor theoretical physics division, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Dr. GEORGE A. KOLSTAD, vice chairman; physics branch, division of research, AEC, Washington, D. C.

Dr. N. C. METROPOLIS, group leader, theoretical division, LASL, Los Alamos, N. Mex.

Dr. ROBERT D. RICHTMYER, secretary; theoretical division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. BERNARD SPINRAD, physics division, Argonne National Laboratory, Chicago, Ill.

Dr. IRA F. ZARTMAN, U. S. Atomic Energy Commission, Washington, D. C.

Committee on Raw Materials

This committee was appointed in October 1947 to review the Atomic Energy Commission's raw materials program and to advise on questions of exploration, development, and procurement.

Chairmanship (vacant).

THOROLD F. FIELD, consulting mining engineer, Duluth, Minn.

FRANCIS C. FRARY, technical advisor, aluminum research laboratory, Aluminum Company of America, New Kensington, Pa.

J. K. GUSTAFSON, consulting geologist, M. A. Hanna Co., Cleveland, Ohio.

ERNEST H. ROSE, staff metallurgist, materials advisory board, National Research Council, Washington, D.C.

WALTER O. SNELLING, director of research and consulting chemist, Trojan Powder Co., Allentown, Pa.

ORVIL R. WHITAKER, consulting mining engineer, Denver, Colo.

CLYDE E. WILLIAMS, director, Battelle Memorial Institute, Columbus, Ohio.

Nuclear Cross Sections Advisory Group

This group is appointed on a yearly basis to make a continuing review of the AEC program of nuclear cross section measurements, and to evaluate the needs for cross section information in the various activities of the AEC. The following members were appointed to serve from July 1954 to July 1955.

Dr. RICHARD F. TASCHEK, chairman; department of physics, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. LOWELL M. BOLLINGER, department of physics, ANL, Lemont, Ill.

Dr. TOM W. BONNER, department of physics, Rice Institute, Houston, Tex.

Dr. JOSEPH L. FOWLER, physics division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. HERBERT GOLDSTEIN, Nuclear Development Associates, Inc., White Plains, N. Y.

Dr. WILLIAM W. HAVENS, Jr., department of physics, Columbia University, New York, N. Y.

Dr. DONALD J. HUGHES, department of physics, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. ALEXANDER S. LANGSDORF, physics division, Argonne National Laboratory, Chicago, Ill.

Dr. HENRY W. NEWSON, professor of physics, Duke University, Durham, N. C.

Dr. JACK M. PETERSON, cyclotron group, University of California Radiation Laboratory, Livermore, Calif.

Dr. Herbert S. Pomerance, physics division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. Thoma M. Snyder, manager, nuclear physics section, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Dr. George A. Kolstad, vice chairman; physics branch, division of research, AEC, Washington, D. C.

Dr. Ira F. Zartman, U. S. Atomic Energy Commission, Washington, D. C.

Dr. Carroll W. Zabel, secretary; department of physics, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Patent Advisory Panel

This panel was appointed in January 1947. It makes informal reports and recommendations to the Commission and its staff on various questions of policy and procedure relating to patents and inventions.

H. Thomas Austern; of Covington & Burling, Washington, D. C.

William H. Davis; of Davis, Hoxie & Faithfull, New York, N. Y.

John A. Dienner; of Brown, Jackson, Boettcher & Dienner, Chicago, Ill.

Casper W. Ooms; firm of Casper W. Ooms, Chicago, Ill.

Personnel Security Review Board

This board was appointed in March 1949 primarily to review specific personnel security cases which arise under the Commission's administrative review procedure and to make recommendations concerning them to the General Manager. The board, in its monthly meetings, 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; of Purcell & Nelson, Washington, D. C.

Dr. Paul E. Klopsteg, associate director, National Science Foundation, Washington, D. C.

William E. Leahy, president, Columbus University, Washington, D. C.

Stack Gas Problem Working Group

The appointment of this group was authorized in May 1948 to advise the Atomic Energy Commission and its contractors on problems in the treatment and control of gaseous effluents. The group meets formally at irregular intervals but renders continuing assistance in the field of air cleaning through specific research and development work directed by individual members and by individual consulting advice.

Dr. Abel Wolman, chairman; head, department of sanitary engineering and water resources, Johns Hopkins University, Baltimore, Md.

Dr. Philip Drinker, professor of industrial hygiene, Harvard University School of Public Health, Boston, Mass.

Dr. Lyle I. Gilbertson, director, research and engineering department, Air Reduction Co., Inc., Murray Hill, N. J.

Dr. H. Fraser Johnstone, professor of chemical engineering, University of Illinois, Urbana, Ill.

Dr. Charles E. Lapple, Stanford Research Institute, Palo Alto, Calif.

Dr. Moyer D. Thomas, Stanford Research Institute, Palo Alto, Calif.

APPENDIX 3

Major Research and Development Installations of the U. S. Atomic Energy Commission

Ames Laboratory (Iowa State College, contractor), Ames, Iowa

Director ---------- Dr. Frank H. Spedding
Associate Director ---------- Dr. H. A. Wilhelm
Assistant to Director ---------- Dr. Adolph F. Voigt

Argonne Cancer Research Hospital (University of Chicago, contractor), Chicago, Ill.

The participating institutions associated with Argonne National Laboratory (listed immediately below) are also affiliated with the Argonne Cancer Research Hospital.

Director ---------- Dr. Leon O. Jacobson
Associate Director ---------- Dr. Robert J. Hasterlik

Argonne National Laboratory (University of Chicago, contractor), Chicago, Ill.

The participating institutions are:

- Battelle Memorial Institute
- Carnegie Institute of Technology
- Case Institute of Technology
- Illinois Institute of Technology
- Indiana University
- Iowa State College
- Kansas State College
- Loyola University (Chicago, Ill.)
- Marquette University
- Mayo Foundation
- Michigan College of Mining and Technology
- Michigan State College
- Northwestern University
- Ohio State University
- Oklahoma Agricultural and Mechanical College
- Purdue University
- St. Louis University
- State University of Iowa
- Washington University (St. Louis, Mo.)
- Wayne University
- Western Reserve University
- University of Chicago
- University of Cincinnati
- University of Illinois
- University of Kansas
- University of Michigan
- University of Minnesota
- University of Missouri
- University of Nebraska
- University of Notre Dame
- University of Pittsburgh
- University of Wisconsin

Director ---------- Dr. Walter H. Zinn
Deputy Director ---------- Dr. Norman Hilberry
Business Manager ---------- John H. McKinley
Associate Director, University Relationships ---------- Dr. Joseph C. Boyce
Assistant Director, Technical Services ---------- John T. Bobbitt

Bettis Plant (Westinghouse Electric Corp., Atomic Power Division, contractor), Pittsburgh, Pa.

Division Manager, Westinghouse Atomic Power Division	CHARLES H. WEAVER
LSR Project Manager	JOSEPH C. RENGEL
PWR Project Manager	JOHN W. SIMPSON
SER Project Manager	ALEXANDER SQUIRE
STR Project Manager	JOHN T. STIEFEL

Brookhaven National Laboratory (Associated Universities, Inc., contractor), Upton, Long Island, N. Y.

The participating institutions are:

Columbia University
Cornell University
Harvard University
Johns Hopkins University
Massachusetts Institute of Technology
Princeton University
Yale University
University of Pennsylvania
University of Rochester

Chairman, Board of Trustees	EDWARD REYNOLDS
President, AUI	LLOYD V. BERKNER
Vice President, AUI and Laboratory Director	Dr. LELAND J. HAWORTH
Deputy Laboratory Director	Dr. GERALD F. TAPE
Assistant Director	Dr. ROBERT A. PATTERSON
Assistant Director	WILLIAM H. FIELDS

Knolls Atomic Power Laboratory (General Electric Co., contractor), Schenectady, N. Y.

General Manager	K. R. VAN TASSEL
Manager, SIR Project	F. E. CREVER
Manager, SAR Project	F. B. HORNBY
Manager, Technical Department	Dr. R. D. BENNETT
Manager, Auxiliary Operations Department	W. W. SMITH

Los Alamos Scientific Laboratory (University of California, contractor), Los Alamos, N. Mex.

Director	Dr. NORRIS E. BRADBURY
Technical Associate Director	Dr. DAROL K. FROMAN

Mound Laboratory (Monsanto Chemical Co., contractor), Miamisburg, Ohio

Project Director	Dr. N. N. T. SAMARAS
Laboratory Director	EDWARD C. MCCARTHY

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Scientific and Educ
Executive Director

Oak Ridge Natio
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Deputy Research Di
Assistant Research I
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Radiation Laborat

Director
Associate Director
Associate Director
Associate Director
Associate Director
Associate Director
Assistant Director
Director, Crocker Lab
Director, Donner Lab
Director, Livermore L
Business Manager and

Oak Ridge Institute of Nuclear Studies (contractor), Oak Ridge, Tenn.

The sponsoring universities of the Institute are:

Agricultural and Mechanical College of Texas
Alabama Polytechnic Institute
Catholic University of America
Clemson Agricultural College
Duke University
Emory University
Florida State University
Georgia Institute of Technology
Louisiana State University
Mississippi State College
North Carolina State College
Rice Institute
Southern Methodist University
Tulane University of Louisiana
Tuskegee Institute
Vanderbilt University
Virginia Polytechnic Institute
University of Alabama
University of Arkansas
University of Florida
University of Georgia
University of Kentucky
University of Louisville
University of Maryland
University of Mississippi
University of North Carolina
University of Oklahoma
University of Puerto Rico
University of South Carolina
University of Tennessee
University of Texas
University of Virginia

Chairman of Council	Dr. GEORGE H. BOYD
Vice Chairman of Council	Dr. T. W. BONNER
President of Institute	Dr. PAUL M. GROSS
Vice President of Institute	Dr. C. K. BECK
Scientific and Educational Consultant	Dr. GEORGE B. PEGRAM
Executive Director of Institute	Dr. WILLIAM G. POLLARD

Oak Ridge National Laboratory (Carbide & Carbon Chemicals Co., Division of Union Carbide & Carbon Corp., contractor), Oak Ridge, Tenn.

Director	Dr. C. E. LARSON
Research Director	Dr. A. M. WEINBERG
Deputy Research Director	Dr. J. A. SWARTOUT
Assistant Research Director	Dr. G. E. BOYD
Assistant Research Director	Dr. R. A. CHARPIE
Assistant Research Director	Dr. E. D. SHIPLEY
Assistant Research Director	Dr. C. E. WINTERS

Radiation Laboratory (University of California, contractor), Berkeley, Calif.

Director	Dr. ERNEST O. LAWRENCE
Associate Director	Dr. LUIS W. ALVAREZ
Associate Director	Dr. DONALD COOKSEY
Associate Director	Dr. EDWIN M. MCMILLAN
Associate Director	Dr. GLENN T. SEABORG
Associate Director	Dr. EDWARD TELLER
Assistant Director	WILLIAM M. BROBECK
Director, Crocker Laboratory Medical Physics	Dr. JOSEPH G. HAMILTON
Director, Donner Laboratory of Medical Physics	Dr. J. H. LAWRENCE
Director, Livermore Laboratory	Dr. HERBERT F. YORK
Business Manager and Managing Engineer	WALLACE B. REYNOLDS

Raw Materials Development Laboratory (National Lead Co., contractor), Winchester, Mass.

Technical Director and Manager ---------- JOHN BREITENSTEIN

Rochester Atomic Energy Project (University of Rochester, contractor), Rochester, N. Y.

Director ---------- DR. HENRY A. BLAIR
Assistant Director for Education ---------- DR. J. NEWELL STANNARD
Business Manager ---------- C. M. JARVIS

Sandia Laboratory (Sandia Corp., contractor), Sandia Base, Albuquerque, N. Mex.

President ---------- JAMES W. MCRAE

University of California, Los Angeles, Atomic Energy Project (University of California, contractor), Los Angeles, Calif.

Director ---------- DR. STAFFORD WARREN
Project Manager ---------- ROBERT J. BUETTNER

University of California, Medical Center, Radiological Laboratory (University of California, contractor), San Francisco, Calif.

Director ---------- DR. ROBERT S. STONE

National Reactor Testing Station, Idaho Falls, Idaho

Nevada Test Site, Las Vegas, Nev.

Pacific Proving Ground, Marshall Islands

APPENDIX 4

ISOTOPE DISTRIBUTION DATA[1]

Isotope	Aug. 2, 1946 Dec. 31, 1954		Jan. 1, 1955 May 31, 1955		Total to May 31, 1955	
	Activity (Curies)	Shipments	Activity (Curies)	Shipments	Activity (Curies)	Shipments
Radioactive:						
Iodine 131	2,583	23,736	275	2,169	2,858	25,905
Phosphorus 32	760	14,464	101	1,176	861	15,640
Carbon 14	34	1,918	2	106	36	2,024
Sodium 24	32	2,376	2	167	34	2,543
Gold 198	1,320	2,192	325	325	1,645	2,517
Tritium	514	243	130	35	644	278
Strontium 89, 90	257	776	61	64	318	840
Cobalt 60	45,857	945	13,777	73	59,634	1,018
Cesium 137	379	515	1,817	49	2,196	564
Iridium 192	1,236	131	1,131	35	2,367	166
Polonium 210	1,131	113	----------	----------	1,131	113
Others	625	16,793	109	1,457	734	18,250
Total	54,728	64,202	17,730	5,656	72,458	69,858
Shipments to AEC installations	----------	8,248	----------	402	----------	8,650
Stable:						
Deuterium oxide	----------	798	----------	71	----------	869
Deuterium	----------	838	----------	40	----------	878
Boron 10, 11	----------	267	----------	36	----------	303
Helium 3	----------	41	----------	3	----------	44
Oxygen 18	----------	344	----------	22	----------	366
Electromagnetically concentrated	----------	986	----------	126	----------	1,112
Argon 38	----------	4	----------	----------	----------	4
Total	----------	3,278	----------	298	----------	3,576
Shipments to AEC installations	----------	1,843	----------	136	----------	1,979

[1] Domestic shipments from Oak Ridge National Laboratory.

