UNITED STATES ATOMIC ENERGY COMMISSION

Twenty-fourth Semiannual Report

OF THE

ATOMIC ENERGY COMMISSION

July 1958

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

LETTER OF SUBMITTAL

WASHINGTON, D. C.,
31 July 1958.

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

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION,
JOHN F. FLOBERG.
JOHN S. GRAHAM.
WILLARD F. LIBBY.
HAROLD S. VANCE.
LEWIS L. STRAUSS, *Chairman.*[a]

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

[a] Mr. Strauss' term included the period covered by this report, expiring June 30, 1958. Mr. John A. McCone was appointed Chairman on July 14.

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SUMMARY

Negotiation of arrangements for a joint United States-European development of United States types of power reactors to provide six Western European Nations with an installed capacity of 1 million kilowatts by 1963 was concluded during the January–June period covered by this report. President Eisenhower sent to the Congress on June 23 a proposed international agreement with the European Atomic Energy Community (Euratom) with a message requesting that it be considered on an urgent basis.

Other major highlights of the Atomic Energy Commission's programs to expand the *peaceful uses of atomic energy* included:

- The technology of nuclear power production was further advanced with successful operation of experimental reactors and of the full-scale prototype Shippingport Atomic Power Station which the President dedicated on May 26.
- Heavy construction was under way on four commercial prototype power reactors.
- Under the joint industry-Government cooperative program, a fifth contract was signed, four other contracts were pending which looked toward construction of additional power stations, and design studies continued in another.
- Progress was being made in research directed toward producing power from controlled release of fusion energy. Part Two of this report gives a special summary of the program.
- In the new radioisotope program, contracts were signed with industrial and academic organizations to develop methods and techniques for encouraging wider use of isotopes and of radiation sources.
- To encourage commercial development, the Commission withdrew from its provision of irradiation services when they are available from commercial sources and, among other steps, acted to broaden its purchases from commercial suppliers, and provided more detailed information on Government charges for chemical processing of used reactor fuel elements.
- The Commission undertook a survey for proposed use of nuclear explosive devices to blast out an artificial harbor on a havenless Alaskan coast above the Arctic Circle, and was considering other peaceful applications of nuclear explosives.

Weapons work was pressed forward with research, development, and tests. A series of tests was under way at the Eniwetok Proving

Ground, at one of which United Nations scientific observers would participate in measurements of fallout potential from a weapon. Missile warheads were being developed, synchronized with Department of Defense missile work.

A fourth nuclear powered submarine was launched.

International Activities

The last 6 months have brought to fruition many aspects of the President's Atoms for Peace program, inaugurated less than 5 years ago by his address December 8, 1953, before the United Nations General Assembly.

The proposed power reactor agreement with Euratom—comprising Belgium, France, the Federal Republic of Germany, Italy, Luxembourg, and The Netherlands—can help supply the energy needs of 160 million people in these countries which possess the major industrial resources of the free world in Continental Europe. United States and European industries will participate in the program.

The Organization for European Economic Cooperation (OEEC) has established the European Nuclear Energy Agency and is receiving United States assistance.

The International Atomic Energy Agency is organized and has begun operations.

Organized support was further advanced for Inter-American research and training projects.

Two additional comprehensive power reactor agreements were ratified during the reporting period—with Italy and Spain—and negotiations on a power agreement with Japan were completed; in all, there were 41 research and power agreements in effect with 39 nations (2 with Switzerland) and the city of West Berlin.

Twenty-six research reactors and 1 power reactor have been built, or are being built, and 2 more research reactors are planned for construction in foreign countries by United States manufacturers. A picture report on many of these reactors is included in the section on International Activities.

The Commission approved 9 more grants (making 16 in all) for research reactor projects in cooperating countries, and inaugurated a program of grants for laboratory equipment to assist training and research.

Preparing for United States participation in the United Nations second International Conference on the Peaceful Uses of Atomic Energy (Geneva, Switzerland; September 1–13), the Commission submitted more than 700 technical papers on behalf of the United States scientific and industrial community, and organized a technical exhibit that included 2 working reactors among some 72 displays.

Nine devices used in research on controlled thermonuclear reactions were to be demonstrated. A trade fair, being presented simultaneously, will include 2 operating research reactors among other exhibits by United States industry.

Reactor Development

Civilian power reactor work in the United States reached a new level of maturity during the last 6 months.

Operation of seven reactor experiments and routine full-power operation of the Shippingport Atomic Power Station produced satisfactory results.

The Experimental Boiling Water Reactor operated successfully at more than three times its design power.

The keel was laid for the Nuclear Ship *Savannah*.

Independently, and in cooperative programs with the Government, industry moved ahead with development, design, and construction of full-scale prototype power reactors. In the Power Demonstration Reactor Program, a fifth contract was signed, contracts for construction of two other reactors were under negotiation, and proposals leading to two more reactors were placed before the Congress for authorization. Design work continued on still another project. One project was canceled as uneconomic.

Controlled Thermonuclear Research

As a result of the exploratory efforts of Commission laboratories, and other scientific groups under Commission contracts, the Commission believes that the prospects for producing power from controlled nuclear fusion are sufficient to warrant continuation of a strong research and development program. A number of extremely difficult problems must be solved, but the efforts of the last 7 years, and particularly during the last 5 years, already have resulted in the creation of a whole new technology.

The research effort is necessarily shaped by the physical conditions that must be achieved in order to realize net power from fusion. These physical conditions apparently have been defined, and promising methods of achieving them have been formulated. Significant progress has been made along several lines of effort; each is contributing knowledge to the art of controlling fusionable material for the achievement of a self-sustaining thermonuclear reaction.

There is steady progress. No unsurmountable obstacles yet have been uncovered. It is equally clear, however, that this is necessarily a long-range program. The primary goal is to design and operate

a device able to generate and contain a material hot enough and dense enough for a self-sustaining reaction which would then serve as a basis for designing power-producing devices. Even this achievement still appears to be an arduous task.

The special report offered in Part Two reviews the goals, the problems, and the lines of attack upon the task of achieving release of controlled fusion power.

Industrial Development

With establishment of an Office of Industrial Development, focusing responsibility in this area, new actions and programs as cited earlier were inaugurated to broaden commercial use of atomic energy technology and to increase private participation in Federal industrial operations.

Additional firms requested and were granted licenses for recovery of uranium scrap, and to market thorium materials.

The prospects for large-scale commercial use of lithium 7 were explored.

The Commission held a public hearing and was studying proposals in connection with a review of its patent policies and practices.

Solutions were sought for the problem of public liability abroad in connection with foreign sales by United States manufacturers and suppliers.

In the radioisotope field, prices were cut to an average of less than 10 percent of former levels on five key materials soon to be mass-produced.

The radioisotope program contracts, signed during this report period, call for development work on new and broader industrial applications of radioisotopes, and high level radiation sources, and for studies on isotope technology, and on radioisotope production and pricing.

There were nearly 5,700 licenses in effect for use of radioisotopes (including medical and research uses). More than 1,200 were issued during this reporting period.

Peaceful Uses of Nuclear Explosives

Besides the Alaskan Harbor project, other possible peaceful applications of nuclear explosive devices being studied by the Commission in *Project Plowshare* include: production of power; production of radioisotopes; recovery of oil from tarsands, shales, and depleted wells; mining; flood control; and scientific research. Industrial participation will be sought where feasible.

Results of the underground Rainier Shot, detonated last fall in Nevada, are contributing to these studies and a report on the results of the shot has been issued.

Licensing, Regulation, Inspection

Private research activity in atomic energy continued to expand, as indicated by the permits issued for construction of 23 research and training reactors, and 60 new licenses for use of special nuclear material in research. Applications were received for licenses to construct and operate 14 research reactors, 10 of them of the same design to be built by one company.

Seven applications were received for licenses to export 7 research reactors.

The Commission issued no new major regulation during the reporting period. Conferences were held and amendments prepared dealing with requirements pursuant to legislation providing for Federal indemnification of nuclear facility operations in incidents involving public liability above certain levels. Altered agreements were offered to prime major contractors of the Commission to bring the contractors and their suppliers under provisions of the indemnity statute.

The Commission kept State governments informed of its licensing and inspection activities and, on request, consulted with State legislative committees and regulatory bodies on proposed laws and regulations.

With highest priority given to examination of facilities and practices of Commission licensees whose operations could involve the greatest radiological hazards, the Commission's inspectors found that approximately 95 percent of those inspected had no potential or actual radiation hazards. Of the 5 percent where potential or actual hazards were found, many involved relatively minor deviations from prescribed standards. Licensees undertook promptly to correct cited conditions and followup inspections were carried out.

Education and Training

Surveys of technical manpower requirements in Government, industry, and colleges and universities showed an estimated 38,000 scientists and engineers employed in atomic energy fields as of late 1957. There were shortages in many lines, but none was believed to be sufficiently serious at present to delay important work. Colleges and universities had an estimated 5,400 scientists and engineers devoting at least part time to teaching and research in atomic energy during

the 1957–58 academic year, and will have 5,700 for the 1960–61 year.

First reports from universities receiving equipment grants from the Commission indicated they had expanded facilities and courses to provide for the equivalent 100 additional students enrolled in four nuclear technology courses.

In training courses for foreign nationals, 420 students have attended the Commission school of nuclear science and engineering. Additional courses in special subjects are planned to accommodate about 100 students. Radioisotope courses will be expanded. They have been attended by 268 foreign nationals.

Information Services

The Commission's traveling exhibits on peaceful uses of atomic energy were visited by an estimated 2.4 million persons during the last 6 months; in all 9.3 million have viewed the exhibits since they were first placed on view in November 1956.

Continuing its broad program for providing the general public, industry and the scientific community with technical information, the Commission: conducted 5 special seminars; published proceedings of 7 scientific and technical meetings; inaugurated 3 series of quarterly technical progress reviews on aspects of reactor design; expanded its translation of Russian-language monographs; and conducted workshops in this country and abroad to assist users of atomic energy technical literature. More than 58,000 classified and unclassified reports were sold during the reporting period.

With growing stability of the industry, the rate of demand for permits to have access to classified documents leveled off somewhat during this reporting period. An average of 17 permits was granted each month, compared to twice that number during the same months of 1957. As of June 30, there were 1,415 permits in force—a slight increase over 6 months ago.

Military Programs

Research and development on *weapons* continued to emphasize a variety of technical, strategic, and defensive devices with reduced radioactive fallout. In carrying out the national policy decision to take every advantage of progress in development of fission and thermonuclear weapons, the United States arsenal continued to be expanded rapidly in total numbers as well as in increasing variety. New areas of research have been opened as a result of the series of test operations

in recent years, and the military usefulness of fissionable materials has been increased. Weapons models have been improved and new types of weapons—smaller, more efficient, more rugged, and more immediately ready—have been developed to meet the requirements of the Armed Forces, and directed toward the continual effort of the United States to maintain the most efficient military strength for purposes of preserving the peace.

In the test series being fired currently at Eniwetok Proving Ground, objectives included development and exploratory tests which will lead to development of improved weapons of various types and to tactical and defensive weapons with greatly reduced fallout. One test shot was to be witnessed by United Nations scientific observers as well as United States and foreign news representatives. The series also will include proof tests of weapons for production, weapons effects tests, and, at Johnston Island, tests of short-range defensive weapons. Ten tests had been made public by June 30.

Using results of 1957 Nevada tests, the Commission continued to improve the safety design of weapons to assure against nuclear explosions in event of a mishap during storage and handling. Especially trained and equipped teams were established at Department of Defense and Commission installations to take necessary action in event of any accident involving a nuclear weapon.

The *military reactor program* continued to gain momentum during this reporting period with operation and design of reactors for various purposes: production of heat and power at remote bases; propulsion of manned and unmanned aircraft; and propulsion of naval vessels. Three nuclear-powered submarines were operating, a fourth had been launched, and 18 others were building. The operating submarines had traveled a total of 182,000 miles, 133,000 miles while submerged; one made a cruise across the Atlantic while submerged.

Production of Materials

Production rates of special nuclear materials exceeded the goals established for the January–June period. The new feed materials production center at Weldon Springs, Mo., was essentially complete, and both this center and the Portsmouth, Ohio, plant were in operation as the reporting period closed.

With domestic and foreign sources providing more than 15,000 tons of uranium oxide concentrates during the reporting period, receipts of raw materials were at an all-time high. Eighteen domestic ore mills were in operation, 5 more were to be built under existing procurement contracts, and an additional limited expansion of mill capacity was planned to provide markets for several producing areas.

The Commission will authorize private commercial sales of ores

and concentrates to domestic and foreign users under special arrangements.

Foreign purchase commitments, all made in 1955 or earlier, were limited by releasing for sale to the United Kingdom some Canadian ores under contract for delivery to the United States, and by establishing a ceiling on combined purchases from South Africa.

Research in Physical and Life Sciences

Research in both the physical and life science fields continued during the last 6 months to contribute basic knowledge to help advance knowledge and technology in varied applications of atomic energy.

The Brookhaven Medical Research Reactor, the first to be built exclusively for treatment of patients and for *life sciences research*, was 85 percent complete as of June 30. A survey of natural background radiation was made in many parts of the United States and may assist work in human genetics. Among other studies, Commission laboratories investigated the inheritance of radiation resistance in mice, investigated protection against long-range as well as short-term radiation effects, improved techniques for using atomic energy materials in treatment of cancer, and continued efforts to improve health and safety protection against radiation. First results are available on stratospheric surveys of radioactivity from weapons tests, and the current status of findings on fallout is reported.

In the *physical sciences*, in addition to supporting research in high energy and nuclear physics, chemistry, and metallurgy and materials, the Commission contributed to design and construction of large experimental machines required in this work. The Oak Ridge Research Reactor went critical; construction and design went steadily ahead on the 25 to 30 billion electron volt Alternating Gradient Synchrotron at Brookhaven—a machine with a half-mile circular vacuum chamber. Design work progressed on other particle accelerators. The two new heavy-ion accelerators were in operation. Both the Cosmotron and Bevatron accelerators were shut down for repairs.

Teams for Nuclear Incidents

State and local officials are being notified by the Commission of the locations of trained Commission or Department of Defense teams available for help to local authorities in dealing with any incidents that occur which may involve radiological hazards, in

operation of nuclear facilities, or, for example, in the unlikely event that packaged nuclear materials in transit might be scattered or released in a traffic accident.

Other Activities

Costs incurred for *new plant and equipment* totaled $145 million for the last 6 months, and for the year were 10 percent below the previous 12 months.

The Commission occupied its *new headquarters* at Germantown, Md., 27 miles northwest of Washington, D. C. Construction continued on an additional wing to accommodate staff still in Washington and, as of June 30, the new wing was 75 percent complete.