LOCATION AND TYPE OF USERS[1]

January 1, 1955–May 31, 1955

States and Territories	Medical Institutions and Physicians		Colleges and Universities		Industrial Firms		Federal and State Laboratories		Foundations and Institutions		Other		Total	
	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable
Alaska					2								2	
Alabama	2												2	
Arizona	3				1								4	
Arkansas	14		1	1	12	1					1		28	2
California	4												4	
Colorado	3				2	1							5	1
Connecticut	1												1	
Delaware	2												2	
District of Columbia	4				1								6	
Florida	3		1		1								5	
Georgia					1								1	
Hawaii														
Idaho	8		1		8								17	
Illinois	4				2								6	
Indiana			1		1								2	
Iowa	1		2										3	
Kansas	3		1		2								5	
Kentucky	2				2								4	
Louisiana	1												1	
Maine	2						2	1					4	1
Maryland	5		1		9	1	2	1		1	1		18	3
Massachusetts	4				3			1					7	1
Michigan	1												1	
Minnesota	1												1	
Mississippi	1				1								2	
Missouri	1												1	
Montana	3			1									3	1
Nebraska	1												1	
Nevada														
New Hampshire	4			1	8								12	1
New Jersey	1												1	
New Mexico	12	1		1	11	2	1				1		25	4
New York	1				2								3	
North Carolina														
North Dakota	6				3								9	
Ohio	4												4	
Oklahoma														
Oregon														
Panama														
Pennsylvania	9	1			6	2							15	3
Puerto Rico														
Rhode Island					1								1	
South Carolina														
South Dakota	1												1	
Tennessee					1								1	
Texas	10				6		1						17	
Utah	1				1								2	
Vermont			1	1									1	1
Virginia					1								1	
Washington	2				1		1						4	
West Virginia					2									

New York	1				2								9	
North Carolina					3								4	
North Dakota	6													
Ohio	4													
Oklahoma														
Oregon														
Panama														
Pennsylvania	[illegible]	1			[illegible]	2							15	3
Puerto Rico													1	
Rhode Island					1									
South Carolina														
South Dakota	1												1	
Tennessee					1								1	
Texas	10				6		1						17	
Utah	1				1								2	
Vermont			1	1									1	1
Virginia					1								1	
Washington	2				1		1						4	
West Virginia					2								2	
Wisconsin	5				3				1				9	
Wyoming														
Total	130	2	9	5	94	7	7	3	1	1	3		244	18

[1] Users are either institutions or individuals receiving isotopes authorized through the Commission's distribution program.

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LOCATION AND TYPE OF USERS

August 2, 1946–May 31, 1955

States and Territories	Medical Institutions and Physicians		Colleges and Universities		Industrial Firms		Federal and State Laboratories		Foundations and Institutions		Other		Total	
	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable	Radio	Stable
Alaska	1		1				1						3	
Alabama	6		2	1	14	1	7	1	2	1			31	4
Arizona	6		1	1			2						9	1
Arkansas	9		1	1	3		2						15	1
California	120	5	17	13	131	20	44	4	3	1	3	1	318	44
Colorado	24	1	4	2	7	1	4		1		2		42	4
Connecticut	14	1	5	3	35	4	4	2					58	10
Delaware	2		1	1	11	3	1		1	1			16	5
District of Columbia	13	4	3	4	7		11	6			5		39	14
Florida	20		6	2	4		5				2		37	2
Georgia	14		4	3	6		5				2		31	3
Hawaii	4		1		1		2		2				10	
Idaho	2		1		2								5	
Illinois	69	4	7	6	71	6	8	4	2	3	8		165	23
Indiana	18		3	3	26	4					1	1	48	8
Iowa	7	1	4	2	8								19	3
Kansas	13		4	2	3								20	2
Kentucky	9		2	1	10		2		1		2		26	1
Louisiana	14	1	3	3	13	2	3						33	6
Maine	5		3	1	12		2						22	1
Maryland	17	5	5	3	17	3	16	6					55	17
Massachusetts	35	6	16	12	79	13	9	6	3	1	2		144	38
Michigan	24	1	7	3	31	5	1	1	1		1		65	10
Minnesota	11	2	5	2	9		1						26	4
Mississippi	4		1	1	4		2	1					11	2
Missouri	33	2	4	4	10	1	1				1		49	7
Montana	7	2	1	1			1		1				10	3
Nebraska	9		2	1			3						14	1
Nevada	3			2	3		1						7	2
New Hampshire	2	1	2	3	3	14	2	3		1			9	22
New Jersey	28		4		82		7		6		1		128	
New Mexico	7		3	3	1		3						14	3
New York	143	14	27	21	129	18	18	1	8	2	2		327	56
North Carolina	12	1	6	3	10		5						33	4
North Dakota	5		2				1						8	
Ohio	41	2	11	9	91	6	12	7	3	2	1		159	26
Oklahoma	15		2	1	20	6	1		3				41	7
Oregon	6	1	3	3	3		5				1		18	[illegible]
Panama	1												[illegible]	
Pennsylvania	60	10	11	8	102	14	11	3	5	2	1		190	37
Puerto Rico	5						2						7	
Rhode Island	4		2	1	9		1						16	1
South Carolina	3		3	2	2		2						10	2
South Dakota	3		3										6	
Tennessee	22		4	4	9	2	5	1			1		41	7
Texas	63	5	5	4	64	7	5	1	4	1			141	18
Utah	7	1	3	2	4		2						16	3
Vermont	3		1	1	2								6	1
Virginia	10	1	4	1	13	2	8	1					35	5
Washington	15		4	3	11	1	6						[illegible]	
West Virginia	[illegible]		[illegible]											

New Jersey	7		3	[illegible]	[illegible]									
New Mexico	143	14	27	21	129	18	18	1	8	2	[illegible]		[illegible]	
New York	12	1	6	3	10		5						33	4
North Carolina	5		2				1						8	
North Dakota	41	2	11	9	91	0	12	7	3	2	1		159	26
Ohio	15		2	1	20	6	1		3				41	7
Oklahoma	6	1	3	3	3		5				1		18	4
Oregon	1						1						2	
Panama														
Pennsylvania	[illegible]	10	11	8	102	14	11	3	5	2	1		190	37
Puerto Rico	6						2						7	
Rhode Island	4		2	1	9		1						16	1
South Carolina	8		8	2	2		2						10	2
South Dakota	3		3										6	
Tennessee	22		4	4	9	2	5	1			1		41	7
Texas	63	5	5	4	64	7	5	1	4	1			141	18
Utah	7	1	3	2	4		2						16	3
Vermont	3		1	1	2								6	1
Virginia	10	1	4	1	13	2	8	1					35	5
Washington	15		4	3	11	1	6						36	4
West Virginia	11		2	1	5	1	2						20	2
Wisconsin	20	1	3	3	34		4		1				62	4
Wyoming	1		1	1			1						3	1
Total	1,000	72	220	152	1,111	134	242	48	47	15	36	2	2,656	423

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SHIPMENTS OF RADIOACTIVE AND STABLE ISOTOPES TO FOREIGN COUNTRIES

Country	Jan. 1, 1955–May 31, 1955		Total Jan. 1947 to May 31, 1955	
	Radio	Stable	Radio	Stable
Argentina	0	0	124	[illegible]
Australia	2	1	109	[illegible]
Austria	0	0	1	[illegible]
Belgian Congo	1	0	3	[illegible]
Belgium	7	0	152	[illegible]
Bermuda	0	0	16	[illegible]
Bolivia [1]	0	0	0	[illegible]
Brazil	52	0	311	[illegible]
British West Africa	0	0	1	[illegible]
Canada	96	2	770	[illegible]
Chile	15	0	114	[illegible]
China [1]	0	0	0	[illegible]
Colombia	1	0	9	[illegible]
Costa Rica [1]	0	0	0	[illegible]
Cuba	54	0	289	[illegible]
Denmark	4	0	227	[illegible]
Dominican Republic	0	0	1	[illegible]
Egypt	0	0	2	[illegible]
El Salvador [1]	0	0	0	[illegible]
England	7	2	152	[illegible]
Finland	0	0	14	[illegible]
France	7	1	118	[illegible]
Germany	7	8	31	[illegible]
Gold Coast	0	0	1	[illegible]
Greece	0	0	1	[illegible]
Guatemala	4	0	16	[illegible]
Honduras	1	0	1	[illegible]
Iceland	0	0	5	[illegible]
India	4	0	26	[illegible]
Indonesia	0	0	3	[illegible]
Ireland [1]	0	0	0	[illegible]
Israel	1	0	7	[illegible]
Italy	3	0	37	[illegible]
Japan	31	0	361	[illegible]
Korea [1]	0	0	0	[illegible]
Lebanon	0	0	6	[illegible]
Mexico	25	0	121	[illegible]
Netherlands	4	1	61	[illegible]
New Zealand	0	0	12	[illegible]
Nicaragua [1]	0	0	0	[illegible]
Norway	0	2	43	[illegible]
Pakistan	0	0	7	[illegible]
Paraguay [1]	0	0	0	[illegible]
Peru	9	0	29	[illegible]
Philippines	1	0	3	[illegible]
Portugal	3	0	8	[illegible]
Spain	1	0	10	[illegible]
Sweden	7	0	199	[illegible]
Switzerland	6	0	69	[illegible]
Syria [1]	0	0	0	[illegible]
Thailand [1]	0	0	0	[illegible]
Trieste	0	0	3	[illegible]
Turkey	0	0	5	[illegible]
Union of South Africa	0	3	29	[illegible]
Uruguay	0	0	10	[illegible]
Venezuela	7	0	15	[illegible]
Yugoslavia	0	0	1	[illegible]
Total	361	18	3,533	[illegible]

[1] Authorized to receive isotopes; no shipments made.

SHIPMENTS OF RADIOACTIVE AND STABLE ISOTOPES TO FOREIGN COUNTRIES—Continued

Kind of Isotope	Jan. 1, 1955–May 31, 1955	Total Jan. 1947 to May 31, 1955
Radioactive Isotopes		
Phosphorus 32	45	905
Iodine 131	148	1,112
Carbon 14	18	326
Sulfur 35	3	123
Iron 55, 59	14	125
Cobalt 60	17	198
Strontium 89, 90	14	92
Calcium 45	9	107
Other	87	545
Total	355	3,533
Stable Isotopes		
Argon 38	2	2
Deuterium Gas	2	2
Deuterium Oxide	1	2
Boron	3	13
Electromagnetically concentrated	9	16
Helium 3	2	2
Rare earths	0	3
Total	19	40
Total Foreign Isotope Shipments	374	3,573

APPENDIX 5

Current AEC Unclassified Physical Research Contracts

Chemistry

Alabama, University of. J. L. Kassner and E. L. Grove, A Study of the Principles, Theory and Practice of High Frequency Titrimetry.

Arizona, University of. E. B. Kurtz, Jr., Study of Uranium Accumulation in Plants.

Arkansas, University of. R. R. Edwards, Chemical Effects of Nuclear Transformation.

Arkansas, University of. R. R. Edwards, Investigation of the Radioactivity of Thermal Waters and Its Relationship to the Geology and Geochemistry of Uranium.

Brooklyn, Polytechnic Institute of. R. B. Mesrobian and H. Morawetz, Study of Radiation Induced Solid State Polymerization.

Buffalo, University of. G. M. Harris, Applications of Isotopes in Chemical Kinetics.

California Institute of Technology. Norman Davidson, Complex Ions and Reaction Mechanisms in Solution.

California Institute of Technology. Harrison Brown, Study of Fundamental Geochemistry of Critical Materials and Development of Economic Processes for Their Isolation.

California, University of. J. H. Hildebrand, Studies in Intermolecular Forces and Solubility.

California, University of. C. S. Garner, Isotopic Exchange Reactions.

California, University of. R. A. James, Nuclear Chemistry Research.

California, University of. R. L. Scott, Fluorocarbons Solutions.

Carnegie Institute of Technology. T. P. Kohman, Nuclear Chemistry Research.

Catholic University of America. F. O. Rice, The Thermal Production and Identification of Free Radicals.

Chicago, University of. H. C. Urey, Natural Abundance of Deuterium and Other Isotopes.

Chicago, University of. Nathan Sugarman and Anthony Turkevich, Nuclear Chemical Research.

Chicago, University of. C. A. Hutchinson, Paramagnetic Resonance Absorption.

Clarkson College of Technology. H. L. Shulman, The Determination of Interfacial Area in Packed Absorption and Distillation Columns.

Colorado, University of. R. N. Keller, The Scintillation Properties of Coordination Compounds.

Columbia University. J. L. Kulp, Helium in the Atmosphere and Lithosphere.

Columbia University. J. L. Kulp, U-Pb Method of Age Determination.

Columbia University. V. K. LaMer, Fundamental Investigation of Phosphate Slimes.

Columbia University. J. M. Miller, Research in the Field of Radiochemistry.

Columbia University. R. M. Noyes, Photochemical Reactions of Iodine.
Columbia University. W. A. Selke, Ion Exchange Chromatography.
Columbia University. T. I. Taylor, Separation of Isotopes by Chemical Exchange.
Connecticut, University of. Roland Ward, Tracer Element Distribution Between Melt and Solid.
Cornell University. R. Bernsohn, *et al.*, Gradient of the Electric Field in Ionic Crystals.
Cornell University. J. L. Hoard, Structure of Fluorocarbons, Elementary Boron and Boron Compounds.
Cornell University. F. A. Long, Kinetic and Equilibrium Salt Effects.
Delaware, University of. R. L. Pigford, Thermal Diffusion in Liquids.
Duke University. D. G. Hill, A Study of Some Chemical Reactions at High Temperatures.
Emory University. W. H. Jones, Mass Distribution in Proton-Induced Fission.
Florida State University. R. E. Johnson, Exchange Between Labelled Halogens and Certain Inorganic Halides.
Florida State University. Raymond Sheline, Search for Long-Lived Radioactivities; Theoretical Nuclear Studies.
Florida, University of. G. B. Butler and A. H. Gropp, Studies in the Preparation and Properties of Quaternary Ammonium Ion Exchange Resins.
Fordham University. Michael Cefola, Studies on Formation of Complexes by Thenoyltrifluoroacetate and Other Chelating Agents.
George Washington University. Theodore Perros, Studies of Fluorides of the Rare Earth Elements.
Harvard University. E. S. Barghoorn, Radioactivity in Uraniferous Plant Fossils.
Harvard University. R. M. Diamond and Geoffrey Wilkinson, Nuclear and Inorganic Chemistry of the Transitional Elements.
...ward College. J. A. Southern, Cyclotron Research.
...ater College. G. R. Burns, Mechanism of the Oxo Reaction Using Carbon 14.
Illinois Institute of Technology. M. L. Bender, Correlation of Isotopic Effect on Reaction Rate with Reaction Mechanism.
Illinois Institute of Technology. H. E. Gunning, Studies in the Field of Stable Isotopes.
Illinois Institute of Technology. George Gibson, Fundamental Chemistry of Uranium.
Illinois Institute of Technology. H. E. Gunning, Decomposition of Molecules by Metal-Photosensitization.
Illinois, University of. E. A. Alperovitch, Occurrence of Technetium in Nature.
Illinois, University of. P. E. Yankwich, Studies in Radiochemistry.
Illinois, University of. H. G. Drickamer, The Mechanism of Molecular Motion as Determined from Diffusion and Thermal Diffusion Measurements.
Indiana University. L. L. Merritt, Studies with Radioactive Tracers.
Indiana University. W. J. Moore, Rate Processes in Inorganic Solids at High Temperatures.
Indiana University. W. B. Schaap and F. C. Schmidt, Electrochemical Research in Amine Solvents.
...c. State University of. LeRoy Eyring, Preparation of Rare Earth Oxides.

Iowa, State University of. Karl Kammermeyer, Separation of Gases by Diffus-
Thru Permeable Membranes.

Johns Hopkins University. W. S. Koski, Nuclear Chemistry Studies.

Kansas State College. R. E. Hein, Labeled Chemical Species Produced by Ne-
tron Irradiation of Phosphorus Trichloride and Related Compounds.

Kansas State College. E. R. Lippincott, Raman Spectra of Colored and Absor-
Substances.

Kansas, University of. P. W. Gilles, High Temperature Research.

Little, Inc., Arthur D. G. A. Bleyle, Study of Deuterium Separation.

Louisville, University of. R. H. Wiley, The Synthesis and Properties of Io-
Exchange Resins.

Massachusetts Institute of Technology. Manson Benedict, Transfer of Deuterium
from Steam to Hydrogen.

Massachusetts Institute of Technology. C. D. Coryell, D. N. Hume, J. I.
Sheehan, C. G. Swain, Nuclear Chemistry Research.

Massachusetts Institute of Technology. T. K. Sherwood, Mechanism of Mas-
Transfer to Drops.

Massachusetts Institute of Technology. P. M. Hurley, Investigations on Isotope
Abundances of Strontium, Calcium and Argon in Certain Minerals.

Massachusetts Institute of Technology. A. M. Gaudin, Techniques in Mineral
Engineering.

Michigan, University of. E. F. Westrum, Low Temperature Chemical Thermo-
dynamics.

Michigan, University of. W. W. Meinke, Nuclear Chemical Research.

Michigan, University of. P. J. Elving, Polarographic Behavior of Organic Com-
pounds.

Michigan, University of. R. B. Bernstein, Fundamental Research in Isotope
Reactions.

Michigan State College. M. T. Rogers, A Physico-Chemical Investigation of
Interhalogen Compounds.

Michigan State College. C. H. Brubaker, Investigations into Aperiodic Oxidation
States.

Michigan State College. James L. Dye, Thermodynamic Investigation of Dilute
Solutions of the Alkali Metals in Liquid Ammonia.

New Hampshire, University of. H. M. Haendler, Infra-red Spectroscopy of
Inorganic Fluorides.

New York State College for Teachers. O. E. Lanford, Concentration of Nitrogen
15 by Chemical Exchange.

North Carolina State College. F. P. Pike, Performance of Contactors for Liquid-
Liquid Extraction.

North Carolina, University of. Kerro Knox, The Preparation and Properties of
Compounds of Technetium and Rhenium.

Northwestern University. Fred Basolo and R. G. Pearson, Mechanism of Substi-
tution Reactions of Inorganic Complexes.

Northwestern University. Malcolm Dole, The Mechanism of High Energy
Radiation Effects on Polyethylene.

Notre Dame, University of. Milton Burton, Radiation Chemistry Studies.

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Oklahoma, University of. J. R. Nielsen, Spectroscopic Properties of Fluorocarbons and Fluorinated Hydrocarbons.

Oklahoma A & M College. T. E. Moore, The Separation of Inorganic Salts by Liquid-Liquid Extraction.

Oklahoma A & M College. E. M. Hodnett, The Isotope Effect in the Study of Chemical Reactions.

Oregon State College. T. H. Norris, A Study of Generalized Acid-base Phenomena with Radioactive Tracers.

Oregon, University of. D. F. Swinehart, Study of Gaseous Chemical Reaction Kinetics Using a Mass Spectrometer.

Pennsylvania State University. W. C. Fernelius, Stabilities of Coordination Compounds and Related Problems.

Pennyslvania State University. T. F. Bates, Investigation of the Mineralogy and Petrography of Uranium-Bearing Shales and Lignites.

Pennsylvania State University. B. F. Howell, Jr., Studies of the Dielectric Constant of Rocks and Minerals.

Pennyslvania State University. C. R. Kinney, An Investigation of the Chemical Nature of the Organic Matter of Uraniferious Shales.

Pennsylvania State University. W. W. Miller, Chemical Reactions Induced in Condensed Systems by Beta-decay.

Pennyslvania State University. H. D. Wright, Mineralogy of Uranium-Bearing Deposits in the Boulder Batholith, Montana.

Pennsylvania, University of. J. O'M. Bockris, A Study of the Structure of Molten Salts and Silicates.

Pittsburgh, University of. Robert Levine, Synthesis of Beta-Diketones and Beta-Ketoesters with Heterocyclic Nuclei.

Pittsburgh, University of. Henry Freiser, The Development and Testing of Organic Reagents for Use in Inorganic Analysis.

Princeton University. John Turkevich, Temporary and Permanent Effects Produced by Radiation on Solids.

Princeton University. John Turkevich, Study of Nucleation Processes.

Providence College. M. A. Fineman, The Nature of Gaseous Negative Ions Formed by Electron Impact.

Purdue University. Thomas DeVries, Polarographic Studies in Non-Aqueous Solvents.

Purdue University. W. F. Edgell, Studies in Molecular Spectroscopy.

Purdue University. W. H. Johnston, Gas Phase Exchange Reactions.

Purdue University. H. C. Brown, Chemistry of Polyvalent Metal Halides.

Purdue University. James W. Cobble, Chemistry of the Heavy Elements.

Rensselaer Polytechnic Institute. H. M. Clark, Extraction of Inorganic Substances by Organic Solvent.

Rochester, University of. E. O. Wiig, Radiochemistry.

Rutgers University. E. R. Allen, Polar Inorganic Molecules.

Rutgers University. William Rieman, Analytical Chemistry of the Polyphosphates.

Southern California, University of. H. L. Friedman, Solutions of Inorganic Electrolytes in Solvents of Low Dielectric Constant.

Southern California, University of. W. K. Wilmarth, The Mechanism of the Base Catalyzed Exchange of Hydrogen Gas and Protonic Solvents.

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South Carolina, University of. O. D. Bonner, Fundamental Studies of Ion Exchange Equilibria.

Syracuse University. Henry Linschitz, Photochemical Reactions of Complex Molecules in Condensed Phase.

Syracuse University. B. P. Burtt, Mechanism of Gaseous Radiation Chemical Reactions and the Chemical Reactions of Electrons.

Syracuse University. Louis Gordon, Coprecipitation Studies.

Tennessee, University of. J. F. Eastham, Chemical Fractionations of Hydrogen Isotopes.

Tennessee, University of. G. K. Schweitzer, Study of Radiocolloids.

Tennessee, University of. H. A. Smith, Catalytic Reactions Involving Deuterium and Vapor Pressure Studies of H^2O–D^2O Mixtures.

Tennessee, University of. P. B. Stockdale, Investigation of the Chattanooga Black Shale of Tennessee as a Source of Uranium.

Texas, University of. G. W. Watt, Unusual Oxidation States of Transition Elements.

Texas, University of. E. F. Gloyna, Effects of Biological Slimes on Sea Water.

Tufts College. T. R. P. Gibb, Research on Hydrides.

Utah, University of. Henry Eyring, Studies on Surface Chemistry.

Utah, University of. R. B. Parlin, Induction of Chemical Reactions by High Frequency Discharges in Gases.

Utah, University of. A. L. Wahrhaftig, Ionization and Dissociation of Molecules by Electron Bombardment and the Interpretation of Such Data.

Vanderbilt University. E. A. Jones, Raman Spectra of Some Inorganic Fluorine Compounds.

Vanderbilt University. M. D. Peterson, Radiation Stability and Inorganic Radiochemistry.

Virginia Polytechnic Institute. N. F. Murphy, Mass Transfer Studies in Liquid-Liquid Extraction.

Washington State College. H. W. Dodgen, The Formulae and Stability of Complex Ions in Solution.

Washington University. J. W. Kennedy, Study of Reaction Kinetics Using Stable Isotope Tracers.

Washington University. J. W. Kennedy, Generation of High Voltages by Means of Nuclear Radiations.

Washington, University of. G. H. Cady, Preparation of Compounds Containing O–F or N–F Bonds.

Wayne University. K. H. Gayer, Solubility of Uranium and Thorium Oxides in Dilute Acid and Base.

Western Reserve University. E. L. Pace, Thermodynamic Properties of Gases Absorbed on Solids.

Wisconsin, University of. J. E. Willard, Application of Radioisotopes to Chemical Problems.

Wisconsin, University of. E. L. King, Studies of Rates and Equilibria in Inorganic Reactions in Solution.

Wisconsin, University of. Farrington Daniels, Studies on the Geochemistry of Uranium and the Recovery of Uranium from Low Grade Ores.

Wisconsin, University of. J. O. Hirschfelder, Quantum Mechanical and Semi-empirical Determination of Intermolecular Forces.

Yale University. H. S. Harned, Diffusion Coefficients of Electrolytes and Molecules.

Metallurgy and Materials

Alfred University. V. D. Frechette, Graphitization of Carbon.

Armour Research Foundation. D. J. McPherson, Heat Treatment of Zirconium Base Alloys.

Bausch and Lomb Optical Co. J. J. Kreidl, Irradiation Damage to Glass.

Brown University. Rohn Truell, Radiation Damage Studies.

Buffalo, University of. Stanislaw Morzowski, Basic Principles of Manufacture of Carbons.

California, University of. E. R. Parker, Creep of Alloys.

California, University of. J. A. Pask, The Mechanics of Metal-Ceramic Bonding.

Carnegie Institute of Technology. Roman Smoluchowski, Study of Grain Boundaries; and Lattice Imperfections.

Carnegie Institute of Technology. Gerhard Derge, Electrochemical Studies of Non-Aqueous Melts.

Carnegie Institute of Technology. Roman Smoluchowski, Radiation Effects in Materials.

Carnegie Institute of Technology. J. E. Goldman, Research on Properties of Rare Metals.

Case Institute of Technology. W. J. Baldwin, Scaling of Zirconium in Air at Elevated Temperatures.

Chicago, University of. Lothar Meyer, Research on the Structure and Properties of Graphite.

Columbia University. H. H. Kellogg, Electrolytic Production of Zirconium Metal.

Columbia University. G. L. Kehl, A Study of Inclusions in Uranium.

Franklin Institute. R. L. Smith and F. E. Jaumot, Basic Research on Solid State Physics.

General Electric Company. W. R. Hibbard, Developing of Zirconium Base Alloys.