At both Oak Ridge and Richland *communities*, additional lots have been offered for residence construction and the percentage sold has increased; an additional 2,600 housing units have been offered at Richland and 54 percent of the total sold. Sales have begun, and streets and utility contracts have been let, for development of Barranca Mesa at Los Alamos for residential purposes.

The *safety record* of activities of the Commission and its contractors continued to improve for the calendar year 1957, and the rate for lost time injuries per million man-hours worked for the total program was 25 percent below 1956. The Commission received a Presidential Award for its employee safety program of 1957. Twelve radiation incidents were reported during 1957 in Commission installations. Commission licensees reported 28 cases. Many involved no exposures of personnel, and few resulted in exposures above permissible levels. In June 1958, the accidental occurrence of a chain reaction in salvage work at Oak Ridge involved 8 workers.

Principal Officers

The term of Lewis L. Strauss as Commissioner and Chairman of the Atomic Energy Commission expired June 30.

John A. McCone, of California, was sworn in as Commissioner and appointed Chairman by the President on July 14. His term will run to June 30, 1963. Mr. McCone's nomination was sent to the Senate June 6 and he was confirmed July 9.

There were three resignations of principal officers: K. E. Fields as General Manager, effective June 30; R. W. Cook, as Deputy General Manager, effective on adjournment of Congress; W. Kenneth Davis, as Director, Division of Reactor Development, effective July 31.

Maj. Gen. Alvin R. Luedecke, United States Air Force, was selected as General Manager, the appointment to be effective after conclusion

of the 1958 weapons tests. He is Commander of Joint Task Force Seven conducting these tests. Paul F. Foster, Assistant General Manager for International Activities, will serve as General Manager, effective July 1 until General Luedecke assumes the position.

Loren K. Olson was appointed General Counsel, effective March 19.

John H. Williams was appointed Director, Division of Research, effective April 17.

Part One

Major Activities in the Atomic Energy Programs

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Raw Materials

Uranium production continued to increase during the January–June reporting period of 1958. Present and proposed domestic commitments, plus existing foreign commitments for delivery to the Atomic Energy Commission, appear adequate for military and power requirements as projected on an annual basis for the next few years.

New proposals for additional domestic milling capacity, announced April 2, will result in moderate expansion of domestic purchases of U_3O_8 concentrate.

Foreign purchase commitments have been reduced through the release for United Kingdom purchase of Canadian uranium which was under contract for delivery to the United States. By agreement a ceiling was placed on future deliveries from South Africa.

On May 8, the Commission announced that it would license private, domestic and foreign sales of uranium ores and concentrates.

Domestic Activities

Domestic production of uranium ore and concentrates continued to increase during the reporting period. The United States maintained its position as the free world's leading uranium producer with a predicted annual rate of production in excess of 15,000 tons of U_3O_8 by the end of this calendar year. Receipts in the first half of 1958 totaled 5,850 tons of U_3O_8.

Ore Production

Uranium ore production in the United States totaled about 2.5 million dry tons during the first 6 months of 1958 as compared to approximately 2 million dry tons for the last 6 months of 1957.

Bonus payments. Bonus payments paid to mine operators on initial production from properties from inception of the program in March 1951 totaled $12.5 million through June 30. This bonus, currently in effect until March 31, 1960, provides for payments in addition to the guaranteed price and may total as much as $35,000 for the first 10,000 pounds of U_3O_8 contained in ore produced from a new property and accepted by specified mills or buying stations. This bonus has encouraged prospecting and exploration and has assisted miners during early development of new ore bodies.

In April, Lisbon Uranium Co. of Salt Lake City produced and shipped 22.25 tons of high-grade uranium ore (22.92 percent U_3O_8) of the uraninite-pitchblende type from its property in the Big Indian Wash Area, Utah. For this, the company received the $10,000 bonus offered under circular 2 for delivery to the Commission of the first 20 short tons of uranium-bearing ores or mechanical concentrates assaying 20 percent or more of U_3O_8 from any single mining location in the United States. This offer expired at midnight April 11, 1958, 10 years from the date of its promulgation.

Although the bonus had been offered for a full decade, Lisbon Uranium was the first and only producer to make delivery and claim it. The ore was delivered in a single truckload on April 10, just one day prior to expiration of this bonus offer. The company received a total of $61,016.72, including the ore price and $10,000 bonus.

Mill Capacity and Contracts

During the first half of 1958 the following new uranium ore mills went into operation:

Location	*Company*	*Capacity in tons of ore per day*
Rifle, Colo	Union Carbide Nuclear Co	1,000
Grants, N. Mex	Homestake New Mexico Partners	750
Fremont Co., Wyo	Lucky Mc Uranium Corp	750
Gunnison, Colo	Gunnison Mining Co	200

Including these 4 new mills, 18 mills were in operation as of June 30, as shown in table I.

Two mills discontinued operation: the old Rifle, Colo., plant of Union Carbide Nuclear Co. and the Naturita, Colo., plant of Vanadium Corp. of America. The capacity of the latter company's Durango, Colo., plant was increased to compensate for the closing of the Naturita mill.

Except for a Government-owned, contractor-operated plant at Monticello, Utah, all the mills are both privately owned and operated. The Commission buys uranium concentrates produced in the mills under the terms of contracts with each mill operator.

Uranium from phosphates. Three plants continued uranium production as a byproduct in the treatment of Florida phosphate rock for the manufacture of fertilizers and other chemicals.

TABLE I.—URANIUM MILLS IN UNITED STATES

MILLS IN OPERATION

Location	Company	Tons of ore per day	Estimated cost of mill
1. Rifle, Colo	Union Carbide Nuclear Co.	1,000	$8,500,000
2. Uravan, Colo	Union Carbide Nuclear Co.	850	5,000,000
3. Grand Junction, Colo	Climax Uranium Co	350	3,088,000
4. Durango, Colo	Vanadium Corp. of America	750	813,000
5. Gunnison, Colo	Gunnison Mining Co	200	2,025,000
6. Maybell, Colo	Trace Elements Co	300	2,208,000
7. Monticello, Utah	Government-owned	600	5,000,000
8. Salt Lake City, Utah	Vitro Uranium Co	550	5,500,000
9. Moab, Utah	Uranium Reduction Co	1,500	8,250,000
10. Mexican Hat, Utah	Texas-Zinc Minerals Co	775	7,000,000
11. Shiprock, N. Mex	Kerr-McGee Oil Industries	500	3,161,000
12. Grants, N. Mex	Anaconda Co	3,000	19,358,000
13. Edgemont, S. Dak	Mines Development, Inc	400	1,900,000
14. Tuba City, Ariz	Rare Metals Corp. of America.	350	3,600,000
15. Split Rock, Wyo	Western Nuclear Corp	400	3,600,000
16. Ford, Wash	Dawn Mining Co	400	3,100,000
17. Grants, N. Mex	Homestake-New Mexico Partners.	750	5,325,000
18. Fremont County, Wyo	Lucky Mc Uranium Corp	750	6,900,000
Subtotal		13,425	94,328,000

MILLS UNDER CONSTRUCTION OR CONTRACTED FOR

1. Grants, N. Mex	Homestake Sapin Partners	1,500	9,000,000
2. Grants, N. Mex	Phillips Petroleum Co	1,725	9,500,000
3. Grants, N. Mex	Kermac Nuclear Fuels Corp.	3,300	16,000,000
4. Lakeview, Oreg	Lakeview Mining Co	210	2,600,000
5. Riverton, Wyo	Fremont Minerals, Inc	500	3,500,000
Subtotal		7,235	40,600,000
Grand total		20,660	134,928,000

Added capacity. On April 2, the Commission announced it would expand to a limited extent its domestic procurement of uranium concentrates, revising to that degree a policy, announced October 28, 1957, of negotiating no new contracts for delivery prior to 1962 of concentrates which involved additional milling capacity.[1] This action resulted from a study made by the Commission of the marketing problems arising from its limitations on further expansion of domestic concentrate procurement. The study, issued as a report dated March 31,[2] indicated a need for an additional ore market in several producing areas.

[1] See p. 147, Twenty-third Semiannual Report to Congress (July–December 1957).

[2] "A Report on the Domestic Mining and Milling Problems Resulting From Limitation on Additional Milling Capacity," by the Division of Raw Materials, AEC, is printed in app. 11.

The Commission anticipates that, under its revised policy, it will enter into additional procurement contracts for concentrates increasing total domestic milling capacity in selected areas by a total of about 3,000 tons of dry ore a day, and increasing annual concentrate production by about 2,500 tons of U_3O_8.

The October 1957 policy of limiting new contracts for concentrates was adopted in order to maintain the Commission's annual purchases in reasonable balance with currently estimated requirements. Foreign purchases, all under commitments made in 1955 or earlier, already are limited. The prospect of continued rapid domestic expansion under an unlimited procurement program posed a threat of overproduction that, in the end, might have had a serious adverse effect on the uranium industry, and resulted in excessive purchases by the Commission.

Private sales of uranium. On May 8, the Commission announced in general terms the conditions under which private sales of uranium ores and concentrates by domestic producers will be authorized. Licenses may be granted on application under the existing regulation.

Sales under this program may be made either to domestic or to foreign buyers for peaceful uses of the materials, but as is the case with all uranium products, sales will be subject to licensing by the Commission.

United States companies wishing to sell or to purchase uranium materials in the United States, and those wishing to sell uranium ores or concentrates to firms in friendly foreign countries, must first obtain a license by application to the Commission through the normal channels. Since the United States purchaser must be licensed, his possession of the license warrants that the Commission has authorized the use of the material.

For materials to be sold abroad, the Commission will require satisfactory information concerning proposed use, and will grant export licenses for amounts of materials required by other countries which have comprehensive agreements of cooperation, or other suitable agreements, with the United States which provide suitable assurances against diversion to military use. Export licenses may be granted for small shipments up to a fixed amount even in the absence of such international agreements. The limits are cumulative totals of 100 kilograms of contained normal uranium to a single consignee in a foreign country, providing that under these circumstances, all consignees in any one country may not receive more than 1,000 kilograms.

Uranium for private sales may come from existing mills having a production capacity in excess of that required to meet deliveries under Commission contracts, or from expanded facilities constructed to

supply the commercial market. Also, the Commission will consider releasing uranium which it has already under contract for its own use, subject to such modification of contract as may be deemed appropriate.

This further step toward a normal commercial market for uranium producers will make it possible for United States industry to compete with other suppliers for the growing foreign and domestic market for nuclear fuel.

Exploration

Estimated reserves of uranium ores as of June 30 were approximately 78.5 million tons at 0.28 percent U_3O_8; in addition, Government and private stockpiles totaled approximately 2 million tons at the same grade. There has been no significant change in these figures since December 31, 1957, development of new reserves having about kept pace with depletion by mining.

Prospecting and development declined during the current period as a result of the Commission's limitations on uranium procurement, but are expected to increase as the market for uranium for commercial power expands.

During the first 6 months of calendar year 1958, more than 95 percent of the ore produced was delivered to private buying stations. The Commission continued to operate only two ore-buying stations, one at Monticello, Utah, and one at Grants, N. Mex.

Process Development

Process development work was continued during the reporting period at the Raw Materials Development Laboratory, Winchester, Mass.; at the Grand Junction Pilot Plant, Colo.; at the Bureau of Mines Experimental Plant at Salt Lake City; and at the Mackay School of Mines, Reno, Nev.

Most of this work is scheduled to be brought to an orderly conclusion during the next 6 months except that the Bureau of Mines will continue certain unit operations as required to test the amenability of ores to processing.

Thorium Program

The Commission's requirements for thorium have been limited to relatively small quantities for research and development. To meet these requirements and also to provide a modest stockpile against future needs, thorium salts have been purchased under contracts negotiated with processors of monazite sands. The procurement

program will be fulfilled through deliveries under contracts entered into several years ago; no new contracts for thorium have been signed since 1955, and no further contracts are contemplated at present. Thorium deliveries in the year ended June 30 totaled the equivalent of 400 tons of thorium metal.

Foreign Activities

Deliveries of foreign uranium concentrates to the United States during the first half of 1958 totaled 9,450 tons of U_3O_8, with more than half coming from Commission contracts in Canada, and the rest from contracts of the Combined Development Agency, representing the United Kingdom and the United States. No new foreign commitments have been made since 1955, and deliveries under these commitments have been reduced or limited by subsequent negotiations. In the case of the Commission's Canadian commitment, deliveries have been reduced by releasing material under firm United States contract and enabling Canada to make direct sales to the United Kingdom. A recent agreement with South Africa placed a ceiling on deliveries beginning July 1.

Canada

Deliveries from Canada to the United States during the first 6 months of 1958 totaled an estimated 5,730 tons of U_3O_8, as compared with deliveries during the previous 6 months of 3,850 tons of U_3O_8.

Construction of six additional plants was completed and by May 19 mining and milling facilities in the program were in operation. It is expected that deliveries to the United States during the last 6 months of 1958 will total about 6,800 tons of U_3O_8.

The Port Radium Mine of Eldorado Mining and Refining Co., Ltd., near the Arctic Circle, continued to produce at a rate of about 400 tons U_3O_8 a year but existing reserves are expected to be mined out by early 1960.

In the Lake Athabaska region of Saskatchewan, Eldorado's 2,000-ton Beaverlodge mill and the 1,650-ton plant of Gunnar Mines, Ltd., continued to operate at capacity. However, rated output of the 700-ton custom mill operated by Lorado Mines, Ltd., was not reached because of a temporary shortage of process acid production.

Five additional plants were completed in the Blind River district of Ontario, north of Lake Huron. Rated capacity of the 11 mills in this area is 34,000 tons of ore a day. Ore grades and mill recoveries are generally fulfilling estimates. Capital costs for mines and mills generally have exceeded original estimates.

In the Bancroft area of eastern Ontario, Bicroft Uranium Mines operated its mill at a rate of about 1,200 tons of ore a day while Faraday Uranium Mines increased the capacity of its 750-ton plant to 1,200 tons a day in order to treat ores from Greyhawk Uranium Mines. The 1,000-ton plant of Canadian Dyno Mines commenced operation in May.

Eldorado's Port Hope Refinery produced metal-grade uranium oxide (UO_3) at an average rate of about 330 tons a month from mill concentrates supplied by the Port Radium, Beaverlodge, Gunnar, Pronto and Algom mines.

No new official estimates of ore reserves have been released since the announcement, in October 1957, of Canadian Geological Survey figures showing indicated reserves of economic ore in the Blind River area at 320 million tons of ore containing 380,000 tons of U_3O_8. Additional millions of tons of probable ore were estimated for other uranium producing areas. Since Canada's announcement in August 1955 that no further applications for special contracts would be considered after March 31, 1956, interest in uranium prospecting and exploration has practically ceased. A new deposit has been developed on the coast of Labrador with an indicated potential of some 200,000 tons of ore averaging 0.66 percent U_3O_8.

Combined Development Agency

Except for its bilateral purchase contracts with Canada, the United States has undertaken all foreign procurement jointly with the United Kingdom. The Combined Development Agency (CDA) was established in 1944 as one of the United States-United Kingdom operations of wartime atomic development. CDA's principal current function is the purchase of uranium under existing procurement contracts with Australia, Belgium, Portugal, and Union of South Africa producers.

Canada does not participate in these procurement arrangements.

South Africa. No significant change occurred in reserves during the reporting period, though small-scale exploration has revealed commercial grade uranium ores containing practically no gold at the extreme western edge of the Klerksdorp gold mining area in the Transvaal.

All 17 authorized plants operated during the reporting period, with production during the second quarter of this year increasing to a rate of 6,200 tons of U_3O_8 annually, as compared to the 1957 rate of 5,700 tons. Further substantial increases in U_3O_8 output were in prospect

as a result of greater plant efficiency and improvement in the uranium content of material fed into the process.

Negotiations in South Africa in May resulted in agreement with the South African Atomic Energy Board that, beginning July 1, 1958, production deliverable to the Combined Development Agency would not exceed 6,200 tons of U_3O_8 annually.

Australia. Uranium concentrate deliveries to the Combined Development Agency from Rum Jungle and Radium Hill continued at a normal rate.

Portugal. Portuguese production continued at a normal rate with mill throughput increased to offset the fact that ores were of lower grade.

Belgian Congo. Shinkolobwe uranium concentrate production continued at its scheduled rate. *Union Miniere du Haut-Katanga* is preparing to refine a portion of its Shinkolobwe production to metal-grade uranium oxide. This more highly refined product will be delivered in lieu of the uranium concentrate heretofore scheduled for delivery.

Assistance to Foreign Countries

During the first 6 months of 1958, the Commission continued to provide limited technical assistance in uranium exploration in Australia, Brazil, Chile, and Peru.

Several geologists and technicians from Arabia, Greece, India, Pakistan, Thailand, and Turkey participated in a training program in uranium exploration, mining and processing in the western United States.

Production of Special Nuclear Materials

Production rates of special nuclear materials during the first half of 1958 exceeded the established goals and were sufficient to meet all scheduled requirements for the military and civilian programs.

Plant Construction

Construction of the Weldon Spring, Mo., feed materials production center was essentially completed by June 30. A portion of the green salt plant began operation in March and the balance was in operation

by May 31. Some operations began in the metal plant during March.

Operations at the Destrehan Street plants in St. Louis were shut down as new units at Weldon Spring assumed the processing load. All major operations in downtown St. Louis were shut down by June 30.

The hexafluoride feed plant at Portsmouth, Ohio, began production operations during May.

New Production Reactor

A report on preliminary design of a new large-scale production reactor was submitted to Congress on April 1.[3] The report was based on studies by the General Electric Co. and Burns and Roe, Inc., which considered several alternative cases ranging from a plutonium-only reactor to a dual-purpose unit producing a large amount of electric power as well as substantial amounts of plutonium. The estimated cost of the reactor ranged from $126 million for a large plutonium-only reactor to $256 million for a large reactor producing plutonium plus 700,000 kilowatts of electric power.

A pressurized-water, graphite-moderated reactor fueled with slightly enriched uranium and designed to operate at high temperature was the basis for the study. The report concluded that a reactor based on this concept was feasible, but that a number of difficult development problems would require solution.

Military Applications

During the period of this report, emphasis continued on research and development activities designed to improve and increase the United States arsenal of nuclear weapons. Current weapons research and development programs include those aimed at meeting requirements for:

(*a*) Weapons of greatly reduced radioactive fallout in a variety of sizes for strategic, tactical, and defensive use.

(*b*) Smaller, immediately ready—that is, ready within minutes—and more rugged weapons, for use in more advanced weapons systems.

Production of nuclear weapons continued during the period in accordance with Presidential direction. Continual efforts are made at production facilities to develop the most efficient production techniques and expedite all steps from initial design and laboratory model to actual factory production.

[3] Pursuant to the Authorization Act for fiscal year 1958 (Public Law 85-162). Results of other reports requested under the act are described in the section on Reactor Development.

The Commission and its weapons laboratories continued to coordinate with various Department of Defense agencies research and development work on missile programs so that the missile warhead will be an integrated part of a weapon system and ready when the missile system is ready.

Accident Safeguards

A joint statement released by the Commission and Department of Defense on February 14 included an announcement that key United States military command and Commission establishments have teams especially trained and equipped to take action in the event of a accident involving a nuclear weapon including, if necessary, decontamination of the immediate scene of the accident.

The statement said, in part:

> It can be stated with assurance that the possibility of an accidental nuclear explosion while transporting or storing nuclear weapons is so remote as to be negligible.
>
> For the past 12 years nuclear weapons have been moved from places of manufacture in the United States to places of storage and readiness for use. * * * Although, as in the case of any toxic, inflammable or explosive material, accidents may occur in the manufacture, transportation and storage of nuclear materials and weapons, there have been few accidents in the handling and transportation of the latter. It is significant that not one of these accidents caused a nuclear explosion.
>
> By a nuclear explosion is meant a fission or fusion reaction creating a large explosive effect. Many nuclear weapons, however, contain some amount of conventional explosives, that is, chemical explosives similar to TNT. An accident such as the crash of an aircraft or severe wreck of a train carrying a nuclear weapon may cause this conventional explosive to detonate by impact or fire. In most cases, the detonation of a conventional explosive represents the maximum damage that can happen and, of course, its effect is limited to the vicinity of the accident. This kind of accident has occurred on a few occasions without any damage appreciably greater than caused by the crash itself, or any injury to persons due to the presence of the nuclear material.
>
> An accidental detonation of conventional explosives might possibly cause local scattering of nuclear materials in the form of dust. This would not be a fallout of fissioned materials, but unfissioned nuclear material could be spread locally, by wind or explosion. Such materials could be hazardous only if taken internally, as by breathing. Even then, under strict safety measures adopted by

Defense and AEC restricting the quantities that may be carried it is unlikely any person inadvertently exposed would inhale dangerous amounts of the unfissioned materials.

To minimize all unnecessary exposure, key United States military commands and AEC establishments have teams especially trained and equipped to decontaminate the area in the immediate scene of the accident if the nuclear materials have been scattered by the fire or conventional explosion. * * *

* * * The likelihood that a particular accident would involve a nuclear weapon is extremely limited. Further, in the majority of aircraft accidents involving a nuclear weapon, the nuclear materials would not be burned or scattered and no radiological problem would exist.

Weapons Testing

Operation Hardtack

The 1958 series of nuclear tests began in April at Eniwetok Proving Ground. Major objectives of the test series include development and exploratory tests designed to lead to development of improved weapons; smaller, more efficient, and more rugged strategic, tactical and defensive weapons; development of strategic, tactical and defensive weapons with greatly reduced radioactive fallout; proof tests of weapons scheduled for production; and weapons effects tests in which the Department of Defense will participate.

As part of operation Hardtack, certain short-range defensive missiles with nuclear warheads will be fired from Johnston Island. This island is located some 540 statute miles southwest of the nearest inhabited island of the Hawaiian chain and some 900 statute miles from the nearest other inhabited island.

A demonstration firing of a weapon with limited radioactive fallout has been planned for United Nations scientific observers and will be witnessed also by United States and foreign news representatives. The scientific observers may assist if they wish in measuring the potential fallout of the weapon by photography and radiochemical tests.

Safety precautions. Safety precautions for the operation are basically the same as for *Operation Redwing* in 1956. (See Appendix 10.)

Each test detonation was carefully evaluated as to necessity and as to safety before it was included in the schedule and every effort is being made to reduce offsite fallout.

A danger area was announced on February 14 and a regulation established by the Commission was filed in the Federal Register on

April 11 prohibiting United States citizens and other persons subject to United States jurisdiction from unauthorized entry into the prescribed danger area. (See Appendix 7.)

On June 10, the Commission published notice of a surface danger area which will be established around Johnston Island effective July 25, and to remain in effect for a period of approximately 3 or 4 weeks, and issued a similar regulation (see Appendix 7). An air danger area will be established by warnings to aircraft issued by the Civil Aeronautics Administration shortly before firing time planned for each test.

Operation Plumbbob

Safety experiments. Data obtained from safety experiments conducted at Nevada Test Site in 1957 provided further information relative to the design of weapons which, in the event of a mishap during storage and handling, would not result in a nuclear explosion.

Some radioactive contamination of the immediate area may occur in accidents in which conventional high explosive detonates and scatters the unexploded nuclear material. The Commission is continuing to study ways of making nuclear weapons still more safe during handling and storage.

Rainier Shot. On September 19, 1957, a 1.7 kiloton nuclear device was fired in a tunnel in a mesa at the Nevada Test Site. The purpose was to examine the possibilities of a weapons testing technique which would eliminate fall-out, be independent of weather, and eliminate other offsite effects. The principal questions of feasibility concerned (*a*) the overburden above the tunnel required for containment of the radioactive products, (*b*) the short-range seismic effects, and (*c*) the possibility of ground water contamination.

When the shot was fired, a few observers felt a weak ground shock at the control point, 2.5 miles away, although sensitive seismic recorders detected the effects at much greater distances. Investigative studies after the detonation made the following findings: there was no venting of radioactive products; practically all radioactive fission products were trapped in highly insoluble fused silica, indicating very little likelihood of ground water contamination; three months after the shot, temperatures up to 194° F. still existed in the central region; at least 700 tons of material were heated to the fusing range (2,200° F. to 2,700° F.); about 500,000 tons of tuff were crushed to sand, and at least 200,000 tons of broken tuff were produced by caving. As a result of continuing analyses, it is believed that devices 100 times as powerful as Rainier could be safely fired underground at the Site.

The University of California Radiation Laboratory, Livermore, which had overall responsibility for design and execution of the successful experiment published an unclassified report on the subject on February 4.[4]

Plowshare Program

Project Plowshare, initiated at the University of California Radiation Laboratory at Livermore in 1957, is primarily a study program directed toward determining possible nonmilitary applications of nuclear explosive devices. From time to time, nuclear devices may be detonated to verify calculated data experimentally, or to demonstrate a peaceful application.

Use of a nuclear explosion in excavation work is one application being investigated. A survey is under way to obtain detailed information on the possibility of excavating a harbor in Northwest Alaska, between Cape Seppings and Cape Thompson, north of the Arctic Circle. Absence of a harbor in this region has hampered development of nearby mineral resources. The survey will estimate detailed costs, collect physical and economic data, and evaluate safety factors. The governments of Canada and the Union of Soviet Socialist Republics have been advised about the Alaskan Harbor studies, announced June 9.

Another promising peaceful application for nuclear explosive devices being studied is the production in large quantities of radioisotopes. This might be accomplished by placing various materials around the device to be detonated in containing media so as to effect changes in the materials through nuclear reaction. Containing media with properties essential for this kind of experiment are being investigated. One that appears promising is large salt formations which occur in nature.

Peaceful applications of nuclear explosive devices being investigated include:

(*a*) Excavation.

(*b*) Power production.

(*c*) Isotope production.

(*d*) Recovery of oil from oil shales, tarsands, and depleted wells.

(*e*) Mining (breaking up underground deposits of low-grade ore).

(*f*) Excavating aquifers for replenishing water tables and for flood control.

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[4] UCRL 5124 "The Underground Nuclear Detonation of September 19, 1957, Rainier, Operation Plumbbob," Office of Technical Services, Department of Commerce, Washington 25, D. C., $1.

(*g*) Scientific studies in seismology, geology and special chemical reactions.[5]

Procedures are being formulated to obtain industrial participation in projects when feasible.

Weapons Facilities

The Pinellas Area Office, formerly identified as the Clearwater Office, was opened on February 3 at the Commission's Pinellas Peninsula Plant, which produces electronic equipment. It is located between Clearwater and St. Petersburg, Fla. The subcontract of the Sandia Corp. (a subsidiary of the Western Electric Co.) with the General Electric Co. for operation of this plant was assigned to the Commission as a prime contract on April 1.

Work was completed in February on a manufacturing support facility for the Kansas City plant at Kansas City, Mo.

Permanent facilities estimated to cost $7.9 million are under construction at the Eniwetok Proving Ground, consisting mainly of additional airfield facilities, communications facilities, utilities, living quarters, warehouses, laboratories, and administration facilities. This work is scheduled for completion during the fiscal year ending June 30, 1959.

An additional 3,000 acres of land was acquired just west of Site 300, the University of California Radiation Laboratory Explosive Test Site, in southwestern San Joaquin County, Calif., some 12 miles east of Livermore. The land will provide an additional firing area for nonnuclear high explosives and test facilities in support of the laboratory's weapons and device development programs. The present test site consists of approximately 4,000 acres and contains four major areas of operation, the Firing Area for conducting experiments with high explosives, the Test Area for performing tests of physical properties, the High Explosive Process Area, and the Administrative and Service Area.

International Activities

Negotiation with the European Atomic Energy Community (Euratom) of a joint program embracing installation by 1963 of United States types of power reactors with a generating capacity of about 1,000,000 kilowatts in the six Member States of the Community was the outstanding development in the United States Atoms for Peace programs during the January–June reporting period.

[5] Appendix 13 reproduces a list of test detonations useful for seismologists.

The United States Atomic Energy Commission also broadened its cooperation with other international organizations and to nations with which the United States has bilateral agreements. Besides the proposed United States-Euratom program, other highlights of the period include:

Inauguration by the International Atomic Energy Agency of a survey, headed by a United States scientist of Latin American needs and capabilities in the field of nuclear energy.

Offer by the Commission to the International Atomic Energy Agency of cost-free consultant services, two mobile radioisotopes training units, matching grants for the IAEA fellowship fund, and of a separate fellowships program for training foreign students in the United States.

Establishment by the Organization for European Economic Cooperation of a European Nuclear Energy Agency.

Preparation for United States participation in the United Nations second International Conference on the Peaceful Uses of Atomic Energy (September 1–13, Geneva, Switzerland) including submission of more than 700 technical papers, organization of 72 exhibits with 2 operating reactors and operating experimental machines for research on controlled thermonuclear reactions, a 4-language library of films, and an operating technical information center.

Final ratification of comprehensive power agreements with Italy and Spain, making a total of 41 research and power or research agreements with 39 nations (4 going into effect in this reporting period). Conclusion of negotiations for a comprehensive power agreement with Japan.

Approval of grants to 9 nations for research reactor projects. Donation of 3 technical libraries. Provision of 3 additional courses for foreign students of nuclear energy technology in the United States.

Liberalization of conditions under which cooperating nations may receive from the Commission highly enriched uranium for reactors.

Operation in 7 foreign countries of 8 research reactors built by United States organizations, 2 of which went critical during this reporting period, and of 6 research reactors in 5 foreign countries which obtained materials in the United States, 2 going critical during this reporting period.