General Electric Company. D. Turnbull, Fundamental Metallurgical Research.

Illinois Institute of Technology. T. J. Neubert, Imperfections in Solids.

Illinois, University of. Frederick Seitz and D. Lazarus, Mechanism and Substitutional Diffusion in Metals.

Illinois, University of. P. A. Beck, Annealing of Cold Worked Metals.

Illinois, University of. T. A. Read, Diffusionless Phase Changes in Non-Ferrous Metals and Alloys.

Illinois, University of. Frederick Seitz, Experimental and Theoretical Investigation of Radiation Damage in Solid Materials.

Iowa, State University of. N. C. Baenziger, Structures and Properties of Intermetallic Compounds.

Massachusetts Institute of Technology. B. E. Warren, Studies of Radiation Damage.

Massachusetts Institute of Technology. F. H. Norton, The Measurement of Thermal Conductivity of Refractory Materials.

Massachusetts Institute of Technology. M. B. Bever, Thermodynamics of Metal Solution.

Massachusetts Institute of Technology. M. Cohen, Solid Solutions and Grain Boundaries.

Massachusetts Institute of Technology. B. Averbeck, Fundamentals of Cold Work and Recrystallization.

Massachusetts Institute of Technology. F. H. Norton and W. D. Kingergy, Metal-Ceramic Interactions.

Massachusetts Institute of Technology. S. C. Collins, Mechanical Properties of Metals at Low Temperatures.

Massachusetts Institute of Technology. A. R. Kaufmann, The Physical Metallurgy of Uncommon Metals.

New York University. J. P. Nielsen, Origin of Secondary Recrystallization Nuclei.

North Carolina State College. K. O. Beatty, Jr., Thermal Properties of Non-Metallic Materials at High Temperatures.

Ohio State University. C. H. Shaw, Soft X-ray Absorption and Emission Spectra.

Ohio State University. Edward Mack, Jr., Investigation of Separative Processes.

Oregon, University of. Pierre Van Rysselberghe, Polarographic Studies on the Corrosion of Zirconium.

Pennsylvania State University. C. R. Kinney, Factors Affecting the Mechanism of Graphitization and the Heterogeneous Gas Reactions of Graphites.

Pittsburgh, University of. W. E. Wallace, Thermochemistry of Alloys.

Purdue University. Karl Lark-Horovitz, Radiation Damage Studies.

Rensselaer Polytechnic Institute. H. B. Huntington, Anistropic Self-Diffusion in Metals.

Rutgers University. Sigmund Weissmann, Radiation Damage of Metals and Alloys.

Tennessee, University of. E. E. Stansbury, Energy Changes from Plastic Deformation.

Utah, University of. I. V. Cutler, Recrystallation and Sintering of Oxides.

Virginia, University of. A. T. Gwathney, Growth and Chemical Properties of Nearly Perfect Crystals.

Wichita, University of. Luther Lyon, The Permeability Method of Determining Surface Areas of Finely Divided Materials.

Physics

Alabama Polytechnic Institute. Howard E. Carr, Research with Mass Spectrometer.

Armour Research Foundation. R. F. Humphreys, Research Reactor.

Bartol Research Foundation of the Franklin Institute. C. E. Mandeville, Neutron Scattering Measurements.

Brigham Young University. Richard W. Hales and E. John Eastmond, Research in Shock Waves.

Brown University. R. A. Peck, Precision Measurements of Neutron Interactions.

California Institute of Technology. J. W. DuMond, Precision Nuclear Spectroscopy.

California Institute of Technology. R. F. Bacher, High Energy Physics.

California, University of. W. F. Giauque, Low Temperature Physics.

California, University of. C. D. Jeffries, Nuclear Moments.

Carnegie Institute of Technology. Edward Creutz, 400 Mev Synchrocyclotron and Associated Research.

Case Institute of Technology. E. F. Shrader, Electron and Gamma Interactions with 26–Mev Betatron.

Case Institute of Technology. E. F. Shrader, Reactor Studies.

Chicago, University of. S. K. Allison, Reactions of the Light Nuclei and the Penetration of Charged Particles Through Matter.

Chicago, University of. G. Wentzel and M. L. Goldberger, Theoretical Research in Elementary Particle Physics.

Columbia University. W. W. Havens, Neutron Spectroscopy and Nuclear Physics Research.

Columbia University. C. H. Townes, Microwave Spectroscopy.

Connecticut, University of. S. S. Friedland, Inelastic Scattering of Neutrons.

Duke University. H. W. Newson, Shell Structure and Fast Neutron Cross Section.

Florida, University of. D. C. Swanson, Electrostatic Generator Program.

Florida State University. A. E. S. Green and M. A. Melvin, Analysis of Nuclear Forces.

Iowa, State University of. J. A. Jacobs, Research in Nuclear Structure.

Johns Hopkins University. S. S. Hanna, Fast Neutron Cross-Section Measurements.

Johns Hopkins University. G. H. Dieke, Absorption and Fluorescent Spectra of Solid Uranium Compounds.

Johns Hopkins University. S. S. Hanna, L. Madansky and C. D. Swartz, Properties of Nuclei.

Kansas State College. C. M. Fowler, Precision Beta-ray Spectrometry.

Kansas State College. R. G. Taecker, Research Reactor.

Kentucky Research Foundation. Bernard D. Kern, Study of Nuclear Energy Levels.

Louisiana State University. R. C. Mobley, Neutron Scattering.

Massachusetts Institute of Technology. G. R. Harrison, Echelle Spectroscopy.

Michigan, University of. H. R. Crane, Nuclear Research with 300-Mev Synchrotron.

Michigan, University of. H. T. Gomberg, Research Reactor Studies.

Michigan, University of. W. C. Parkinson, 42″ Cyclotron Program.

Minnesota, University of. J. H. Williams, 60 Mev Proton Linac.

National Academy of Sciences. Kay Way, Preparation of Tables of Nuclear Data.

National Bureau of Standards. H. W. Koch, Neutron Yield and Neutron Energy Distribution Studies.

Nebraska, University of. Theodore Jorgensen, Jr., Mechanism of Energy Transfer of Slow Ions.

New York University. R. Richtmyer and E. Bromberg, AEC Computing Facility.

North Carolina State College. Clifford Beck, Studies for the Development of a Low-Powered Nuclear Reactor.

North Carolina, University of. A. V. Masket, Measurement of Inelastic Neutron Scattering.

Northwestern University. Edward N. Strait, Completion of 5 Mev Electrostatic Generator.

Notre Dame University. Bernard Waldman, Assistance in Remodeling of Electrostatic Generator.

Ohio State University. J. G. Daunt, Nuclear Paramagnetism and Low Temperature Physics.

Ohio State University. J. N. Cooper, Nuclear Spectroscopy with Van de Graaff.

Oregon State College. E. A. Yunker, 37″ Cyclotron.

Pennsylvania, University of. K. B. Atkins, Solid State Physics at Low Temperatures.

Pennsylvania State University. Ray Pepinsky, Neutron Single Crystal Structure Analysis.

Pennsylvania State University. William Breazeale Construction and Operations of Research Reactor.

Princeton University. M. G. White, Nuclear Research Using 18-Mev Cyclotron.

Purdue University. K. Lark-Horovitz, Linear Electron Accelerator.

Purdue University. Ernst Bleuler, Research With Cyclotron.

Purdue University. R. M. Whaley, Research With Synchrotron.

Purdue University. Karl Lark-Horovitz and R. M. Whaley, Modification of the Purdue Cyclotron

Rice Institute. T. W. Bonner, Nuclear Physics Research.

Rochester, University of. R. E. Marshak, High Energy Nuclear Physics.

Stanford University. E. L. Ginzton, Limitations of Electron Linear Accelerators.

Syracuse University. Kurt Sitte, Nuclear Interactions of Cosmic Rays.

Texas, University of. E. L. Hudspeth, Fast Neutron Interactions.

Vanderbilt University. S. K. Haynes, Precision Beta-Ray Spectroscopy.

Vanderbilt University. Cyril Curtis, Transfer of ORNL Cockroft-Walton to Vanderbilt University and Related Research.

Vanderbilt University. M. D. Peterson, Reactor Studies.

Virginia, University of. Frank L. Hereford, Interaction of Polarized Photons With Matter and Other Research with a 1 Mev Van de Graaff.

Washington, State College of. S. T. Stephenson and S. E. Hazlet, Design Study and Development of Research Reactor.

Washington University. J. H. Manley, 60″ Cyclotron Program.

Wisconsin, University of. W. F. Fry and W. D. Walker, High Energy Interactions.

Wisconsin, University of. R. G. Herb, Nuclear Research With Electrostatic Generator.

Wisconsin, University of. R. G. Sachs, Theory of Light Nuclei.

Wisconsin, University of. C. K. McLane and J. R. Dillinger, Low Temperature Research.

Wisconsin, University of. D. A. Lind, Inelastic Scattering of Fast Neutrons.

Yale University. W. W. Watson, Isotope Separation of Radioactive Studies.

Yale University. H. L. Schultz, Electron Linac Neutron Velocity Selector.

Yale University. H. L. Kraybill and E. C. Fowler, High Energy Physics.

Yale University. Franklin Hutchinson, Stopping Power of Water.

Yale University. E. R. Beringer, Heavy Particle Linear Accelerator.

APPENDIX 6

Publications of the U. S. Atomic Energy Commission

Listed here are a number of special publications sponsored by the AEC. In addition, the AEC encourages project scientists to submit nonclassified articles for publication in the established scientific and technical journals. Hundreds of reports, not published elsewhere, may be obtained from the Office of Technical Services, Department of Commerce, Washington 25, D. C. Lists of titles and prices of these reports are available from the Office of Technical Services. Essentially complete collections of the AEC's nonclassified reports are available in a number of libraries (see pages 144–145). Guides to the published and report literature may be found in Nuclear Science Abstracts (see page 140).

Semiannual Reports to Congress

The AEC semiannual reports to Congress on the progress of the Commission's program are published and made available to the public by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. An alternate title, indicating the principal subject of the report, has been given to each of the later reports. Indexes to the semiannual reports are also available from the Superintendent of Documents.

First Semiannual Report, January 1947.

Second Semiannual Report, July 1947.

Third Semiannual Report, January 1948.

Fourth Semiannual Report, *Recent Scientific and Technical Developments in the Atomic Energy Program of the United States*, July 1948. 35 cents.

Fifth Semiannual Report, *Atomic Energy Development, 1947–1948*, January 1949. 45 cents.

Sixth Semiannual Report, *Atomic Energy and the Life Sciences*, July 1949. 45 cents.

Seventh Semiannual Report, *Atomic Energy and the Physical Sciences*, January 1950. 50 cents.

Eighth Semiannual Report, *Control of Radiation Hazards in the Atomic Energy Program*, July 1950. 50 cents.

Ninth Semiannual Report, *AEC Contract Policy and Operations*, January 1951. 40 cents.

Tenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1951*, July 1951. 35 cents.

Eleventh Semiannual Report, *Some Applications of Atomic Energy in Plant Science*, January 1952. 50 cents.

Twelfth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1952*, July 1952. 35 cents.

Thirteenth Semiannual Report, *Assuring Public Safety in Continental Weapons Tests*, January 1953. 50 cents.

Fourteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1953*, July 1953. 30 cents.

Fifteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, July–December 1953,* January 1954. 45 cents.

Sixteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1954,* July 1954. 45 cents.

Seventeenth Semiannual Report, *Major Activities in the Atomic Energy Programs, July–December 1954,* January 1955. 45 cents.

Cumulative Index to the First Fifteen Semiannual Reports to Congress, January 1947–December 1953. 35 cents.

Index to the Sixteenth Semiannual Report to Congress, January–June 1954. 10 cents.

Index to the Seventeenth Semiannual Report to Congress, July–December 1954. 15 cents.

General Publications

The following is a list of nontechnical publications pertaining to atomic energy or the administration of the AEC programs, and available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Selected Readings on Atomic Energy, July 1954, a bibliography of official publications, books, magazines, pamphlets and teaching units for educators, and indexes and bibliographies on atomic energy, 21 pages, 15 cents.

Isotopes—An 8-Year Summary of Distribution, March 1955, a detailed account of isotope utilization during the first 8 years of the Commission's distribution program. It is also a supplement of the 3-year and 5-year reports of similar title issued by the Commission in 1949 and 1951. This report is a useful reference to the uses of isotopes and a bibliography of published articles on isotope work, 364 pages, $2.00.

Prospecting for Uranium, revised October 1951, a nontechnical booklet prepared by the United States Geological Survey and AEC describing the uranium-bearing minerals, where to look for them, and instruments to use in prospecting and in laboratory testing and analysis of ores. It contains six color plates of principal minerals. Laws, regulations, and price schedules for uranium-bearing ores are included, 128 pages, 55 cents.

Prospecting with a Counter, revised July 1954, a summary of information on field counters, their operation, use, abuse, and their application to prospecting, mining and geologic problems, 68 pages, 30 cents.

Selling to AEC, revised 1955, provides certain basic information helpful to those who want to do business with AEC or its contractors. It indicates who does the buying, what is bought, where procurement offices are located, and other general information, 28 pages, 25 cents.

A Guide for Contracting of Construction and Related Engineering Services, revised January 1955, gives AEC policy on awarding contracts for construction and architect-engineering services, procedures followed when requests for bids are formally advertised and when contracts are negotiated. Operations offices and officials responsible for letting such contracts are listed, 16 pages, 15 cents.