Building of 18 research reactors and one power reactor by United States firms for 15 foreign countries, 7 of these getting underway in this reporting period. Two additional research reactors were planned in 2 foreign countries, in this reporting period.

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Other highlights of the reporting period included: completion of plans for the Puerto Rico Nuclear Center; planning for additional inter-American symposia; United States donation of a cobalt 60 source to the Agricultural Institute at Turrialba, Costa Rica; drafting of a statute by the Organization of American States for the Inter-American Nuclear Energy Commission. Atoms for Peace missions were sent to Australia and New Zealand.

European Atomic Energy Community (Euratom)

President Eisenhower on June 23 submitted to Congress and asked early approval of an international agreement between the European Atomic Energy Community (Euratom) and the United States as the first step in a broad program of cooperation in the peaceful uses of atomic energy to be carried out with the six Western European nations that comprise Euratom.

The Nations are Belgium, France, The Federal Republic of Germany, Italy, Luxembourg, and The Netherlands. They have a population of 160,000,000 people and within their borders are located the major industrial resources of the free world on the continent of Europe.

In his message[6] accompanying the submission of the proposed international agreement, pursuant to section 124 of the Atomic Energy Act of 1954, and which will require approval by the Senate and the House, the President said:

"The specific program which I am asking the Congress to consider and approve on an urgent basis is a joint undertaking by the United States and Euratom to foster the construction in Europe by 1963 of approximately six major power reactors which would produce about one million kilowatts of electricity * * *

"The Europeans see atomic energy * * * as something which they must develop quickly if they are to continue their economic growth and exercise their rightful influence in world affairs * * *

"It is gratifying that the reactor research, development, testing, and construction program in the United States has progressed to the point that United States reactors of proven types are available and will be selected for commercial exploitation in the joint program of large-scale nuclear reactors * * *

"The basic arrangements which have been worked out with Euratom * * * promise to result in a program that will initially be of great benefit to Euratom and the United States, and thereafter to nations everywhere that choose to profit from Euratom's experience. American knowledge and industrial capacity will be joined with the

[6] Full text of President's message is given in app. 14.

scientific and industrial talents of Europe in an accelerated nuclear power program to meet Europe's presently urgent need for a new source of energy * * *

"I believe that the initiation of this program * * * represents a major step in the application of nuclear technology for the benefit of mankind."

Statutory requirements. The basic arrangements referred to by the President are incorporated in a Memorandum of Understanding signed by the Euratom Commission and the Chairman of the United States Atomic Energy Commission and the Secretary of State. (See Appendix 15.) If Congress approves the international agreement, there will be submitted formally to the Joint Committee on Atomic Energy, pursuant to section 123 of the United States law, an agreement for cooperation which has been negotiated.

The Commission, with the approval of the President and after review by the Bureau of the Budget, has submitted to Congress a draft measure titled "Euratom Cooperation Act of 1958" which contains the necessary authorizations for appropriations and other enabling legislation required for the United States to carry out its share of the joint program.

The Euratom Council of Ministers and the Euratom Commission already have taken the necessary statutory actions to ratify the several agreements.

The Joint Program

The joint program would cover understandings on capital and operating costs, financing, research and development, reactor fuel, guarantees, information and training, and safeguards and controls.

Objective. The objective of the joint program is to bring into operation in the Community by 1963 about 1 million electric kilowatts of installed nuclear capacity in reactors of proven types developed in the United States and to start immediately a joint research and development program centered on those reactors.

The program would be so conducted so as to obtain the maximum support of the industries of the Community and of the United States. Their active participation is indispensible to the success of the program.

Capital cost. The total capital cost, exclusive of fuel, for the reactors and equipment is estimated not to exceed $350 million. This is based on an average cost per installed kilowatt of capacity of $350.

Approximately $215 million will be provided by the participating utilities and other European sources of capital, such financing to be arranged with the appropriate assistance of Euratom.

Up to $135 million would be provided by the United States Government to Euratom in the form of a long-term line of credit from the United States Export-Import Bank. These funds will be relent by Euratom for the construction of nuclear powerplants.

The nuclear plants under the program will be built, owned and operated by the utilities in Euratom countries. All risks due to uncertainties in construction, maintenance and operating costs, and load factors, will be borne directly by these utilities.

Research and development. Upon enactment of the necessary legislation, there will be initiated a 10-year joint research and development program centered on improving the performance of the United States-type reactors involved in the joint venture and on lowering the fuel cycle costs. During the first 5 years, the Community and the United States will contribute about $50 million each to this research and development. The sum required for the second 5-year period will be determined later.

Reactor fuel. Under the proposed arrangements, the United States would sell to the Community a net quantity of 30,000 kilograms of contained uranium 235 to cover the fueling and other program requirements for such material over a 20-year operating period.

The initial fuel operating inventory of approximately 9,000 kilograms of uranium 235 would be sold to the Community on a deferred payment basis. The balance of about 20,000 kilograms which represents estimated burnup and process losses over the 20-year operation period, and 1,000 kilograms to fuel research and test reactors associated with the program, would be paid for on a current basis.

The Atomic Energy Commission will process in its facilities, at prices and under terms and conditions established for United States reactor operators, the spent fuel elements from the reactors included in the joint program.

The International Atomic Energy Agency will have first option to purchase any special nuclear material (principally plutonium) produced under the joint program which is in excess of the peaceful needs of the Community. If the Agency does not exercise its option, the United States would be prepared during the first 10 years of reactor operation to purchase this material. Such transfers would be at the fuel value prices in effect in the United States at the time of purchase. Material so acquired by the United States would be used only for peaceful purposes.

Guarantees. In the course of the negotiations, it was determined that the economic risks associated today with the reactor fuel cycle must be minimized if participation by the European utility industry is to be reasonably assured. To this end, for a 10-year operating period, the United States will guarantee ceiling costs for the fabrication of the fuel elements required as well as a fixed life for these elements.

Initially, the integrity of elements clad in stainless steel or zirconium and used in light-water cooled and moderated reactors will be guaranteed to an average irradiation level of 10,000 megawatt days per metric ton of contained uranium.

For each type of fuel element, there will be computed a mutually agreed upon "standard fuel cycle cost" which will factor in charges for fabrication, inventory, chemical reprocessing, transportation and the credit for plutonium produced in the reactors.

This "standard" cost will be based on $100 per kilogram of contained uranium for fuel elements made of uranium dioxide with a uranium 235 concentration up to 3 percent by weight, with specified diameters and clad with stainless steel. The cost ceiling for zirconium-clad elements of the same specifications will be $140 per kilogram of contained uranium.

It is expected that commercial guarantees extended by United States fuel fabricators will come close to or equal the performance and price guarantees offered Euratom by the Commission. In event the fuel elements exceed the guaranteed performance, the arrangements contemplate that one-half of the resultant savings in fabrication costs will be credited to the United States Commission—up to the cost of payments by the United States for fabrication charges for the particular core concerned.

The United States Commission is prepared, at such time as sufficient technical information is available, to develop guarantees for fuel elements which have specifications different from those covered above and which are to be used in reactors of proven types.

Information and training. Technological and economic data developed under the program would be made available to the industries within the Community and the United States under provisions designed to assure the widespread dissemination of information developed in the course of the program.

Principles to govern the use of patentable information have been agreed upon with both parties pledging that neither will discriminate against the other in the granting of licenses and sublicenses to use discoveries made as a result of the joint program.

The overall objective of Euratom is to develop as soon as possible a relatively self-sufficient nuclear power industry in Western Europe.

Trained manpower is a critical requirement. Euratom and the Commission will work closely together to develop training programs to satisfy the Community's needs. It is expected that the Commission will be able to assist Euratom in meeting part of its anticipated specialized training requirements by arranging for training in reactor design, engineering, operation, maintenance, supervision, etc., in selected industrial, educational and Commission facilities in the United States.

Safeguards and controls. The Community and the United States recognized their mutual interest in assuring that special nuclear and other materials received from the United States as well as special nuclear material produced therefrom are used only for peaceful purposes.

To accomplish this objective, the program requires the Community to assume responsibility for establishing a safeguards system in accordance with agreed upon principles that are compatible with and based on safeguards provisions (art. XII) of the Statute of the International Atomic Energy Agency. The agreement for cooperation, already negotiated, will contain all the guarantees required by section 123 of the Atomic Energy Act of 1954.

This agreement also will provide for frequent and continuing consultation and visits to assure that the Euratom system is operating effectively under the agreed upon principles. By exchange of letters, both parties have agreed that the terms of the agreement for cooperation include permission for verification, by mutually approved scientific methods, of the effectiveness of the Euratom controls as applied to nuclear materials received by the other party or derived therefrom in connection with the joint program.

Continuation of the cooperative program will be contingent upon Euratom establishing and maintaining a mutually satisfactory safeguards and controls system.

Relations with the IAEA

In his message to Congress the President said that "The United States and Euratom have reaffirmed their dedication to the objectives of the International Atomic Energy Agency and intend that the results of this program will benefit the Agency and the nations participating in it."

Euratom has agreed to consult with and exchange experiences with the IAEA with the objective that the Euratom control system will be reasonably compatible with that of the Agency. The United States and Euratom will consult with each other to determine whether

there are any areas of responsibility, with regards to safeguards and controls and matters of health and safety, in which the IAEA may be asked to assist.

In addition, in the event of the establishment of an international system by the IAEA, the United States and Euratom will consult regarding assumption by the Agency of safeguards and controls over fissionable material used and produced in the course of the joint program.

United States Bilateral Agreements with Euratom Nations

Comprehensive nuclear power agreements for cooperation are currently in effect with all of the Euratom nations except Luxembourg. These agreements will not be modified by the joint program but will be subject to appropriate negotiations provided for in the Euratom Treaty. Modifications may be necessary to permit transfer of reactor projects now contemplated under the existing agreement that qualify for and are accepted under the joint program.

The 30,000 kilograms of uranium 235 estimated as required for the United States-Euratom program will be in addition to the quantities already authorized in the existing accords between the United States and the individual Community member states. These and other provisions of the bilateral agreements now in effect will remain intact until they are renegotiated.

History of United States-Euratom Negotiations

Formation of Euratom. Cooperation with Europe to the end of continuing economic growth has long been United States foreign policy. The first postwar assistance program was the Marshall Plan, inaugurated in 1947. It resulted in the formation in 1948 of the Organization for European Economic Cooperation (OEEC). Economic integration of Europe took another substantial step forward in 1952 with the formation of the European Coal and Steel Community which has worked well.

An attempt to form an European Defense Community in 1954 failed, but a new effort was launched in 1955 with the object of setting up a common market and a common effort to promote the peaceful development of nuclear energy. After intensive technical and economic studies, a committee composed of Louis Armand of France, Franz Etzel of Germany and Francesco Giordani of Italy held discussions in Great Britain, Canada and the United States. It was obvious that costs of electricity were higher in Europe than in the

United States and that nuclear power would be competitive economically in the Euratom states before that goal was achieved in the United States.

On March 25, 1957, in Rome, the six nations signed the treaties establishing the European Economic Community and the European Atomic Energy Community. These treaties established a Council of Ministers to serve the two proposed organizations and the earlier Coal and Steel Community.

In May 1957, the comprehensive committee report "A Target for Euratom" was completed. It emphasized that the Euratom nations now import about one-quarter of their energy supplies, mostly as oil from the Middle East. The report predicted that these imports would double in 10 years and triple in 20 years unless nuclear power was installed rapidly.

The committee's visit was followed in July 1957, by a tour of United States installations and atomic industries and conference in Washington by a group of 50 leading industrialists from Euratom countries and the Commission sent a technical mission to Luxembourg to assist in Euratom planning.[7]

Ratification of the Euratom Treaty was completed in December 1957, and the Community came into being on January 1, 1958. Louis Armand of France was chosen president of the Euratom Commission.

United States-Euratom negotiations. The United States welcomed the formation of the European Atomic Energy Community as an important step towards the goal of an integrated Europe. With the approval of the President, the United States began in January 1958, to explore the possibility of reaching an agreement with Euratom on a program under which existing utilities in the Member States would build and operate nuclear powerplants using equipment produced in the United States and the Euratom area.

A meeting held in Paris in February led to establishment of a Joint United States-Euratom Working Party to study the various areas of possible cooperation and the means by which a cooperative program might be carried out. The heads of the working groups were Max Kohnstamm, Special Euratom Advisor on United States Relations for the Community, Walter W. Butterworth, United States Ambassador to Euratom, and Richard W. Cook, Atomic Energy Commission Deputy General Manager for the United States. They were supported by technical, political, and legal advisors.

The Joint Working Party held meetings in Luxembourg in March and in Washington in April and May. As a result, a comprehensive program was drawn up and incorporated in a Memorandum of Under-

[7] See pp. 216-17, Twenty-third Semiannual Report to Congress (July-December 1957).

standing signed on May 29 by Euratom Commission with the approval of the Euratom Council of Ministers and on June 12, by Chairman Lewis L. Strauss of the United States Atomic Energy Commission and Secretary of State J. F. Dulles.

Clarification of points developed subsequent to the drafting of the Memorandum of Understanding was accomplished through the exchange of letters. The International Agreement also was signed, and both parties initialed an Agreement for Cooperation.

The President approved the program and took the first step toward congressional approval on June 23 by sending the International Agreement to the Congress.

Other International Activities

International Atomic Energy Agency

One of the first projects undertaken by the International Atomic Energy Agency (IAEA), formally inaugurated in Vienna October 1, 1957,[8] was a survey of nuclear energy training needs and capabilities in Latin America. During May and June, an international team of scientists, engineers and administrators headed by Dr. Norman Hilberry, Director of the United States Atomic Energy Commission's Argonne National Laboratory, and including representatives from the Organization of American States, visited Caribbean, Central and South American nations.

At the January meeting of the IAEA Board of Governors, the United States made the following offers of additional support to the IAEA:

(*a*) Cost-free services for limited periods of 20 to 30 expert consultants for use in the Agency's surveys of programs in member countries.

(*b*) Grants matching contributions of other member nations up to $125,000 for a $250,000 IAEA fellowships fund.

(*c*) Approximately 120 fellowships, at an estimated cost of $840,000 over the next 2 years, for education and training in nuclear sciences in the United States for students from IAEA countries.

The United States also offered two mobile radioisotope training laboratories to the Agency.

In addition to these offers, the United States previously announced that, subject to congressional concurrence, it would provide the IAEA with a research reactor, and an isotopes laboratory. Major

[8] See pp. 192–195, Twenty-third Semiannual Report to Congress (July–December 1957).

quantities of special nuclear materials also have been offered as has a technical library.

Throughout the reporting period, the Agency has mapped programs concerning acceptance and supply of fissionable materials, the conducting of a fellowships program, provision of technical assistance to members, health and safety activities, and measures to promote the use of radioisotopes.

An agreement for cooperation between the IAEA and the United States, was being negotiated.

As of June 30, a total of 67 nations had become participating members of the IAEA.

Organization for European Economic Cooperation

The European Nuclear Energy Agency (ENEA) was officially established February 1 within the framework of the Organization for European Economic Cooperation (OEEC) and Pierre Huet, of France, was appointed its first Director.

Representatives of the 12 nations among the 17 OEEC members which have organized the European Co. for the chemical processing of irradiated fuel (Eurochemic) were selected to study the projected construction of an ENEA chemical separation plant at Mol, Belgium. The Commission is providing design assistance for this project.

In March, United States Atomic Energy Commission representatives met in Paris with the Experimental Reactors Group of the OEEC Steering Committee on Nuclear Energy which discussed plans for reactor experiments. Commission representatives met with another OEEC group to study the problems of public liability, especially in the power reactor field.

Inter-American Activities

In response to a recommendation made in May 1957 by Presidential representatives of the 21 American republics, the Organization of American States (OAS) is studying the needs of members for research and training in the peaceful uses of atomic energy.

A draft statute has been completed which will establish an Inter-American Nuclear Energy Commission. This action was authorized last November by the OAS Council.[9]

Plans for additional inter-American symposia on the peaceful uses of atomic energy to be held in South America were being considered by the OAS. The United States Atomic Energy Commission, the

[9] See p. 218, Twenty-third Semiannual Report to Congress (July–December 1957).

Department of State, and the International Cooperation Administration have indicated their willingness to participate. The first inter-American symposium was held at the Brookhaven National Laboratory under the sponsorship of these three United States agencies in May 1957.[10]

As part of the Commission's program for support of agricultural research and radioisotopes training at the Inter-American Institute of Agricultural Sciences at Turrialba, Costa Rica, a 200-curie cobalt 60 gamma irradiation source was installed at the Institute.

Asian Nuclear Center

Review continued during the last 6 months on the possibility of establishing an Asian Nuclear Center in the Philippine Islands for training scientists and technicians from Asian countries.

Australian Symposium

Seven Commission representatives participated in an Australian Symposium on the Peaceful Uses of Atomic Energy held at Sydney, June 2–6. The United States presented papers on the following subjects: experimental and power reactors, chemical processing, uranium metal production, reactor materials, and thermonuclear fusion.

The United States representatives also conferred with the Australian Atomic Energy Commission concerning legal and administrative aspects of atomic energy, experimental power reactor technology, uranium extraction, and waste disposal.

Mission to New Zealand

A five-man Commission technical mission visited New Zealand March 22–April 3 to consult with that Government concerning administration and organization of a nuclear energy laboratory, site and operation of a research reactor, and health and safety problems.

Agreements For Cooperation

New Provisions for Uranium Supply

The Commission announced on April 25 a liberalization of conditions under which uranium enriched to more than 20 percent in

[10] See pp. 23–25, Twenty-second Semiannual Report to Congress (January–June 1957).

uranium 235 may be made available to friendly nations under agreements for cooperation. The Commission will consider requests for highly enriched fuel for both research and materials testing reactors, when using this fuel has an economic and technical advantage for the reactor proposed over uranium containing up to 20 percent of uranium 235, the former general ceiling on enrichment. Highly enriched fuel may be made available for reactors using up to 8 kilograms of uranium 235 per core loading.

To be eligible, the requesting nation must have in effect an agreement containing comprehensive safeguards and controls against diversion of special nuclear material to military uses, and have definite plans to build the reactor requiring highly enriched fuel.

Also United States commercial suppliers may be licensed to export uranium ores and concentrates. (See section of this report on Raw Materials.)

New Agreements in Force and Pending

During the first half of 1958, 4 agreements for cooperation came into effect, 2 for research and 2 for power. As of June 30, there was a total of 41 agreements in effect with 39 nations and the city of West Berlin (There are separate research and power agreements with Switzerland). Four research and 3 power agreements with 4 additional countries are awaiting final action within respective governments. (See table I, Status of Agreements for Cooperation as of June 30.)

TABLE I. STATUS OF AGREEMENTS FOR COOPERATION AS OF JUNE 30, 1958

Cumulative Numbers Countries	Agreements	Country	Scope of Exchange	Effective Date
1	1	Argentina	Research	July 29, 1955
2	2	Australia	Research and Power	May 28, 1957
3	3	Austria	Research	July 13, 1956
4	4	Belgium	Research and Power	July 21, 1955
5	5	Brazil	Research	Aug. 3, 1955
6	6	Canada	Research and Power	July 21, 1955
7	7	Chile	Research	Aug. 8, 1955
8	8	China, Republic of	Research	July 18, 1955
9	9	Colombia	Research	July 19, 1955
10	10	Cuba	Research	Oct. 10, 1957
11	11	Denmark	Research	July 25, 1955
12	12	Dominican Republic	Research	Dec. 21, 1956
13	13	Ecuador	Research	Feb. 6, 1958
14	14	France	Research and Power	Nov. 20, 1956
15	15	Germany, Federal Republic	Research and Power (a)	Aug. 7, 1957
	16	West Berlin, City	Research	Aug. 1, 1957

See footnotes at end of table.

TABLE I. STATUS OF AGREEMENTS FOR COOPERATION AS OF JUNE 30, 1958—Continued

CUMULATIVE NUMBERS COUNTRIES	AGREEMENTS	COUNTRY	SCOPE OF EXCHANGE	EFFECTIVE DATE
16	17	Greece	Research	Aug. 4, 1955
17	18	Guatemala	Research	Apr. 22, 1957
18	19	Israel	Research	July 12, 1955
19	20	Italy	Research and Power (f)	Apr. 15, 1958
20	21	Japan	Research	Dec. 27, 1955
21	22	Korea, Republic of	Research	Feb. 3, 1956
22	23	Lebanon	Research	July 18, 1955
23	24	Netherlands	Research and Power (b)	Aug. 8, 1957
24	25	New Zealand	Research	Aug. 29, 1956
25	26	Nicaragua	Research	Mar. 7, 1958
26	27	Norway	Research and Power	June 10, 1957
27	28	Pakistan	Research	Aug. 11, 1955
28	29	Peru	Research	Jan. 25, 1956
29	30	Philippines	Research	July 27, 1955
30	31	Portugal	Research	July 21, 1955
31	32	South Africa	Research and Power	Aug. 22, 1957
32	33	Spain	Research and Power (c)	Feb. 12, 1958
33	34	Sweden	Research	Jan. 18, 1956
34	35	Switzerland	Research	July 18, 1955
	36	Switzerland	Power	Jan. 29, 1957
35	37	Thailand	Research	Mar. 13, 1956
36	38	Turkey	Research	June 10, 1955
37	39	United Kingdom	Research and Power	July 21, 1955
38	40	Uruguay	Research	Jan. 13, 1956
39	41	Venezuela	Research	July 21, 1955
		SIGNED AND IN RATIFICATION PROCESS AS OF JUNE 30, 1958		
				DATE SIGNED
	42	Brazil	Power (d)	July 21, 1957
40	43	Costa Rica	Research	May 18, 1956
41	44	Iran	Research	Mar. 5, 1957
42	45	Iraq	Research	June 7, 1957
43	46	Ireland	Research	Mar. 16, 1956
		Japan	Research and Power (e)	June 16, 1958
		Peru	Research and Power (e)	July 19, 1957

NOTES.—(a) Superseded Research Agreement effective from Apr. 23, 1956, to Aug. 7, 1957. (b) Superseded Research Agreement effective from Dec. 30, 1955, to Aug. 8, 1957. (c) Superseded Research Agreement effective from July 19, 1955, to Feb. 12, 1958. (d) Will be separate from Research Agreement already in effect. (e) Will supersede Research Agreement now in effect. (f) Superseded Research Agreement effective from July 28, 1955, to Apr. 15, 1958.

SUMMARY.—*In effect:* 29 research and 12 power agreements with 39 countries and the city of West Berlin. *Signed:* 4 research and 3 power agreements with 4 additional countries.

A comprehensive power agreement with Spain went into effect February 12 and superseded the research agreement of 1955. A research agreement with Italy also was superseded by a power agreement, effective April 15.

Denmark was the first nation to take advantage of the availability of highly enriched uranium, and its agreement for cooperation was being amended to permit the transfer of 50 kilograms of uranium 235 over a 10-year period, some of which may be 90 percent enriched fuel for use in a research reactor.

The agreement for cooperation with Sweden was modified to permit the transfer of 200 kilograms of uranium 235 over a 10-year period. Some of this material may be made available at up to 90 percent enrichment for a materials testing reactor.

Amendments to the research agreements for cooperation with the Republic of Korea and with Venezuela became effective, providing for the transfer of limited quantities of special nuclear materials for use in defined research projects.

United States Built or United States Assisted Reactors Abroad

Twenty-six research reactors have been or are being built by United States manufacturers for foreign locations. Of these, 8 already were in operation abroad during the January–June reporting period; in Belgium (World's Fair Reactor), Brazil, Denmark, Federal Republic of Germany (2), Japan, The Netherlands, and Switzerland. Eighteen research reactors for 14 foreign countries were in various stages of construction: Canada, Denmark, Federal Republic of Germany, Greece, Italy (3), Republic of China, Israel, Japan, The Netherlands, Portugal, Spain, Sweden, Switzerland (2), Venezuela, and the city of West Berlin. One power reactor was under construction for Belgium.

In addition, 2 research reactors were planned for construction by United States firms in Austria and Italy.

United States-built reactors are sold abroad under the terms of agreements for cooperation. In each case, the United States also has supplied the nuclear fuel used in the reactors. In addition, the United States has supplied nuclear fuel or special materials for reactors built by other countries, for example, by Argentina, Australia, Canada, France, and India.

As of June 30, letters of commitment for $350,000 grants for research reactor projects have been made to 16 countries, nine of them during this reporting period: Austria, Belgium, Brazil, Republic of China, Denmark, Federal Republic of Germany, Greece, Israel, Italy, Japan, The Netherlands, Norway, Portugal, Spain, Sweden, and Venezuela.

In carrying out the "prudent safeguards" against diversions of special nuclear materials from peaceful uses, stipulated from the first as part of the Atoms for Peace program, United States representatives have been present at the startup or during the initial operating period

of all reactors abroad using United States fuel. This type of international cooperation has proved mutually beneficial.

The photographs on the following pages show the progress of construction and operation of reactors in foreign countries which either were built by United States concerns or employ special materials supplied by the United States. With the exception of the Argentine and Belgian reactors, which have respectively received United States assistance in fuel and in design, all the reactors pictured are of United States design and manufacture.

Activities Under Agreements for Cooperation

Detailed reports on type and scope of United States assistance and cooperation with foreign countries under the Atoms for Peace program are given in the following items, country by country:

Australia. The Government of Australia purchased one short ton of heavy water from the Commission for research purposes in addition to 11 tons purchased in July 1957 for use as a moderator in its Lucas Heights Nuclear Center research reactor, which went into operation during this reporting period.

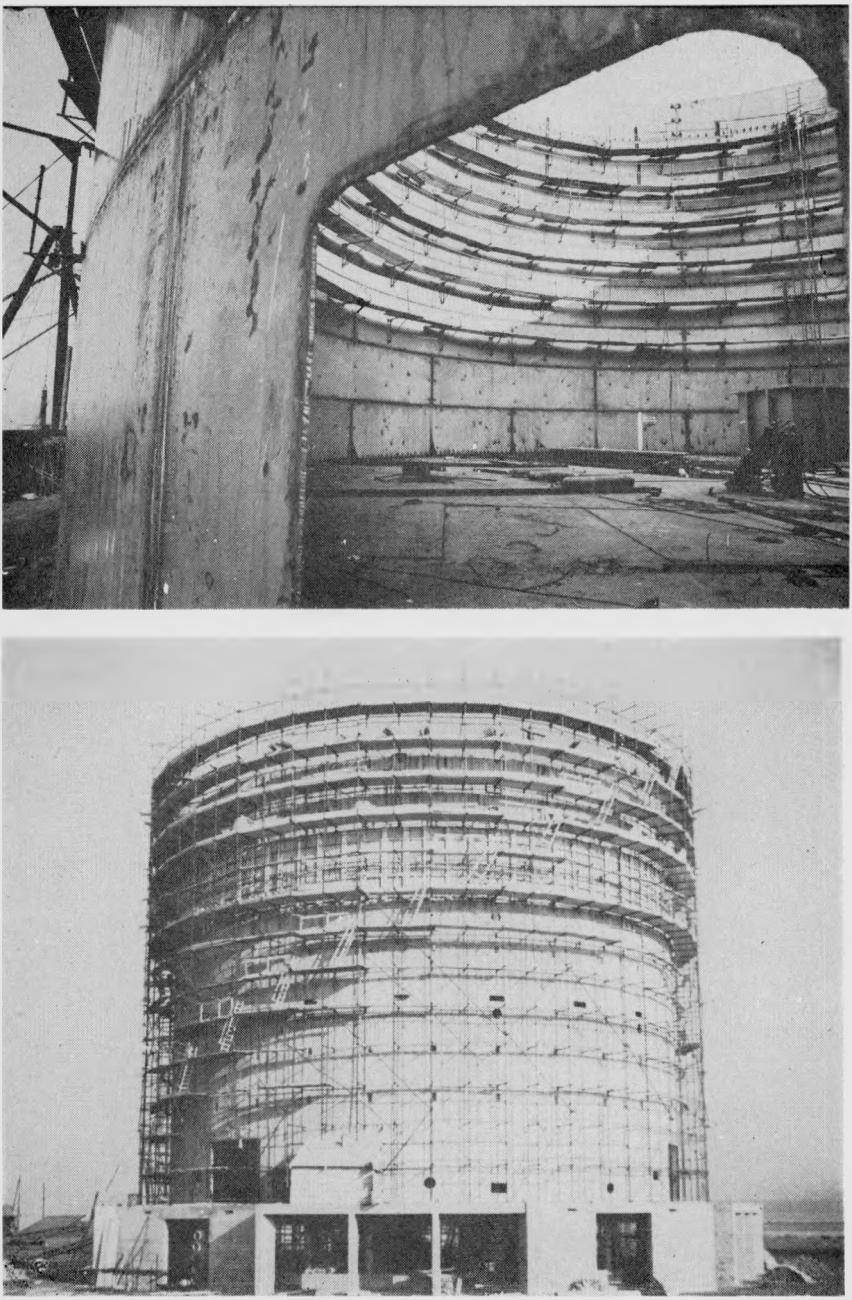
Austria. Representatives of the Austrian Study Co. for Atomic Energy completed negotiations with a United States firm for construction of a research reactor. A $350,000 research reactor grant was approved by the Commission toward construction costs of this project.