TECHNICAL PUBLICATIONS

The items listed below, together with the National Nuclear Energy Series described in the next section, are publications of scientific and technical interest.

Books

Principles of Nuclear Reactor Engineering, Samuel Glasstone, D. Van Nostrand Co., N. Y., 1955, is written for the student and the practicing engineer. An overall review of the fundamental scientific principles upon which reactor engineering is based, 861 pages, $7.95.

The Elements of Nuclear Reactor Theory, Samuel Glasstone and Milton C. Edlund, D. Van Nostrand Co., N. Y., 1952, is written for scientists, engineers, and advanced students interested in the field of nuclear reactors. It explains the physical concepts and processes involved in a nuclear chain reaction and the methods for calculating critical conditions for chain reacting systems, 416 pages, $4.80.

Sourcebook on Atomic Energy, Samuel Glasstone, D. Van Nostrand Co., N. Y., 1950, presents a comprehensive, technical description of the theory, history, development, and uses of atomic energy. Chapters are included on the structure of the atom, radioactivity, isotopes, neutron research, acceleration of charged particles, and other phases of nuclear science, 546 pages, $3.75.

Energy in the Future, Palmer Cosslett Putnam, D. Van Nostrand Co., N. Y., 1953, presents a study of the problem of where we can find sources of low-cost energy in an abundance equal to the maximum plausible demands by the expanding and industrializing populations of the future, and what is the maximum plausible role that nuclear fuels may be called on to play in the next 50 years, or so, 556 pages, $12.75.

The Effects of Atomic Weapons, 1950, prepared for the Department of Defense and the AEC by a board of editors under the direction of the Los Alamos Scientific Laboratory, presents a technical summary of the results to be expected from the detonation of atomic weapons, with chapters describing an atomic explosion, the shock from air, underwater, and underground bursts; blast, radiation, and fire effects; methods of protecting personnel; and decontamination methods, 456 pages, $1.25.[1]

Introduction to the Theory of Neutron Diffusion, Volume I, 1954, is intended for purposes of research in physics and mathematics as well as teaching on the graduate level. This monograph, presenting work sponsored by the Los Alamos Scientific Laboratory, gives a detailed discussion of the general equations of one-velocity neutron diffusion theory and of their solution for the special case of a homogeneous infinite medium with isotropic scattering. Emphasis is placed on fairly complete tables and graphs, 174 pages, $1.25.[1]

Manuals, Handbooks and Reports

Nuclear Power Reactor Technology, May 1953, reports to the U. S. Atomic Energy Commission by four separate teams of industrial representatives appraising the prospect for possible nuclear power development. Studies were made to determine the engineering feasibility for designing, constructing and operating dual-purpose reactors to produce fissionable material and power, and to recommend industry's role in designing, building, and operating such reactors, 88 pages, 25 cents.[1]

Nuclear Power Reactors, Volume II, March 1955 (Submitted October 1953), reports to the U. S. Atomic Energy Commission of two teams of industrial representatives. Appraises the practicability of building a nuclear reactor for the generation of central-station power. The study group undertook to determine

[1] Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

whether any of the known reactor systems can be shown to be technically and economically feasible, and competitive for central-station power. Studies were made on the projected possibilities of different reactor systems, 30 pages, 15 cents.[1]

Handbook on Aerosols, 1950, contains chapters from the National Defense Research Committee Summary Technical Report, Division 10, declassified by the Army at the request of AEC, on the properties and behavior of aerosols, principles and instruments used in meteorology studies, and information useful in studies of the disposal of gaseous radioactive wastes, the dispersal of insecticides, the disposal of industrial gases, etc., 147 pages, 70 cents.

Handbook on Air Cleaning—Particulate Removal, Sheldon, K. Friedlander, Leslie Silverman, Philip Drinker and Melvin W. First, Harvard University, September 1952, a compilation of data resulting from the study of air cleaning equipment and procedures. Such studies applied principally to the removal of radioactive dust and contamination from exhaust gases, etc., 89 pages, 45 cents.[1]

Liquid Metals Handbook, second edition (revised) January 1954, R. N. Lyon et al., compiled by the Department of the Navy and AEC, summarizes current information on the physical and chemical properties of liquid metals, their present industrial uses, and their use and potentialities as heat-transfer media, 269 pages, $1.25.[1]

Handling Radioactive Wastes in the Atomic Energy Program, revised August 1951, reports on the sources and types of radioactive wastes in atomic energy operations, methods developed for their safe handling and disposal, and methods specified for the safe handling of radioisotopes by private users, 30 pages, 15 cents.[1]

Trilinear Chart of Nuclear Species, W. H. Sullivan, John Wiley & Sons, Inc., N. Y., 1949, shows physical data for all the nuclear species known as of June 1949, $2.50.

Neutron Cross Sections, May 15, 1952, revised to include supplementary editions to 1955, a compilation of data in tabular and graphic form prepared by the AEC Neutron Cross Section Advisory Group. Cross section values for nuclides, elements, and compounds are given for neutrons ranging in energy from 0.0001 electron volts to 100 Mev., 336 pages, $3.50.[1]

Reactor Handbook, provides a condensed and reliable source of nuclear reactor data.

Volume I.—*Physics*, two sections, Reactor Physics and Radiation Shielding, 804 pages, $4.25.[1]

Volume II.—*Engineering*, eight sections. Light- and Heavy-water-cooled Systems, Liquid-metal-cooled Systems, Gas-cooled Systems, Aqueous Fuel Systems, Liquid-Metal Fuel Systems, Fused Salt Systems, Handling and Control, and Reactor Designs, 1088 pages, $5.50.[1]

Volume III.—*General Properties of Materials*, 610 pages, $3.50.[1]

Isotopes in Medicine, comprises a collection of papers presented at the September 1953 training course of the Medical and Special Training Divisions of ORINS. This publication covers the entire field of clinical isotope use. Discussion sessions are summarized and edited.

High Voltage Problems, J. D. Trimmer and Harry Pearlman, Clinton Engineer Works—Tennessee Eastman Corporation, Oak Ridge, Tenn., 1951, presents an account of work done in connection with the high voltage systems used in the electromagnetic separation process. Sparking and insulator breakdowns are treated in detail, 226 pages, $1.85.[2]

[1] Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
[2] Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Vacuum Problems and Techniques, C. E. Normand, Frank A. Knox, G. W. Monk, Alan A. Samuel, W. R. Perret, Clinton Engineer Works—Tennessee Eastman Corporation, Oak Ridge, Tenn., 1950, describes and evaluates the original vacuum equipment required in the operation of the electromagnetic separation process. It presents significant improvements in efficiency resulting from changes in operating techniques, and brings together information widely spread throughout the literature, 265 pages, $1.75.[2]

Research Reactors, a volume describing the nuclear research reactors developed in the national atomic energy program. The document was prepared to present the details of the U. S. program to delegates attending the International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955, 452 pages, $2.00.[1]

Chemical Processing and Equipment, like *Research Reactors* described above, was prepared for the benefit of delegates to the International Conference. It describes the chemical and engineering aspects of processing materials associated with nuclear reactors. It includes descriptions of radio-chemical laboratories, remote control handling equipment, and the like. In press, 302 pages, $2.00.[1]

Periodicals and Catalogs

Nuclear Science Abstracts, issued twice a month by the AEC Technical Information Service, contains abstracts of all current AEC declassified and unclassified reports, of non-AEC reports related to atomic energy, and of articles appearing in both of foreign and domestic periodical literature, $6 per year. ($8 per year foreign.)[1]

Isotopes—Catalog and Price List, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 1952, lists and describes radioactive and stable isotopes available from ORNL and includes prices and instructions for ordering the isotopes, $1 per copy.

THE NATIONAL NUCLEAR ENERGY SERIES

These volumes were written by the scientists who performed the research and development on the atomic energy enterprise under the Manhattan Engineer District and later under the Atomic Energy Commission. The following volumes have been published for the AEC project by the McGraw-Hill Book Co., New York, N. Y.

Division I: The Electromagnetic Separation Process

Vacuum Equipment and Techniques, vol. 1, edited by A. Guthrie and R. K. Wakerling, 1949, describes the development and study of high vacuum equipment and high vacuum systems for the large-scale separation of isotopes by the electromagnetic process, 264 pages, $3.75.

The Characteristics of Electrical Discharges in Magnetic Fields, vol. 5, edited by A. Guthrie and R. K. Wakerling, 1949, cover most of the significant studies by The University of California Radiation Laboratory on electrical discharges with emphasis on studies of electrical discharges in vapors of uranium compounds, 376 pages, $5.

[1] Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
[2] Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Division II: Gaseous Diffusion Project

Engineering Developments in the Gaseous Diffusion Process, vol. 16, edited by M. Benedict and C. Williams, 1949, describes a number of mechanical, electrical, and chemical engineering developments related to the operation and handling of materials used in the gaseous diffusion process—principally special plant instruments, vacuum engineering, development of heat-transfer equipment, and absorption of uranium hexafluoride and fluorine, 129 pages, $2.

Division III: Special Separations Project

The Theory of Isotope Separation, vol. 1B, by Karl Cohen, 1951, presents the theory of cascades as generally applicable to the problems of isotope separation. Different types of centrifuges and other methods of separation are also discussed, 165 pages, $2.50.

Spectroscopic Properties of Uranium Compounds, vol. 2, edited by G. H. Dieke and A. B. F. Duncan, 1949, presents data compiled from a comprehensive study of the absorption and fluorescence spectra of uranium compounds and describes the experimental techniques used in the studies, 290 pages, $4.25.

Physical Properties and Analysis of Heavy Water, vol. 4A, by I. Kirschenbaum, 1951, describes the physical properties of heavy water, chemical equilibria or exchange reactions and methods of isotopic analysis, 438 pages, $6.

Bibliography of Research on Heavy Hydrogen Compounds, vol. 4C, compiled by A. H. Kimball, edited by H. C. Urey, and I. Kirschenbaum, 1949, contains about 2,000 references to published literature on research with heavy hydrogen. References are arranged by subject with an index of the hydrogen compounds and authors, 350 pages, $4.75.

Production of Heavy Water, vol. 4F, edited by G. M. Murphy, is being compiled from works of other authors. It will present laboratory pilot-plant studies for various separation processes investigated and engineering surveys of actual production plants with descriptions of their operations. (In process.)

Division IV: Plutonium Project

Optical Instrumentation, vol. 8, edited by G. S. Monk and W. H. McCorkle, 1954, contains useful and practical techniques and methods of optical instrumentations in nuclear research. It is a summary of the optics work carried out as part of the plutonium project, 262 pages, $3.75.

Radiochemical Studies: The Fission Products, vol. 9, edited by C. D. Coryell and N. Sugarman, 1951, presents 336 original research papers on the techniques and results of radiochemical studies of uranium and plutonium fission products, 2,086 pages (in 3 parts), $27.75.

The Actinide Elements, vol. 14A, edited by G. T. Seaborg and J. J. Katz, 1954, is a companion volume to vol. 14B, Division IV, NNES, *The Transuranium Elements*, published in 1949, and summarizes available information on the elements in the actinide series. Also included is an Index for the Transuranium Elements, 870 pages, $11.75.

The Transuranium Elements, Research Papers, vol. 14B, edited by G. T. Seaborg, J. J. Katz, and W. M. Manning, 1949, includes 163 research papers on neptunium, plutonium, americium, curium, and several of the heavy elements re-

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The Chemistry and
19B, edited by L
dynamic properti
$4.50.
Industrial Medicine
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R. E. Zirkle, 19
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small laboratory
Biological Effects of
offers a collection
surface of the ma
Histopathology of Ir
by W. Bloom, 19
logical effects of t
Toxicology of Urani
studies made on
physiological effec
323 pages, $4.75.

Division V: Los

Electronics: Experim
Sands, 1948, desc
developed at Los
417 pages, $5.50.
Ionization Chambers
B. Rossi and H.
chambers and cou
ments by scientist
Miscellaneous Physic
edited by A. C. G
techniques used at
laboratory and ap

Division VI: Uni

Pharmacology and To
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3 years research on
nism of uranium p
Parts III and IV, p
of long-term studi
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carbohydrate meta
2 parts), $18.

lated to them, and historical summaries of transuranium element research, 1,733 pages (in 2 parts), $23.75.

The Chemistry and Metallurgy of Miscellaneous Materials; Thermodynamics, vol. 19B, edited by L. L. Quill, 1949, contains 10 research papers on the thermodynamic properties of the elements and several of their compounds, 329 pages, $4.50.

Industrial Medicine on the Plutonium Project, vol. 20, edited by R. S. Stone, 1951, describes the medical program established for the care and protection of workers on the plutonium project, 511 pages, $7.

Biological Effects of External X- and Gamma Radiation, part I, vol. 22B, edited by R. E. Zirkle, 1954, deals with radiological research and investigations performed at the National Cancer Institute of the effects of continuous X- and gamma irradiation on life span, weight, blood picture, and breeding behavior of small laboratory mammals, 530 pages, $7.25.

Biological Effects of External Beta Radiation, vol. 22E, edited by R. E. Zirkle, offers a collection of original reports on the effects of beta rays applied to the surface of the mammalian body, 242 pages, $3.50.

Histopathology of Irradiation from External and Internal Sources, vol. 22I, edited by W. Bloom, 1948, is an advanced treatise on the histopathological and cytological effects of total-body irradiation, 808 pages, $10.75.

Toxicology of Uranium, vol. 23, edited by A. Tannenbaum, 1950, describes the studies made on the distribution, accumulation, excretion, and chemical and physiological effects of uranium and uranium compounds in the animal body. 323 pages, $4.75.

Division V: Los Alamos Project

Electronics: Experimental Techniques, vol. 1, edited by W. C. Elmore and M. L. Sands, 1948, describes a number of complete circuits and circuit elements developed at Los Alamos for making nuclear and other physical measurements, 417 pages, $5.50.

Ionization Chambers and Counters: Experimental Techniques, vol. 2, edited by B. Rossi and H. Staub, 1949, describes the physical principles of ionization chambers and counters, and includes previously unpublished project developments by scientists at the Los Alamos Laboratory, 243 pages, $3.25.

Miscellaneous Physical and Chemical Techniques of the Los Alamos Project, vol. 3, edited by A. C. Graves and D. K. Froman, describes a variety of laboratory techniques used at Los Alamos in early studies. Drawings and diagrams of the laboratory and apparatus are given, 323 pages, $4.25.

Division VI: University of Rochester Project

Pharmacology and Toxicology of Uranium Compounds, vol. 1, edited by C. Voegtlin and H. C. Hodge. Parts I and II, published in 1949, summarize the results of 3 years research on the toxicity of various uranium compounds and the mechanism of uranium poisoning, 1,084 pages (in 2 parts), $14.25.

Parts III and IV, published in 1953, continues from Parts I and II, with results of long-term studies, mainly on the chronic inhalation toxicity of uranium compounds. Major problems considered are bone deposition of uranium and carbohydrate metabolism. Bibliography, index. 1,381 additional pages (in 2 parts), $18.

Biological Effects of External Radiation, vol. 2, edited by Henry A. Blair, 1954, reports the studies made during the war period at the University of Rochester on the biological effects of X-radiation along with a collaborative study of the chronic effects of neutron irradiation made with the Biochemical Foundation, Newark, Del. Included in the volume are the effects of single doses of whole-body X-radiation, chronic X-radiation, and fractionated doses of fast neutrons, 508 pages, in press, about $6.50.

Biological Studies with Polonium, Radium, and Plutonium, vol. 3, edited by R. M. Fink, 1949, describes the studies made of the biological effects of these alpha-emitting elements in the animal body, air monitoring precautions, and equipment used in atomic energy laboratories where work with these elements is carried on, 411 pages, $5.50.

Division VII: Materials Procurement Project

Preparation, Properties, and Technology of Fluorine and Organic Fluoro Compounds, vol. 1, edited by C. Slesser and S. R. Schram, describes development in the large-scale manufacture of fluorine, and purifying and handling fluorine. It describes the preparation and the chemical and physical properties of various fluorocarbon compounds, 868 pages, $11.50.

The Metallurgy of Zirconium, Vol. 4, edited by B. Lustman and F. Kerze, 1955, comprises contributions by participants in the Navy-AEC program on the development of zirconium for reactor applications, 780 pages.

Division VIII: Manhattan Project Chemistry

Analytical Chemistry of the Manhattan Project, vol. 1, edited by C. J. Rodden, 1950, describes methods of analyzing the many different materials used in the atomic energy project—with emphasis on analytical methods for the determination of uranium and thorium, 748 pages, $10.00.

Chemistry of Uranium. Part I. The Element, Its Binary and Related Compounds, vol. 5, by J. J. Katz and E. Rabinowitch, 1951, is a detailed discussion of the physical and chemical properties of uranium, its occurrence in nature and extraction from ores, and preparation and physical properties of its binary compounds, 609 pages, $8.25.

DEPOSITORY LIBRARIES

In order to make the nonclassified results of AEC research and development available to the public, the following libraries serve as depositories for essentially all of the Commission's nonclassified reports. A number of other university and public libraries also receive from the AEC copies of the reports that are sold by the Office of Technical Services.

CALIFORNIA
- Berkeley, University of California General Library
- Los Angeles, University of California Library

COLORADO
- Denver, Denver Public Library

CONNECTICUT
- New Haven, Yale University Library

DISTRICT OF COLUMBIA
- Washington, Library of Congress

FLORIDA
- Gainesville, University of Florida Library

GEORGIA
- Atlanta, Georgia Institute of Technology Library

ILLINOIS
- Chicago, John Crerar Library
- Chicago, University of Chicago Library
- Urbana, University of Illinois Library

INDIANA
- Lafayette, Purdue University Library

IOWA
- Ames, Iowa State College Library

KENTUCKY
- Lexington, University of Kentucky Library

LOUISIANA
- Baton Rouge, Louisiana State University Library

MASSACHUSETTS
- Cambridge, Harvard University Library
- Cambridge, Massachusetts Institute of Technology Library

MICHIGAN
- Ann Arbor, University of Michigan Library
- Detroit, Detroit Public Library

MINNESOTA
- Minneapolis, University of Minnesota Library

MISSOURI
- Kansas City, Linda Hall Library
- St. Louis, Washington University Library

NEW JERSEY
- Princeton, Princeton University Library

NEW MEXICO
- Albuquerque, University of New Mexico Library

NEW YORK
- Buffalo, Lockwood Memorial Library
- Ithaca, Cornell University Library
- New York, Columbia University Library
- New York, New York Public Library
- Troy, Rensselaer Polytechnic Institute Library

NORTH CAROLINA
- Durham, Duke University Library
- Raleigh, North Carolina State College Library

OHIO
- Cincinnati, University of Cincinnati Library
- Cleveland, Cleveland Public Library
- Columbus, Ohio State University Library

OKLAHOMA
- Stillwater, Oklahoma Agricultural and Mechanical College Library

OREGON
- Corvallis, Oregon State College Library

PENNSYLVANIA
- Philadelphia, University of Pennsylvania Library
- Pittsburgh, Carnegie Library of Pittsburgh

TENNESSEE
- Knoxville, University of Tennessee Library
- Nashville, Joint University Libraries

TEXAS
- Austin, University of Texas Library

UTAH
- Salt Lake City, University of Utah Library

WASHINGTON
- Seattle, University of Washington Library

WISCONSIN
- Madison, University of Wisconsin Library

INDUSTRIAL DEPOSITORIES

To provide industry with specialized industrial information materials and to facilitate inspection of such materials, the AEC has set up special depositories at the Atomic Industrial Forum, Inc., in New York City, at the John Crerar Library in Chicago, in the Stanford Research Institute, Stanford, Calif., and at the Georgia Institute of Technology Library, Atlanta, Ga. Industrial depository collections are comprised of a complete collection of unclassified "basic science" reports which have been found to contain technological developments of special value to American industry not directly connected with the U. S. Atomic Energy program. Abstracts of these reports were published in a series of special bibliographies entitled, "Selected AEC Reports of Interest to Industry," which is also available at the depositories. A modest program for making unclassified engineering drawings available for inspection at industrial depositories has also been initiated.

APPENDIX 7

A Report by the United States Atomic Energy Commission on Effects of High-Yield Nuclear Explosions [1]

1. Considerable information on the effects of the explosions of atomic weapons has been made public by the Government since the first nuclear detonations in 1945. The Handbook, "The Effects of Atomic Weapons", published in 1950, is being revised and brought up to date to include the effects of thermonuclear weapons, as a result of the most recent tests at the Pacific Proving Ground. References to the effects of thermonuclear explosions have been made in several official statements, beginning with Chairman Strauss' description of the phenomenon of "fall-out" at a White House news conference on March 31, 1954. The following statement is designed to condense and correlate information, some of which already has been made public and other portions of which have been of a classified nature until now.

2. The effects of nuclear tests are evaluated for civil defense planning as well as for military and technological purposes. So long as nuclear weapons are in possession of any unfriendly power, the Commission believes the American public will wish to be as fully informed as possible as to the nature and extent of the dangers of nuclear attack and of the protective measures that can be taken by individuals and communities to avoid or minimize those dangers if we should be attacked.

3. Test conditions, which must necessarily form the principal basis of evaluating the effects of nuclear explosions, may differ markedly from those which might be expected if nuclear weapons were used against our population in wartime. It would be difficult to predict the size or kind of bomb an enemy might use against us in event of war, the exact means of its delivery, the height at which it would be exploded, or the number of bombs which might reach a given target. Nevertheless, the facts to follow are the fundamental ones at this time.

Four Effects of Detonations

4. A nuclear detonation produces four major characteristics—blast, heat, immediate nuclear radiation, and residual radioactivity. Of these, the first three are essentially instantaneous, while the fourth has a more protracted effect. The phenomena of blast, heat, and nuclear radiation from the detonation of a thermonuclear bomb are of the same nature as those of earlier and smaller atomic bombs. The nature of the phenomena is, in general terms, standardized whether the bomb be a 20,000-ton (TNT equivalent) atomic weapon or a thermonuclear bomb of many times that power. The intensity and area of the blast, heat, and nuclear radiation increase in relation to the greater energy yield of the explosion. Information on these effects has been extensively publicized; therefore, the remainder of this report deals principally with effects other than heat and blast.

5. Residual radioactivity, although in no sense exclusive to high yield thermonuclear detonations, does become a matter of major concern when a large thermonuclear device of the type used in the 1954 tests in the Pacific is exploded. The fall-out of radioactivity from such an explosion, may, under certain condi-

[1] Reprinted from *The Effects of High-Yield Nuclear Explosions—Statement by Lewis L. Strauss, Chairman, and Report by the United States Atomic Energy Commission*, February 1955. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., price 10 cents.

tions, settle over wide areas. Therefore, the extent and severity of this radioactive fall-out has been a subject of continuing study since the first full-scale thermonuclear tests at the Pacific Proving Ground on November 1, 1952. The results of these studies and of our evaluation of data obtained from the latest tests in the Pacific in March, 1954, are described in subsequent parts of this report.

6. It should be noted that if we had not conducted the full-scale thermonuclear tests mentioned above, we would have been in ignorance of the extent of the effects of radioactive fall-out and, therefore, we would have been much more vulnerable to the dangers from fall-out in the event an enemy should resort to radiological warfare against us.

Blast and Heat Effects

7. The effects of blast and heat from a nuclear explosion are relatively localized. One A-bomb of the earliest type equivalent to 20,000 tons of TNT (20 kilotons) would produce blast sufficient to destroy or damage severely residences within a radius of more than one mile from the point of burst. Within a radius of about a mile and a half, residences would be so damaged as to be unusable without repairs. A principal hazard to human beings would come from flying and falling debris and from fires due to such causes as broken gas and electric lines or overturned stoves. The area in which injuries to human beings would be caused by blast, therefore, would be about the same as the area of damage to structures.

8. The United States, as announced previously, has developed fission bombs many times as powerful as the first A-bombs, and hydrogen weapons in the ranges of millions of tons (megatons) of TNT equivalent. For these larger weapons, the blast effects can be calculated approximately by means of a scaling law, namely, the distance at which a given blast intensity is produced varies as the cube roots of the yields of the explosions.

9. Similarly, the heat and burn effects of nuclear explosions can be estimated from accumulated data. These effects, of course, are influenced by prevailing atmospheric conditions. The time element also is a prime factor. Very large weapons deliver heat over an appreciably greater period of time than smaller weapons. A given quantity of heat from a high-yield weapon, delivered over a longer period of time, will produce somewhat *less* severe burns than the same quantity of heat from a nominal detonation.

Protection Against Blast and Heat

10. The hazard from both burn and blast effects in the *outer* affected areas would be reduced greatly by shelter. Clothing or almost any kind of shelter would reduce the danger of direct burns, although there might be some danger of clothing and structures becoming ignited. Also, shelter would materially reduce the hazard of blast injury by affording protection against flying or falling debris. The Federal Civil Defense Administration has made extensive studies of shelters and has issued plans for several simple and inexpensive types which can be utilized by householders. As is generally known, the shelter afforded by ordinary city buildings would not suffice within the central area surrounding the point of burst of a large nuclear weapon. For this reason, the Federal Civil Defense Administration recommends evacuation of the central areas of target zones on early warning of approaching attack.

Radiation Effects

11. The immediate nuclear radiation, i. e., the neutrons and gamma rays released instantaneously with the explosion of a large weapon on or near the ground, does not present a serious hazard beyond the area where heat and blast are of great concern.

Fall-Out Radiation

12. However, particles with residual radioactivity produced by a detonation (as opposed to the immediate nuclear radiation) may fall out over an area much larger than that affected by blast and heat, and over a longer period of time. All nuclear detonations produce radioactive materials, but the nature and extent of the radioactive fall-out depends on the conditions under which the bomb is fired. The main radioactivity of a bomb's fall-out decreases very rapidly with time—for the most part, within the first hours after the detonation.

Fall-Out From In-the-Air Detonations

13. In an in-the-air explosion where the fireball does not touch the earth's surface, the radioactivity produced in the bomb condenses only on solid particles from the bomb casing itself and the dust which happens to be in the air. In the absence of material drawn up from the surface, these substances will condense with the vapors from the bomb and air dust to form only the smallest particles. These minute substances may settle to the surface over a very wide area—probably spreading around the world—over a period of days, or even months. But they descend extremely slowly with the result that, by the time they have reached the earth's surface, the major part of their radioactivity has been dissipated harmlessly in the atmosphere, and the residual contamination is widely dispersed.