Belgium. The Commission approved a $350,000 research reactor grant to Belgium to be used toward the costs of constructing the BR–2 research and testing reactor at Mol. Belgian and American firms are working together on this project.

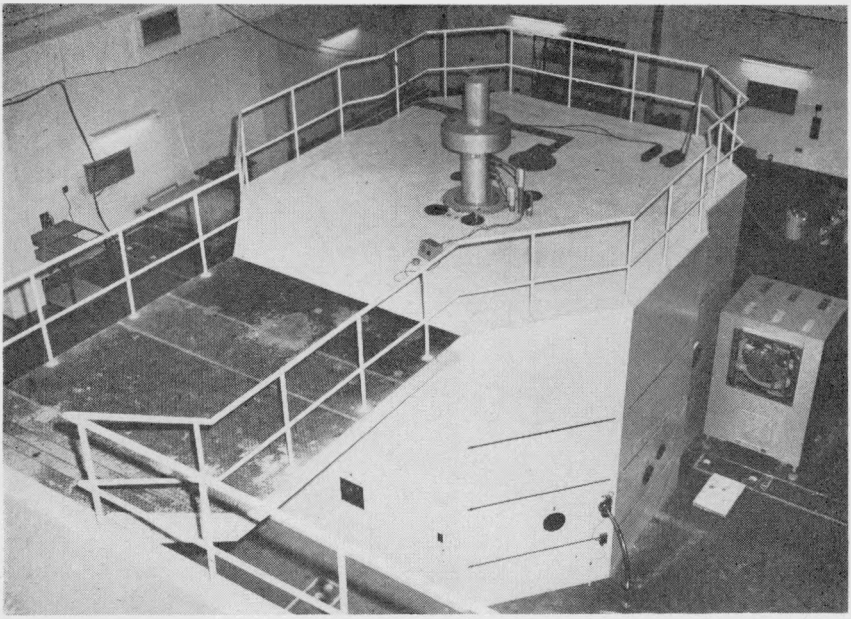
Brazil. On January 25, the Government of Brazil was presented with a check for $350,000 on the occasion of the dedication of its pool research reactor at the University of Sao Paulo. This was the first actual payment of a United States research reactor project grant under the Atoms for Peace program.[11]

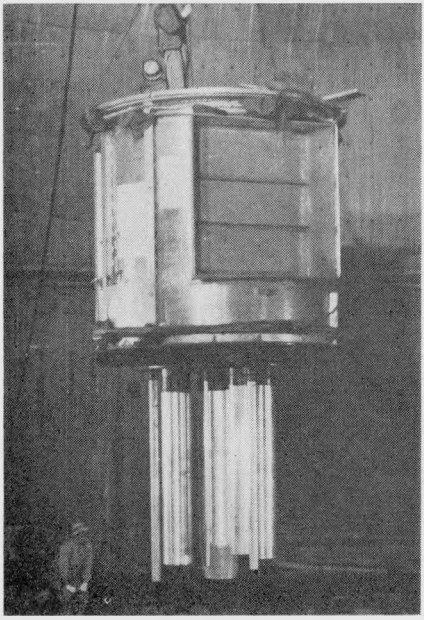
Canada. The large NRU research reactor at Chalk River, Canada, reached criticality on November 3, 1957, and reached full power of 200 megawatts in April 1958. An accident involving removal of a fuel element that failed forced a shutdown on May 24. This natural uranium, heavy water-moderated reactor uses heavy water purchased from the United States.

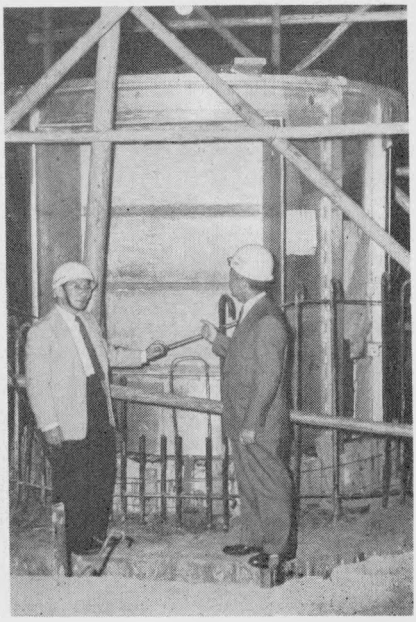
[11] See p. 208, Twenty-third Semiannual Report to Congress (July–December 1957).



Italy. Containment vessel of reactor being built at Ispra by the Comitato Nazionale per le Richerche Nucleari (CNRN); below, general construction view of Societa Richerche Impianti Nucleari (SRIN) reactor facility near Milan.

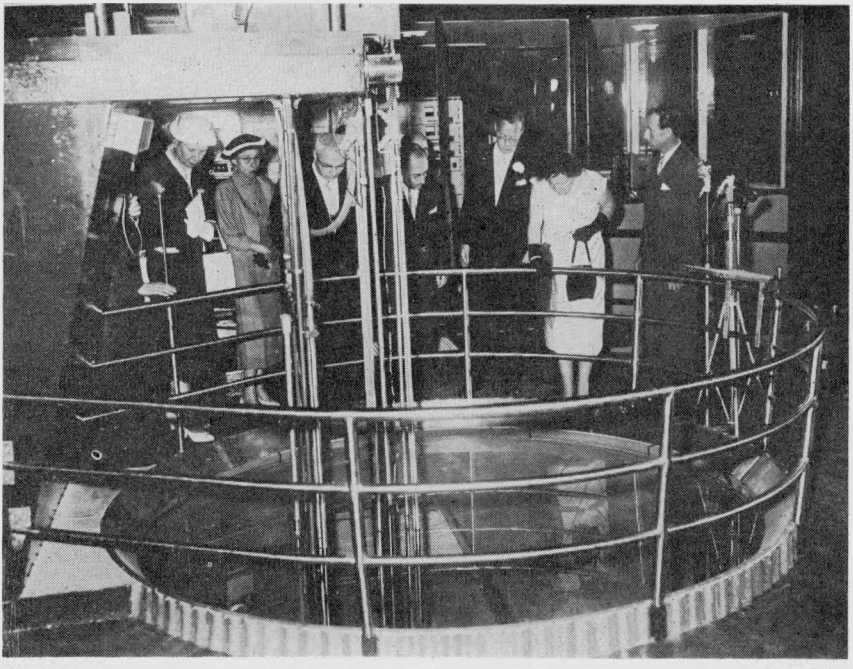


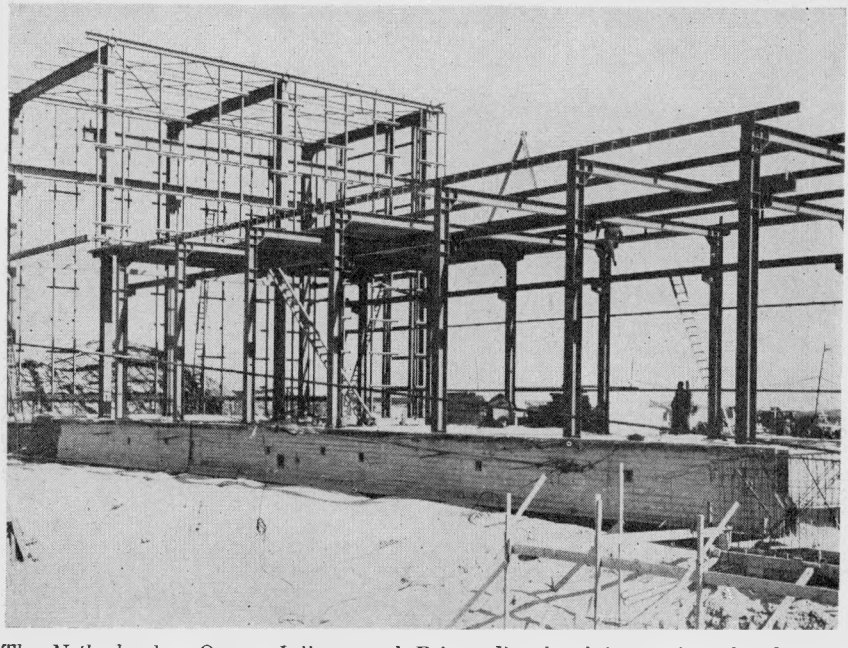




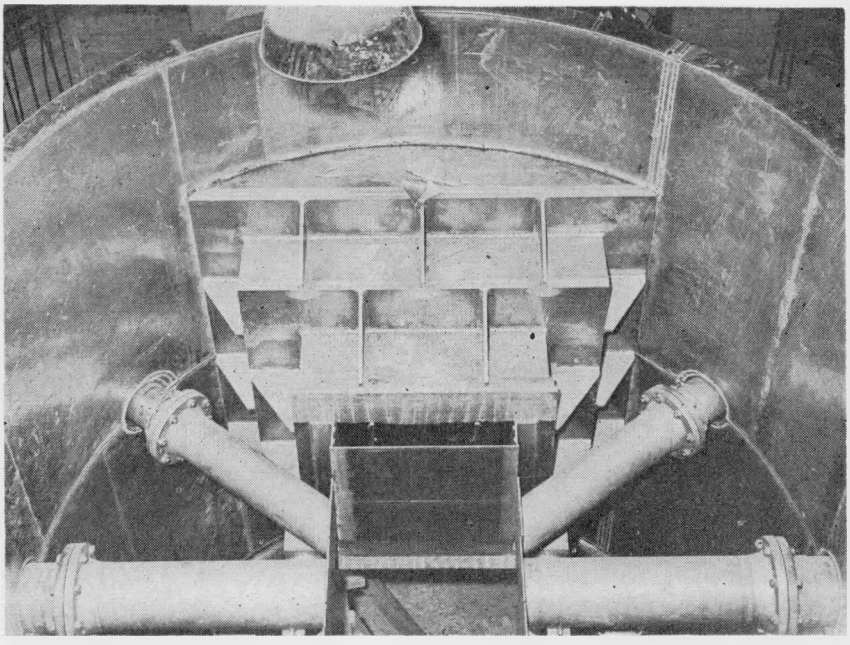
Japan. Japan Research Reactor No. 1 (JRR–1) and experimental equipment; below, left, light water tank for JRR–2 reactor being lowered into place; right, Dr. Sagane, Vice Chairman of the Japan Atomic Energy Research Institute and a U. S. Commission official examine the JRR–2 water tank. Both reactors are at Tokai-Mura, north of Tokyo.

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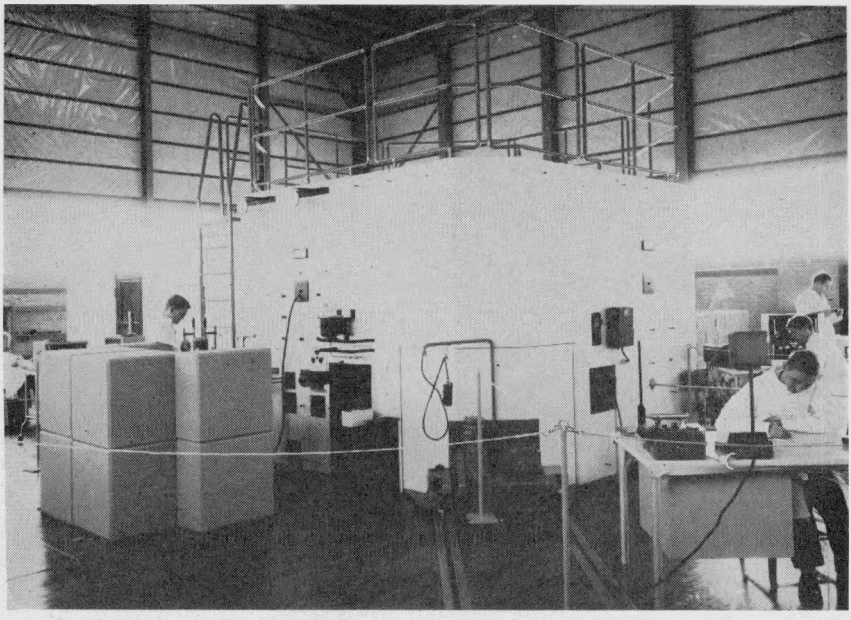
The Netherlands. Queen Juliana and Prince Bernhard inspecting the demonstration reactor at the International Exhibition in Amsterdam; below, construction view of building to house the research and materials test reactor at Petten. Reactor Centrum Nederland (RCN) is the sponsoring organization.

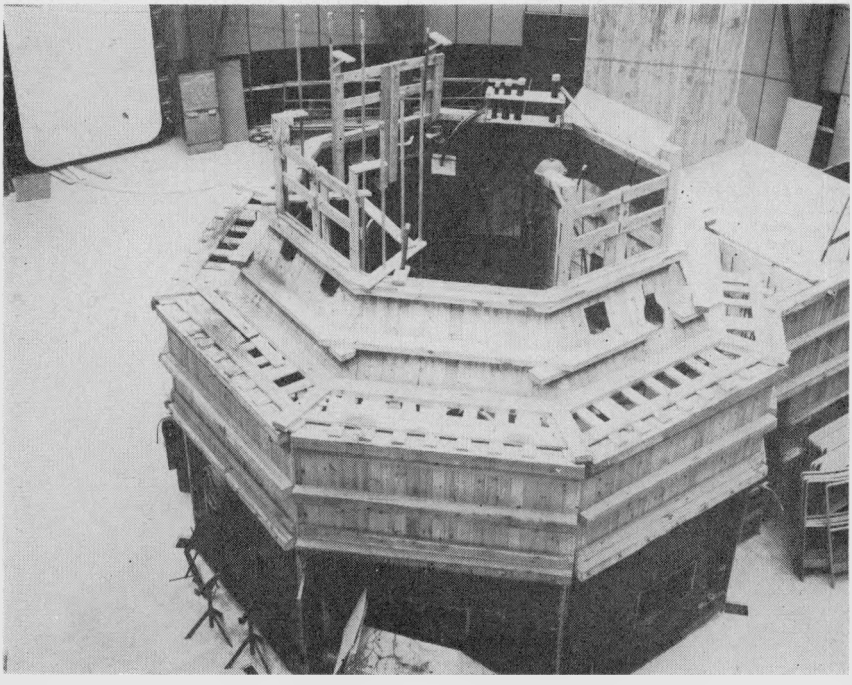


Spain. View of thermal column, beam ports and pool liner of research reactor being built for the Junta de Energia Nuclear in Madrid.