Fall-Out From Surface Detonations

14. If, however, the weapon is detonated on the surface or close enough so that the fireball touches the surface, then large amounts of material will be drawn up into the bomb cloud. Many of the particles thus formed are heavy enough to descend rapidly while still intensely radioactive. The result is a comparatively localized area of extreme radioactive contamination and a much larger area of some hazard. Instead of wafting down slowly over a vast area, the larger and heavier particles fall rapidly before there has been an opportunity for them to decay harmlessly in the atmosphere and before the winds have had an opportunity to scatter them.

15. The area of hazard from radioactive fall-out from a surface or near-surface explosion of a thermonuclear weapon is much larger than the areas seriously affected by heat and blast. The large radioactive cloud of a thermonuclear explosion rises with great rapidity to the highest levels of the atmosphere and spreads over hundreds of square miles in the first hours. During this time the winds toss the extremely radioactive particles about and the pattern of the radioactive fall-out is determined by the size of the particles and by the direction and velocities of the winds, including those up to 80,000 feet and above. The nature of the surface of the earth on which the bomb is fired also must be taken into considera-

tion. Because of these variables, it is impossible to apply a single fall-out pattern to all thermonuclear detonations, even test explosions conducted under selected conditions. However, with adequate knowledge of atmospheric conditions, including wind directions and velocities up to high levels and meteorological reports, the fall-out region for any detonation usually can be predicted with considerable accuracy. In general terms, the region of severe fall-out contamination from the detonation of a thermonuclear weapon fired on or near the surface can be described as an elongated, cigar-shaped area extending downwind from the point of burst.

Fall-Out Pattern of 1954 Test in the Pacific

16. The very large thermonuclear device fired at the Bikini Atoll on March 1, 1954, was exploded on a coral island. Coral consists of calcium carbonate, thus the detonation's radioactivity was spread by particles consisting largely of unslaked lime which, during the hours of descent, was slaked by moisture in the atmosphere. These particles ranged between 1/1000th and 1/50th of an inch in diameter and were, on the average, somewhat adhesive. The prevailing winds were westerly so the bomb cloud moved generally to the east and deposited the radioactive particles in varying amounts over an elliptical or cigar-shaped area. About 160 (statute) miles downwind from the point of burst the early fall-out was observed in the form of fine particles which looked like snow. Fall-out began there about eight hours after the detonation and continued for several hours.

17. The roentgen is the commonly accepted unit of measurement of radiation dosage. A dose of about 25 roentgens of radioactivity received by a person over a brief space of time will produce temporary changes in the blood. A dose of some 100 roentgens received in a short interval may produce nausea and other symptoms of radiation sickness. About 450 roentgens delivered over a day or so might be fatal to approximately half of the persons so exposed. However, because of the body's repair processes, a total radiation dose which would be serious if incurred in a few minutes would produce much less effect if spread over a period of years. These statements may be helpful in understanding the data which follow.

18. The test explosion, at ground surface, contaminated a cigar-shaped area extending approximately *220 statute miles down-wind and varying in width up to 40 miles.* In addition, there was a contaminated area up-wind and cross-wind extending possibly 20 miles from the point of detonation. Data were collected from 25 points on 5 atolls located from 10 to 330 miles down-wind (generally east) from Bikini Atoll. Due to an unexpected shift in the direction of the prevailing winds in the higher altitudes, the fall-out missed the observation rafts that had been placed farther north previous to the test firing. The estimated contour of the pattern of fall-out is, therefore, based only in part on data obtained from actual measurements and partly on extrapolation, i. e., calculations based on known data, including factual information obtained during previous tests of smaller devices.

19. Data from this test permit *estimates* of casualties which would have been suffered within this contaminated area if it had been populated. These estimates assume: (1) that the people in the area would ignore even the most elementary precautions; (2) that they would not take shelter but would remain out-of-doors completely exposed for about 36 hours; and (3) that in consequence they would receive the maximum exposure. Therefore, it will be recognized that the estimates which follow are what might be termed *extreme estimates* since *they assume the worst possible* conditions.

20. On the basis of our data from this and other tests, it is estimated that, following the test explosion on March 1, 1954 there was sufficient radioactivity in a

down-wind belt about 140 miles in length and of varying width up to 20 miles to have seriously threatened the lives of nearly all persons in the area who *did not take protective measures.* During the actual tests, of course, there were no people in this zone. Inside Bikini Atoll at a point 10 miles downwind from the explosion it is estimated that the radiation dosage was about 5000 roentgens for the first 36-hour period after the fall-out. The highest radiation measurement outside of Bikini Atoll indicated a dosage of 2300 roentgens for the same period. This was in the northwestern part of the Rongelap Atoll, about 100 miles from the point of detonation. Additional measurements in Rongelap Atoll indicated dosages, for the first 36-hour period, of 2000 roentgens at 110 miles, 1000 roentgens at 125 miles, and, farther south, only 150 roentgens at 115 miles from Bikini.

21. Some distance farther from the point of detonation, at about 160 miles down-wind and along the axis of the ellipse, the amount of radioactivity would have seriously threatened the lives of about one-half of the persons in the area who *failed to take protective measures.* It is estimated that the radiation dosage at that point was about 500 roentgens for the first 36-hour period.

22. Near the outer edge of the cigar-shaped area, or approximately 190 miles down-wind, it is estimated that the level of radioactivity would have been sufficient to have seriously threatened the lives of 5 to 10 percent of any persons who might have remained exposed out-of-doors for the first 36 hours. In this area the radiation dosage is estimated at about 300 roentgens for the first 36-hour period.

23. Thus, about 7,000 square miles of territory down-wind from the point of burst was so contaminated that survival *might* have depended upon prompt evacuation of the area or upon taking shelter and other protective measures.

24. At a distance of 220 miles or more down-wind, it is unlikely that any deaths would have occurred from radioactivity even if persons there had remained exposed up to 48 hours and had taken no safety measures.

25. The estimates cited above do not apply uniformly throughout the contaminated area inasmuch as the intensity of radioactivity within a region of heavy fall-out will vary from point to point due to such factors as air currents, rain, snow, and other atmospheric conditions. Because of this and because most persons, if given sufficient warning, probably would evacuate the area or take shelter and other precautionary measures, the actual percentage of deaths could reasonably be presumed to be considerably *smaller* than these extreme estimates.

Protection Against Fall-out

26. In an area of heavy fall-out the greatest radiological hazard is that of exposure to *external* radiation. Simple precautionary measures can greatly reduce the hazard to life. Exposure can be reduced by taking shelter and by utilizing simple decontamination measures until such times as persons can leave the area. Test data indicate that the radiation level, i. e., the rate of exposure, indoors on the first floor of an ordinary frame house in a fall-out area would be about one-half the level out-of-doors. Even greater protection would be afforded by a brick or stone house. Taking shelter in the basement of an average residence would reduce the radiation level to about one-tenth that experienced out-of-doors. Shelter in an old-fashioned cyclone cellar, with a covering of earth three feet thick, would reduce the radiation level to about 1/5000, or down to a level completely safe, in even the most heavily contaminated area. Designs of shelters of simple, yet effective construction, have been prepared by the Civil Defense Administration and are available to the public.

27. Radioactive material deposited during fall-out may or may not be visible but would be revealed by radiation detection instruments such as Geiger counters. Any falling dust or ash that can be seen down-wind within a few hours after a nuclear explosion should be regarded as radioactive until measured by a radiation detection instrument and found to be harmless.

28. Care should be taken to avoid the use of solid foods or liquids that may contain fall-out particles.

29. If fall-out particles come into contact with the skin, hair, or clothing, prompt decontamination precautions such as have been outlined by the Federal Civil Defense Administration will greatly reduce the danger. These include such simple measures as *thorough bathing of exposed parts of the body and a change of clothing.*

30. If persons in a heavy fall-out area heeded warning or notification of an attack and evacuated the area or availed themselves of adequate protective measures, the percentage of fatalities would be greatly reduced even in the zone of heaviest fall-out.

Fall-out from Nevada Tests

31. Only relatively small nuclear test explosions are conducted at the Nevada Test Site, in contrast to the tests of high-yield thermonuclear devices at the Pacific Proving Ground. In Nevada, as well as in the Pacific, all tests are planned for times when forecast weather conditions minimize the possibility of fall-out hazard. Methods of forecasting weather patterns in these areas are improving steadily. High air bursts at the Nevada Test Site have produced no significant fall-out; heavy fall-out from near-surface explosions has extended only a few miles from the point of burst. The hazard has been successfully confined to the controlled area of the Test Site. The highest actual dose of radiation at an off-site community has been estimated to be *less than one-third of the greatest amount of radiation which atomic energy workers are permitted to receive each year under the Atomic Energy Commission's conservative safety standards.*

Internal Radiation Effects

32. Several basic facts should be kept in mind in evaluating the hazard from fall-out radiation. First, radiation is not a new phenomenon created by the explosions of fission and thermonuclear weapons. Since the beginning of life, living things have been exposed constantly to radiation from natural sources. Cosmic rays from space constantly pass through our bodies. We are exposed to "background" radiation from radium and radon in the soil, water, and air. Our bodies have always contained naturally radioactive potassium and carbon.

33. As pointed out earlier, detonations of all atomic weapons produce radioactivity, a portion of which is carried to high altitudes and over great distances in the form of fine particles. The percentage of this radioactivity which travels beyond the relatively near area of the explosion depends largely on the conditions under which the bomb is fired, the percentage being higher for in-the-air bursts where the fireball does not touch the earth's surface. The most widespread radioactivity is produced only by the longer-lived fission products, since the radioactivity of the shorter-lived products decays and disappears before the particles come down to earth in a matter of days, weeks, months, and even years. The longer-lived radioactive products may be distributed over the entire earth. However, as the particles are carried farther and farther to remote areas, the possibility of significant amounts of fall-out decreases.

Radiostrontium Fall-Out

34. One of the most biologically important radioactive substances found in fall-out is strontium 90. It has a long lifetime—nearly 30 years on the average. Radiostrontium has a chemical similarity to calcium and, therefore, when taken into the body it has a tendency to collect in the bones. Radiostrontium can enter the body in two ways—by inhaling or by swallowing. Normally, the amount inhaled would be small compared with the amount one might swallow. Fall-out material deposited directly on edible parts of plants may be eaten along with the plants, but washing the plants before they are eaten would remove most of this radioactive material. However, rainfall carrying the radiostrontium down to earth may deposit it in the soil where it can be taken up, in part, by plants and incorporated into plant tissues, later to be eaten by humans or by grazing animals which, in turn, provide food for humans.

35. Since the start of nuclear tests, careful measurements have been made of the distribution of radiostrontium over the earth's surface, in the soils, in plants and animal tissues, in the oceans, in rain, in the atmosphere and in all forms in which it might be expected to occur. The results of this study are reassuring. The amount of radiostrontium now present in the soil as a result of all nuclear explosions to date would have to be increased many thousand times before any effect on humans would be noticeable.

Radioiodine Fall-Out

36. Among the shorter-lived fission products involved in the study of internal radiation, the most biologically important is radioiodine 131 with an average life of only 11.5 days. Even though this product may be widely spread after a nuclear explosion, the possibility of serious hazard is limited by its relatively short life. Like the non-radioactive form of the element, it concentrates in the thyroid gland and, in excessive quantity, conceivably could damage the thyroid cells.

37. Scientists of the Atomic Energy Commission have estimated that the average exposure of people in the United States from radioiodine in the fall-out from the entire series of tests in the spring of 1954 was only a few percent of the annual dose that can be received year after year and still have no noticeable effects.

38. These two isotopes—radiostrontium and radioiodine—constitute the principal internal hazards from the radioactivities produced by the detonations of atomic weapons, both fission and thermonuclear. The Atomic Energy Commission has been engaged for three years in a broad study of the radioactive forms of these isotopes and conducts year-round monitoring of these radioactivities in many locations. Any accumulation of these materials can be detected with great sensitivity so that ample warning of potential hazard could be given long before any actual danger occurred from test detonations. The amounts of radiostrontium and radioiodine which have fallen outside the areas near the test sites as a result of all atomic tests up to now are insignificant compared to concentrations that would be considered hazardous to health.

Genetic Effects of Radiation

39. One other effect of radiation must be considered in evaluating the long-range possibilities of hazard from nuclear detonations. This is the possible genetic effect upon the germ cells which transmit inherited characteristics from

one generation to another. At our present stage of genetic knowledge, there is a rather wide range of admissible opinion on this subject.

40. In general, the total amount of radiation received by residents of the United States from all nuclear detonations to date, *including the Russian and British tests* and all of our own tests in the United States and the Pacific, has been about one-tenth of one roentgen. This is only about 1/100th of the average radiation exposure inevitably received from natural causes by a person during his or her reproductive lifetime. It is about the same as the exposure received from one chest X-ray.

41. The medical and biological advisers of the Atomic Energy Commission believe that the small amount of additional exposure of the general population of the United States from our nuclear weapons testing program will not seriously affect the genetic constitution of human beings. Nevertheless, we are continuing our thorough study of the entire question and will continue to report our findings to the American people.

Summary

42. The Atomic Energy Commission hopes that the information on nuclear weapons effects contained in the foregoing report will never be reflected in human experience as the result of war. However, until the possibility of an atomic attack is eliminated by a workable international plan for general disarmament, the study and evaluation of weapons effects and civil defense protection measures must be a necessary duty of our government.