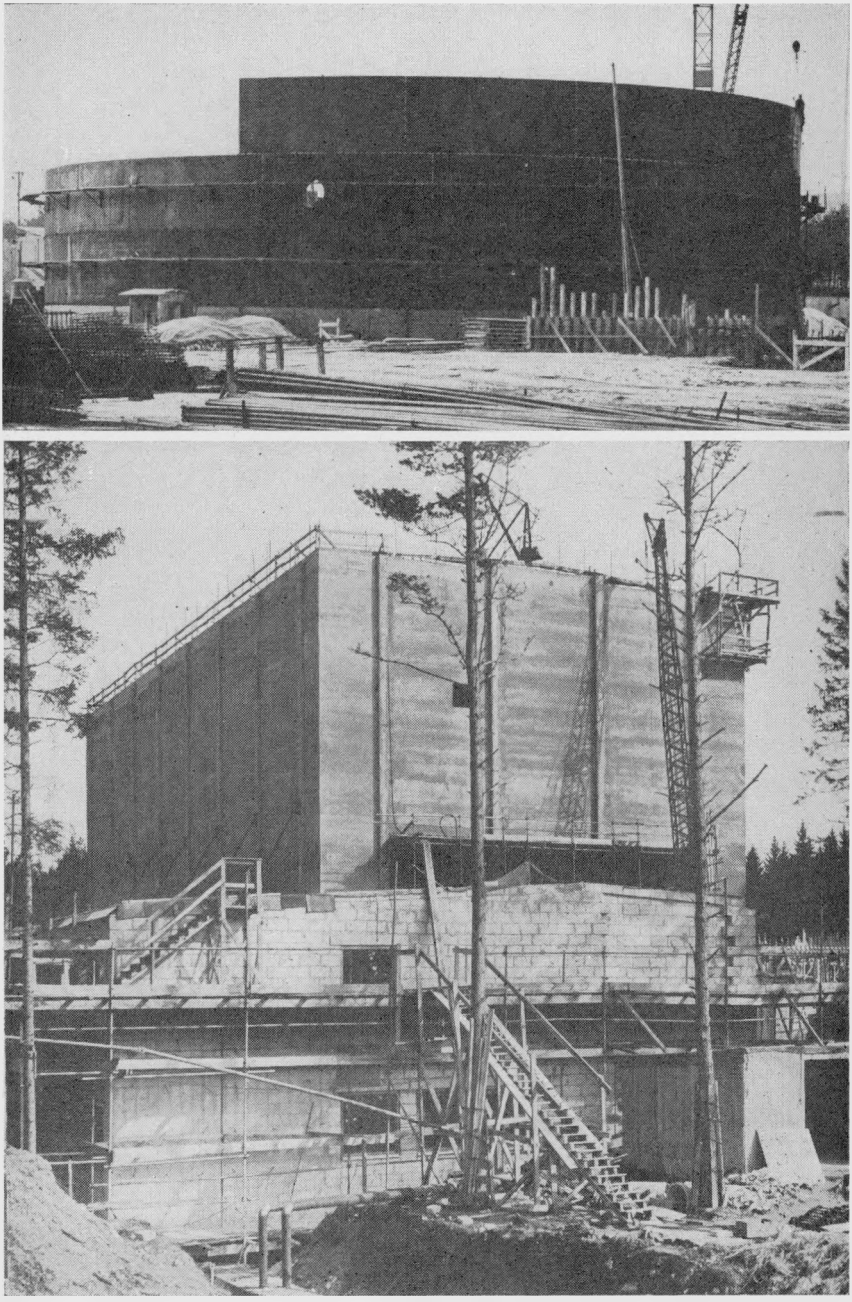


Portugal. Construction view of the Portuguese Nuclear Center where a pool research reactor will be located.

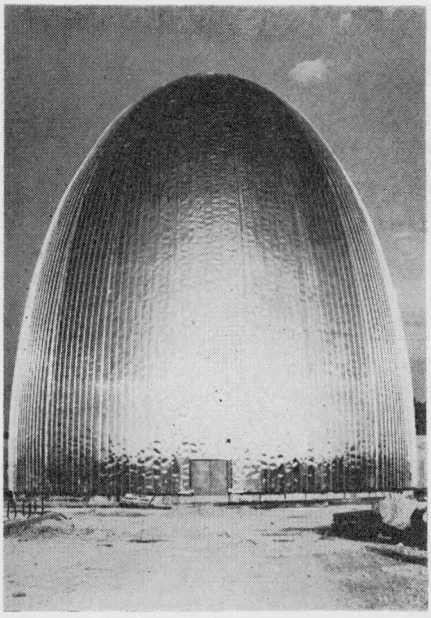


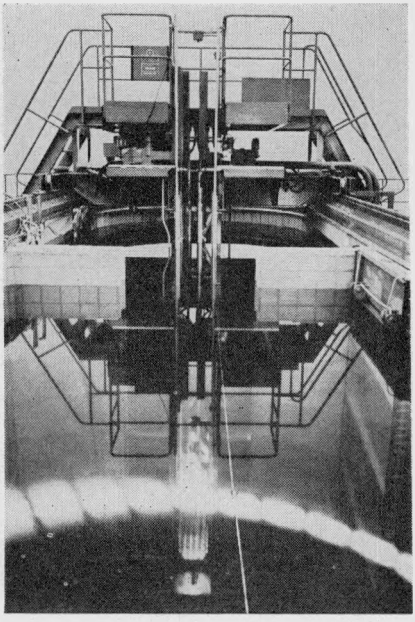


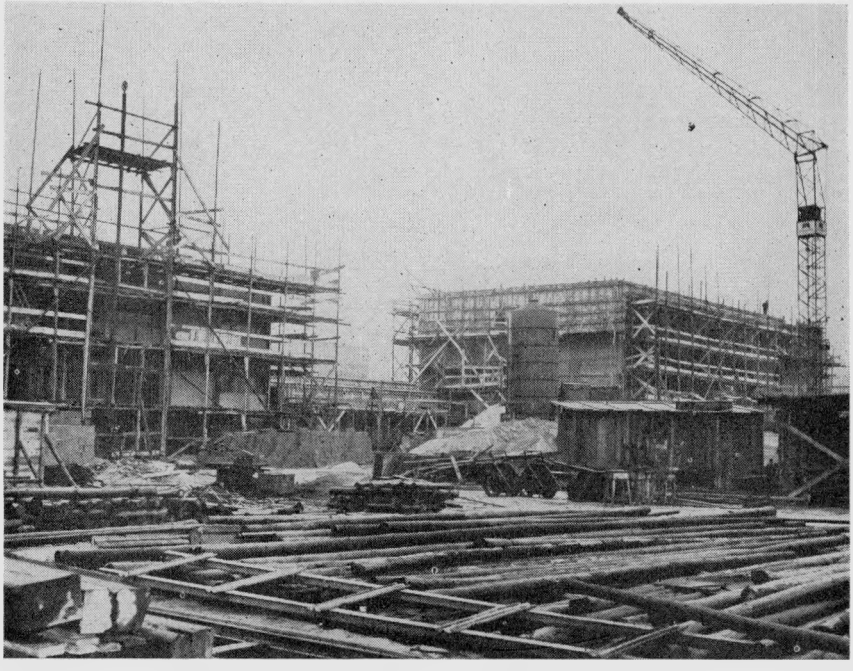
Denmark. Physicists at work with the Danish Reactor No. 1 (DR–1); below, view of the containment tank of DR–2. Both reactors are located at Risoe, the Danish Atomic Energy Commission nuclear research center.



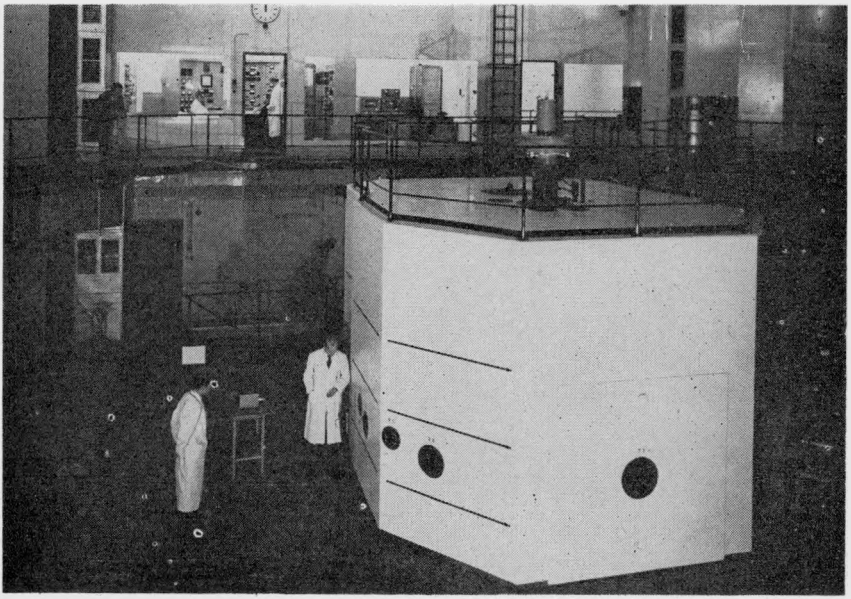
Belgium. Containment building of Materials Test Reactor (BR–2) which is of Belgian manufacture with U. S. design assistance. *Sweden.* Construction view of the Swedish Atomic Energy Co. nuclear project which will house the materials testing reactor (R–2).

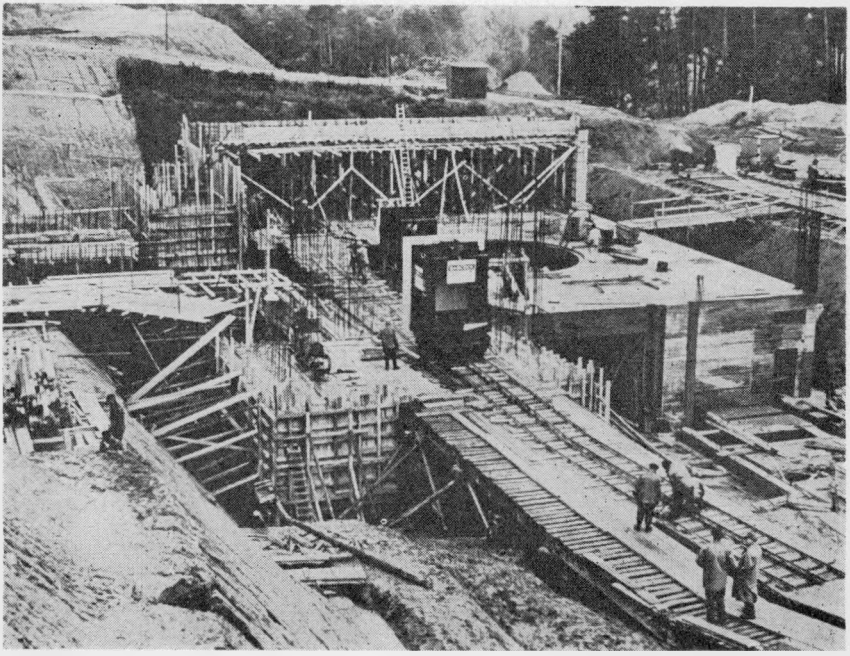




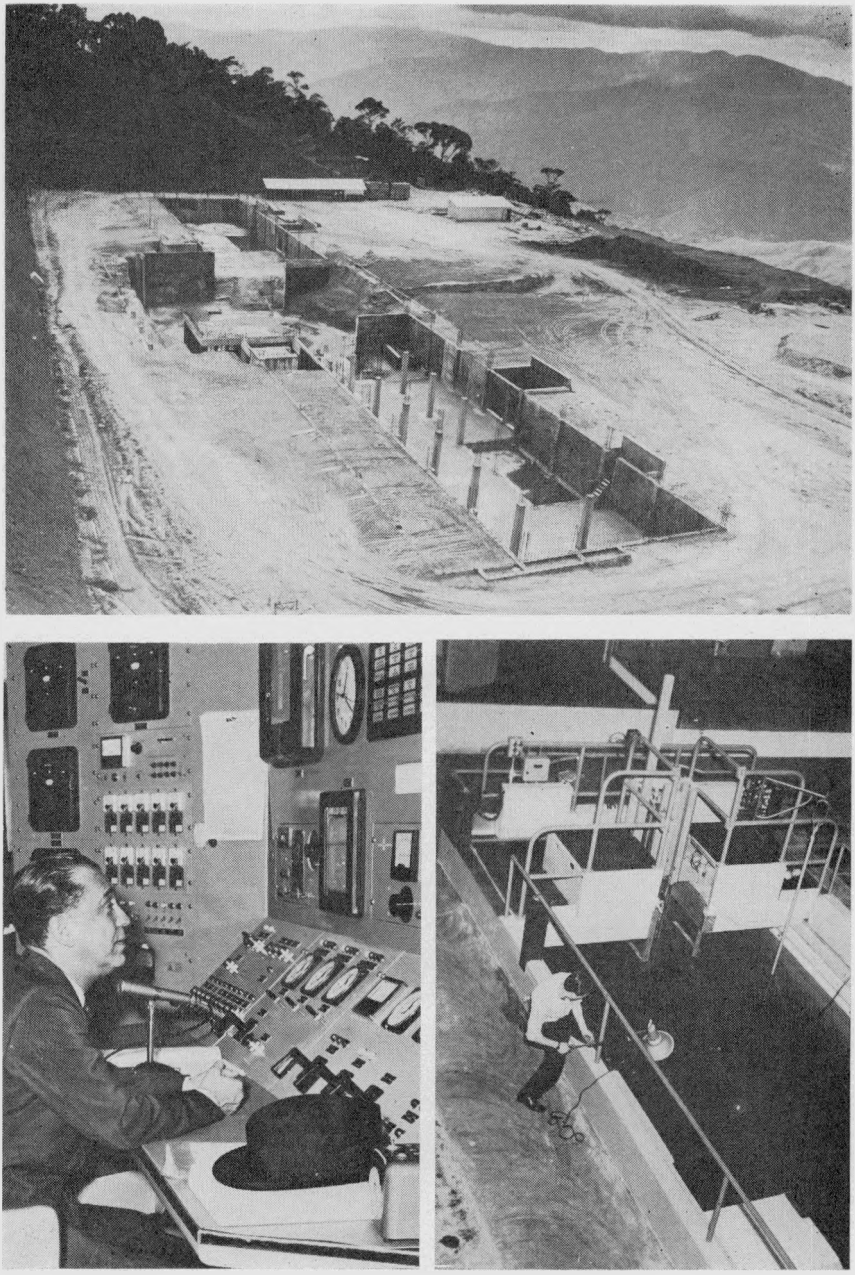


Germany. Left, containment building of the Munich Technical University's research reactor; right, bridge and control rod drive of the Munich reactor; below, general view of construction at the Berlin nuclear center showing the reflector tank for the research reactor.