43. Inevitably, a certain element of risk is involved in the testing of nuclear weapons, just as there is some risk in manufacturing conventional explosives or in transporting inflammable substances such as oil or gasoline on our streets and highways. The degree of risk must be balanced against the great importance of the test programs to the security of the nation and of the free world. However, the degree of hazard can be evaluated with considerable accuracy and test conditions can be controlled to hold it to a minimum. None of the extensive data collected from all tests shows that residual radioactivity is being concentrated in dangerous amounts anywhere in the world outside the testing areas.

44. In the event of war involving the use of atomic weapons, the fall-out from large nuclear bombs exploded on or near the surface of the earth would create serious hazards to civilian populations in large areas outside the target zone. However, as mentioned in the foregoing report, there are many simple and highly effective precautionary measures which can be taken by individuals to reduce casualties to a minimum outside the immediate area of complete or near-complete destruction by blast and heat. Many of these protective measures, such as shelter and decontamination procedures have been detailed by the Federal Civil Defense Administration

APPENDIX 8

United States Firms and Organizations to be Represented in Exhibits at Geneva Conference

Some 100 United States industrial and commercial firms, along with 50 academic, professional and private educational and research organizations, will be represented in exhibits at the International "Atoms-for-Peace" conference at Geneva, Aug. 8–20. Several commercial concerns will have displays in more than one of the exhibits.

Eighty-three firms and organizations have contributed to the official United States technical exhibit at the Palais des Nations, site of the United Nations sponsored conference. Another 19 have furnished parts of a United States Information Agency "teaching" exhibit at Geneva's exposition hall. At least 22 industrial and commercial firms will show independently or under private auspices at an atomic "trade fair," also to be located at the downtown exposition hall.

Fourteen commercial publishers and approximately 30 scientific, engineering, and other professional organizations will be represented in a display of more than 100 United States periodicals in the nuclear energy field.

A 10-kilowatt operating research reactor of the "pool" type will highlight the United States official exhibit. In addition, there will be 10 scale models of power and research reactors operating or planned in the United States.

Other displays in the technical exhibit will show medical, biological, agricultural, and industrial applications of atomic energy, including uses of radioisotopes; a simulated reactor control panel; examples of reactor fuel elements and reactor components; a demonstration of chemical separation techniques for atomic waste products; and radiation-measuring and other instruments. The displays are being assembled by Design and Production, Inc., Alexandria, Va.

The exhibit will be supplemented by a technical reference library, containing several thousand AEC unclassified reports, a collection of technical books being contributed by American publishers, and the display of American scientific and technical journals.

Limitations on space at the Palais building at the conference site resulted in a United Nations requirement that all exhibits there be sponsored by participating governments, be noncommercial in character, and be designed primarily for the delegates and technical experts attending the conference.

However, UN authorities are encouraging national and commercial exhibits at the more spacious Exposition Palace in mid-city. Some exhibits provided by the Atomic Energy Commission will be placed there. So will the USIA popular "Atoms-for-Peace" exhibit, covering 15,000 square feet of floor space, which was recently shown in Germany and Austria.

The atomic energy trade show at the downtown exposition hall is being sponsored by the Organizing Committee, First International Exhibition of the Peaceful Uses of Atomic Energy (1 Place du Lac, Geneva, Switzerland).

Organizations contributing to the technical exhibit are:

American Machine and Foundry Co., New York, N. Y.

Anton Electronic Laboratory, Brooklyn, N. Y.

Argonne Memorial Cancer Research Hospital, University of Chicago, Chicago, Ill.

Argonne National Laboratory, Chicago, Ill.

Atomic Instrument Co., Cambridge, Mass.
Atomic Research Corp. Colorado Springs, Colo.
The Babcock and Wilcox Co., New York, N. Y.
A. O. Beckman, Inc., S., Pasadena, Calif.
Beckman Instruments, Inc., Fullerton, Calif.
Bendix Aviation Corp., Cincinnati, Ohio.
Brookhaven National Laboratory, Upton, N. Y.
The Brush Beryllium Co., Cleveland, Ohio
Cambridge Instrument Co., Inc., New York, N. Y.
Chapman Valve Manufacturing Co., Indian Orchard, Mass.
Commonwealth Edison Co., Chicago, Ill.
Consolidated Edison Co., New York, N. Y.
Consolidated Engineering Corp., Pasadena, Calif.
Consumers Public Power District of Nebraska, Columbus, Nebr.
Crane Co., Chicago, Ill.
The Detectron Corp., North Hollywood, Calif.
Detroit Edison Company, Detroit, Mich.
Allen B. DuMont Laboratories, Inc., Clifton, N. J.
El-tronics Inc., Philadelphia, Pa.
Engineers Syndicate Ltd., Hollywood, Calif.
General Dynamics Corp., Groton, Conn.
General Electric Co., Schenectady, N. Y.
The Harshaw Chemical Co., Cleveland, Ohio
Iowa State College, Ames Laboratory, Ames, Iowa
Johns Hopkins University, Baltimore, Md.

Precision Rad
Radiation Co
Radiation Ind
Radiation Ins
Radiation Res
Radio Corpora
Radioactive P
Raytheon Ma
R–C Scientific
Sherwin Instru
Sloan Ketterin
Sylvania Electr
Technical Asso
Tracerlab, Inc.
Union Carbide
United States A
United States E
United States
United States R
United States V
University of C
University of M
Victoreen Instr
Westinghouse E
N. Wood Count

Precision Radiation Instruments, Los Angeles, Calif.
Radiation Counter Laboratories, Skokie, Ill.
Radiation Industries Co., Brookhaven, N. Y.
Radiation Instrument Development Laboratory, Chicago, Ill.
Radiation Research Corp., West Palm Beach, Fla.
Radio Corporation of America, Princeton, N. J.
Radioactive Products, Inc., Detroit, Mich.
Raytheon Manufacturing Co., Waltham, Mass.
R–C Scientific Instruments Co., Inc., Playa Del Rey, Calif.
Sherwin Instrument Co., New York, N. Y.
Sloan Kettering Institute for Cancer Research, New York, N. Y.
Sylvania Electric Products, Inc., Bayside, Long Island, N. Y.
Technical Associates, Burbank, Calif.
Tracerlab, Inc., Boston, Mass.
Union Carbide and Carbon Corp., New York, N. Y.
United States Atomic Energy Commission, Washington, D. C.
United States Bureau of Mines
United States Geological Survey
United States Radium Corp., New York, N. Y.
United States Weather Bureau
University of California, Radiation Laboratory, Berkeley, Calif.
University of Michigan, Ann Arbor, Mich.
Victoreen Instrument Corp., Cleveland, Ohio
Westinghouse Electric Corp., Pittsburgh, Pa.
N. Wood Counter Laboratory, Chicago, Ill.

Organizations contributing to the USIA exhibit:

Alco Products, Inc., Schenectady, N. Y.
American Machine and Foundry Co., New York City
Anton Electronic Laboratories, Inc., Brooklyn, N. Y.
S. Blickman, Inc., Weehawken, N. J.
Boston Museum of Science, Boston, Mass.
Central Research Laboratories, Redwing, Minn.
Corning Glass Works, Corning, N. Y.
El-Tronics, Inc., Philadelphia, Pa.
General Electric Co., Schenectady, N. Y.
P. M. Lennard Co., Inc., Harrison, N. J.
Lovelace Foundation for Medical Education and Research, Albuquerque, N. Mex.
Newport News (Va.) Shipbuilding and Drydock Co.
Nuclear Instrument and Chemical Corp., Chicago, Ill.
Penberthy Instrument Co., Seattle, Wash.
Radiation Counter Laboratories, Skokie, Ill.
Sylvania Electric Products, Inc., New York City
Tracerlab, Inc., Boston, Mass.
Westinghouse Air Brake Co., Pittsburgh, Pa.
Westinghouse Electric Corp., Pittsburgh, Pa.

Firms that have so far taken space in the "trade fair" exhibit:

American Machine and Foundry Co., New York City
Anton Electronic Laboratories, Brooklyn, N. Y.
Atomic Development Mutual Fund, Inc., Washington, D. C.
AVCO Manufacturing Corp. (Lycoming Division) Stratford, Conn.
Babcock & Wilcox Co., New York City
Bendix Aviation Corp., Detroit, Mich.
Daystrom, Inc., Archbald, Pa.

Foster Wheeler Corp., New York City
General Dynamics Corp., New York City
General Electric Co., Schenectady, N. Y.
High Voltage Engineering Corp., Cambridge, Mass.
Walter Kidde Nuclear Laboratory, Garden City, Long Island, N. Y.
Glenn L. Martin Co., Baltimore, Md.
Micro-Metallic Corp., Glen Cove, Long Island, N. Y.
National Research Corp., Cambridge, Mass.
Nuclear Development Associates, Inc., White Plains, N. Y.
Nuclear Instrument Corp., Venice, Calif.
Tracerlab, Boston, Mass.
Union Carbide and Carbon Corp., New York City
Vitro Corporation of America, New York City
Westinghouse Electric Corp., Pittsburgh, Pa.
Weston Electrical Instrument Corp., Newark, N. J.

Periodicals which will be included in the display of technical literature:

Publication	Contributor
Cancer	American Cancer Society.
American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine.	The American Roentgen Ray Society and The American Radium Society.
A. M. A. Archives of Ophthalmology	American Medical Association.
Endocrinology	The Endocrine Society.
The Journal of Clinical Endocrinology and Metabolism.	
The Journal of General Physiology *The Journal of Experimental Medicine*	The Rockefeller Institute for Medical Research.
Journal of Cellular and Comparative Physiology.	Wistar Institute of Anatomy and Biology.
Federation Proceedings	Federation of American Societies for Experimental Biology.
Journal of Applied Physiology; American Journal of Physiology.	The American Physiological Society
The Journal of Laboratory and Clinical Medicine.	Central Society for Clinical Research
Radiation Research	Radiation Research Society.
Journal of Bacteriology	Society of American Bacteriologists.
Genetics	Genetics, Inc.
Archives of Biochemistry and Biophysics	Academic Press, Inc.
Journal of the American Ceramic Society with Ceramic Abstracts.	American Ceramic Society, Inc.
Soil Science Society of America Proceedings.	Soil Science Society of America.
Agronomy Journal	American Society of Agronomy.
The American Mineralogist	Mineralogical Society of America.
Bulletin of the Society of Economic Geologists.	Society of Economic Geologists and the Economic Geology Publishing Company.

PUBLICATION	CONTRIBUTOR
Journal of the American Chemical Society *The Journal of Physical Chemistry* *Industrial and Engineering Chemistry* *Analytical Chemistry* *Chemical and Engineering News* *Agricultural and Food Chemistry*	American Chemical Society.
The Physical Review *American Journal of Physics* *The Journal of the Acoustical Society of America.* *Journal of Applied Physics* *Reviews of Modern Physics* *The Review of Scientific Instruments* *Journal of the Optical Society of America* *The Journal of Chemical Physics* *Physics Today*	American Institute of Physics.
Nucleonics (plus several reprints)	McGraw-Hill Publishing Company, Inc.
Metal Progress *Zirconium and Zirconium Alloys*	American Society for Metals.
Corrosion	National Association of Corrosion Engineers.
Mechanical Engineering *A Glossary of Terms in Nuclear Science and Technology.*	American Society of Mechanical Engineers.
Chemical Engineering Progress (plus several Chemical Engineering Progress Symposium Series).	American Institute of Chemical Engineers.
A Forum Survey, and three Forum Reports.	Atomic Industrial Forum.
Modern Medicine	Modern Medicine Publications, Inc.
Qualified Contractor	National Electrical Contractors Association.
Electrical Manufacturing	The Gage Publishing Co.
Dun's Review and Modern Industry	Dun and Bradstreet Publications Corp.
Seventeen publications	National Academy of Sciences and the National Research Council.
Twelve publications	U. S. Geological Survey.
Twenty-five publications	National Bureau of Standards.
Journal of the National Cancer Institute	Department of Health, Education and Welfare.

Publication	Contributor
Proceedings of the Society for Experimental Biology and Medicine.	Society for Experimental Biology and Medicine.

Other publishing houses represented:
- Breskin Publications, Inc.
- Case-Sheppard-Mann Publishing Corp.
- Diesel Publications, Inc.
- F. W. Dodge Corp. Publisher
- Fairchild Publications, Inc.
- Gulf Publishing Co.
- Keeney Publishing Co.
- Miller Freeman Publications
- George F. Taubeneck

Films to be shown at the conference include:
- "Developing Homogeneous Reactors," produced by Oak Ridge National Laboratory, 16 mm., black and white, about 25 minutes.
- "Construction of Argonne Research Reactor," produced by Argonne National Laboratory, 16 mm., black and white, about 18 minutes.
- "Safety Experiments With A Boiling Reactor," produced by Argonne National Laboratory, 16 mm., black and white, about 18 minutes.
- "Nuclear Reactors for Research," produced by North American Aviation, Inc., 16 mm., color, about 18 minutes.
- "Sodium-Graphite Reactor Progress Report No. 1," produced by North American Aviation, Inc., 16 mm., color, about 18 minutes.
- "Radioisotopes: Their Application to Humans for Tracer Studies and Therapeutic Use," produced by the Medical Film Guild of New York, 16 mm., color, about 30 minutes.
- "The Radioisotope in General Science," U. S. Government Film, 16 mm., black and white, about 40 minutes.

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