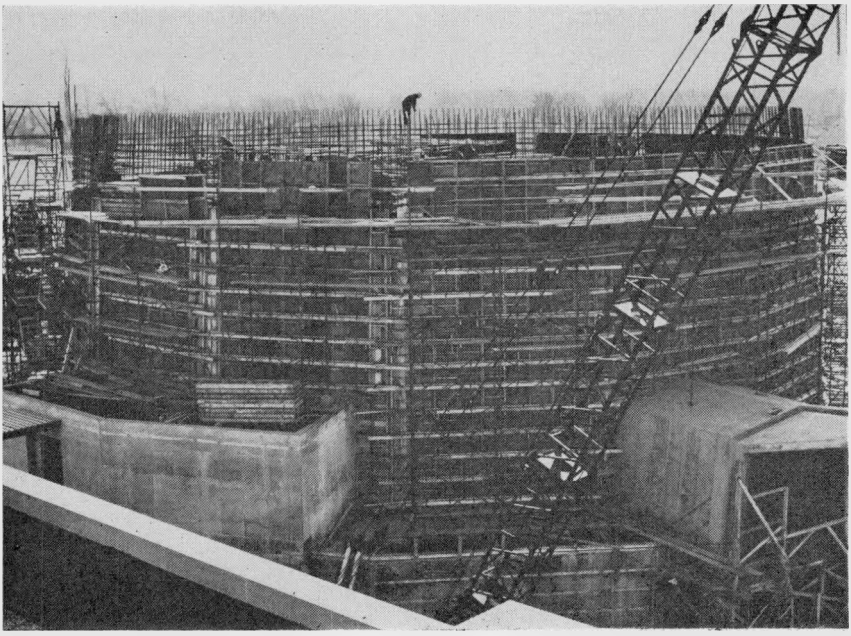




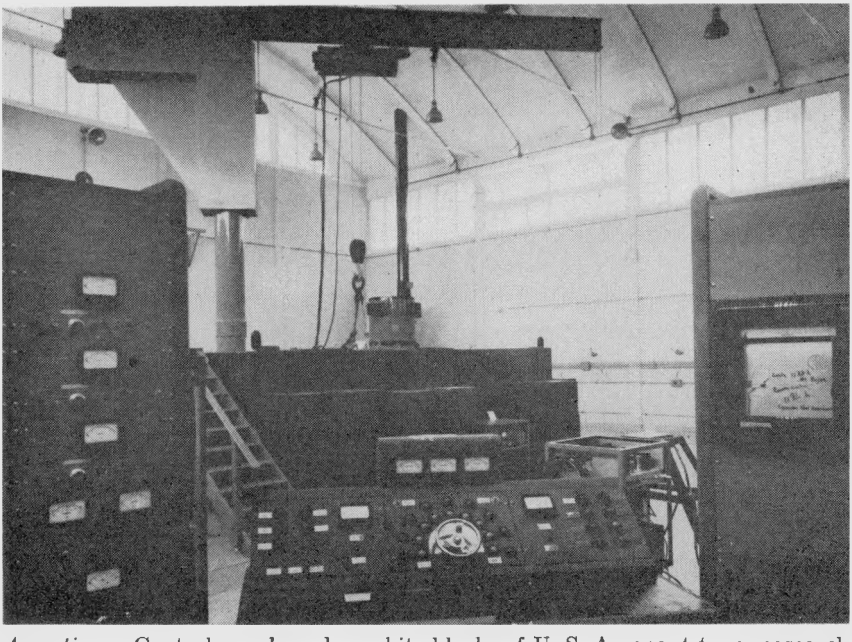
Germany. Reactor and control facilities of the research reactor at the University of Frankfurt; below, construction view of Hamburg site where a pool-type research reactor will be located.



Venezuela. View of building foundations for the research reactor located near Caracas. *Brazil.* Below, left, President Kubitschek at the control panel of the research reactor at the University of Sao Paulo; right, view of pool and drive mechanism of Sao Paulo reactor.



Canada. Construction view of containment building housing the McMaster University research reactor, Hamilton, Ontario, built by an United States firm.



Argentina. Control panels and graphite blocks of U. S. Argonaut type reasearch reactor built by Argentine manufacturers. The United States supplied the nuclear fuel for this reactor located at Buenos Aires.

Republic of China. The Commission approved a $350,000 research reactor grant to the Republic of China to be used toward the construction of a 1-megawatt pool research reactor at the Institute of Nuclear Science of National Tsing Hua University at Hsinchu, Formosa.

Ecuador. A school of nuclear science was established at the National Polytechnic School in Quito, Ecuador. A former Brookhaven National Laboratory scientist supervised a radioactive isotopes techniques course offered at the school in April.

France. During the January–June reporting period, shipments to France included fuel elements containing 5.51 kilograms of contained uranium 235 for the "Melusine" reactor at Grenoble, and 1.98 kilograms of contained uranium 235 for use in metallurgical experiments with the "EL–3" research reactor at Saclay. Also shipped were milligram amounts of thorium oxide and highly purified uranium 234, 235, and 238.

Federal Republic of Germany. Of 4 research reactors West Germany has bought from United States firms, 2 were in operation as of June 30. A pool reactor at the Technical University of Munich has been operating since October 1957. A $350,000 grant has been approved for this reactor. A water boiler at the University of Frankfurt began operating in January. The West Berlin Institute for Nuclear Research water boiler and the pool research reactor at the Society for the Utilization of Nuclear Energy in Shipbuilding and Navigation in Hamburg were scheduled to go into operation during the summer.

Greece. The United States agreed to contribute $350,000 toward the cost of a pool reactor project being built at the new Greek "Democritus" nuclear research center, near Athens. The Government of Greece has expressed interest in negotiating a power bilateral agreement to supersede its research agreement in effect since 1955.

Iran. The University of Tehran signed a contract with a United States company for construction of a 1-megawatt research reactor.

Israel. The Commission approved a $350,000 research reactor project grant to Israel to be used toward the cost of constructing a 1-megawatt pool reactor at Nebi-Rubin, near Rehovoth.

Italy. The United States has committed $350,000 toward the cost of a heavy water research reactor project under construction at Ispra in Northern Italy.

During the reporting period, 1,998 kilograms of reactor-grade normal uranium slugs were shipped to Italy for use in a subcritical assembly at the University of Cagliari, Sardinia.

The comprehensive agreement for cooperation with Italy, which became effective April 15 provides for the transfer to Italy of 7,000 kilograms of uranium 235 over a 20-year period for use as fuel in research, experimental power and full-scale power reactors. This is the largest fuel authorization in any bilateral agreement.

Japan. A comprehensive 10-year agreement for cooperation was signed with the Government of Japan June 16. When effective, it will supersede the 1955 research agreement.

Under the earlier agreement, Japan received fuel for its first research reactor, a 50-kilowatt water boiler which went critical in August 1957. Fuel also will be provided for a 10-megawatt CP–5 type of research reactor which is under construction.

The comprehensive agreement will provide for transfer of 2,700 kilograms of uranium 235 for use as fuel in research, experimental power, demonstration power, and full-scale power reactors. Among Japan's projects are a 50 thermal megawatt experimental power reactor scheduled for operation in 1961, and a full scale 150,000 electric kilowatt power reactor scheduled for operation in 1964. It is planned that both of these reactors will use enriched uranium and be water cooled.

Lebanon. Two senior staff members from the Oak Ridge Institute of Nuclear Studies went to Beirut, Lebanon, in March to assist the American University of Beirut in a 4-week course on the uses of radioisotopes.

The Netherlands. Arrangements were completed to lease to The Netherlands fuel for a high flux 20 thermal megawatt tank-type research reactor being built at Petten.

Panama. The Government of Panama indicated that it might be interested in negotiating a research agreement for cooperation.

Spain. The comprehensive agreement for cooperation with Spain, effective February 12, covers a 10-year period and provides for the transfer to Spain of 500 kilograms of uranium 235 for use in research, experimental power, and power reactors. Gram quantities of other special materials may be provided for defined projects as well as up to 6 kilograms of uranium 235 in 90 percent enriched material.

Sweden. The Commission approved a $350,000 reactor project grant to the Swedish Government toward the cost of a high flux materials testing reactor project at the Studsvik nuclear research center.

Materials Transactions

In addition to the shipments to Australia, France, and Italy reported earlier, special nuclear material transferred during the first half of 1958 included kilogram amounts of ultra high purity depleted uranium metal and milligram quantities of thorium, uranium and plutonium isotopes to the United Kingdom. Canada received several kilograms of enriched and normal uranium, milligram amounts of neptunium and plutonium isotopes, and 5 tons of heavy water.

During the January–June reporting period uranium containing more than 8.5 kilograms of uranium 235 was shipped to foreign countries, for a total to date of nearly 75 kilograms of contained uranium 235.

Six tons of heavy water was shipped abroad during the first half of 1958, bringing total shipments through June 30 to about 252 tons. See table II, Materials Shipments to Foreign Countries, December 1957–June 1958.[12]

TABLE II.—MATERIALS SHIPMENTS TO FOREIGN COUNTRIES, DECEMBER 1957–JUNE 1958

DATE SHIPPED	COUNTRY	URANIUM		OTHER MATERIALS	TYPE OF TRANSACTION	PURPOSE AND REMARKS
		Kg. U-235	Percent enriched U-235			
1957						
Dec. 3	Canada	0.32	90		Sale	For research.
Dec. 3	Canada	1.00	20		Sale	For research.
1958						
Jan. 15	United Kingdom.	(a)	(b)		Exchange	Exchange for U. K. niobium.
Jan. 15	United Kingdom.			Th-230, U-236, U-238 (milligram amounts).	Loan	Loan for research special isotopes; quantities vary from about 30 to 100 milligrams.
Jan. 28	Canada	1.02 UO_2	90		Sale	For research.
Feb. 11	France			U-234, U-235, U-238 (milligram amounts).	Gift	Special isotopes for research.
Mar. 4	France	1.98	20		Sale	Enriched U metal for non reactor research.

See footnotes at end of table.

[12] For list of earlier shipments, see pp. 201–202, Twenty-third Semiannual Report to Congress (July–December 1957).

TABLE II.—MATERIALS SHIPMENTS TO FOREIGN COUNTRIES, DECEMBER 1957–JUNE 1958—Continued

DATE SHIPPED	COUNTRY	URANIUM		OTHER MATERIALS	TYPE OF TRANSACTION	PURPOSE AND REMARKS
		Kg. U-235	Percent enriched U-235			
Mar. 4	France	5.51	20		Lease	In fuel elements for "Melusine" research reactor.
Mar. 5	Australia			Heavy water 1 ton.	Sale	For research reactor.
Mar. 10	Italy			1,998 kg. U (in slugs)	Sale	Canned U slugs for subcritical assembly for University of Caligari (Professor Rollier).
Mar. 14	Canada			2 kg. U (normal metal).	Sale	For research.
Mar. 21	Canada			Heavy water 5 tons.	Sale	For NRX and NRU reactors makeup.
Mar. 25	Japan	(a)	20		Lease	Contained in 3 fission counter tubes (1.035 grams U-235).
Mar. 27	Belgium			3 kg. (normal UO_2).	Exchange	Exchange with Belgium for 3 kg. UO_2 for research.
Mar. 27	Belgium	(a)	90		Gift	2.6 milligrams U_3O_8 on gold foils for Brussels World Fair, 1958.
Mar. 27	Canada			0.193 kg. U (normal).	Gift	Uranium-silicon alloy for research at AECL.
Mar. 28	France			Th-230 (milligram amount).	Gift	Special isotope for research: about 5 milligrams Th-230 as oxide.
Apr. 10	United Kingdom.	(a)	(b)		Exchange	Exchange for U. K. niobium.
Apr. 11	United Kingdom.			Pu isotopes (milligram amounts).	Loan	Cross section measurements.
Apr. 23	Belgium	(a)	90		Sale	1.72 grams U-235 for fission counter tube.
Apr. 24	Canada	0.025	90		Sale	For research.
Apr. 28	Canada			Np 237 (milligram amount).	Gift	For research.
May 5	Canada			Pu 240 (milligram amount).	Gift	For analytical chemical research.
May 20	Switzerland	(a)	20		Sale	0.344 grams U-235 for fission counter tube.
May 27	Norway	(a)	90		Sale	0.02 grams U-235 on platinum foils for research.
May 29	United Kingdom.	(a)	(b)		Exchange	Exchange for U. K. niobium.
June 16	France			Np 237 (milligram amount).	Sale	100 milligrams for research.
June 20	Denmark			U-233 1 gram	Sale	For exploration in Greenland.
June 20	France	0.179	20		Lease	For "Triton" research reactor.

[a] Amount less than 10 grams contained uranium 235.

[b] Depleted uranium containing less than 0.71 percent of uranium 235.

Equipment Grants

The Commission approved establishment of a program of assistance to foreign nations in the acquisition of equipment other than research reactors for nuclear training and research. Grants will be made generally for a specific, integrated and largely self-sufficient assortment of equipment.

Some of the assortments, or "package laboratories," for which equipment grants may be considered are: a general radioisotopes research laboratory, a radioisotopes techniques training laboratory, a nuclear engineering training laboratory with a subcritical assembly in connection with which a neutron source can be made available, a gamma radiation facility which includes a neutron source, a clinical medical laboratory, or other similar project.

Grants are given also for equipment not included in "package laboratories" which will advance a nation's nuclear training and research program.

The first grants under this program, totaling about $168,000 were made: to Greece for equipment of a nuclear engineering laboratory; to Italy, for a cobalt 60 gamma-ray source for agricultural uses; to Uruguay, for a biochemical laboratory, a medical diagnostic laboratory and a cobalt 60 teletherapy unit.

International Conferences

Conference on Peaceful Uses of Atomic Energy

The United Nations second International Conference on the Peaceful Uses of Atomic Energy (September 1–13 in Geneva, Switzerland) is expected to have an attendance of approximately 1,800 leading scientists and engineers from more than 60 nations.

The United States program at the conference, organized by the Commission at the request of the Department of State, will cover a wide range of the peaceful applications of nuclear science and technology. Universities, private research institutions, industry, Commission staff, laboratories and contractors, and other government agencies—all are making contributions. United States participation will include:

(*a*) More than 700 technical papers dealing with aspects of the atomic energy program.

(*b*) Seventy-two exhibits, including two nuclear reactors and scores of operating demonstrations and experiments which will depict,

among other research, progress in research on the production of power from controlled thermonuclear reactions. The exhibits will fill an area of 40,000 square feet—more than 5 times the area occupied by the United States exhibit in the Geneva Conference of 1955.

(*c*) A specially designed, rear-projection motion picture exhibit hall with an extensive library of short, new technical films with four-language sound tracks that can be listened to selectively.

(*d*) A technical information center in which current technical books and pamphlets published in the United States on the subject of atomic energy will be available for reference in addition to the technical library which the United States donated during the 1955 conference.[13]

In addition, the Commission and United States firms will participate in a commercial exhibit concurrent with the conference. Two United States firms will have research and training reactors on display there.

A major emphasis of the 1958 conference will be nuclear production of electric power. Complementing the United States papers on power reactors will be an exhibit demonstrating the principal avenues of approach in the search for means of producing power from controlled thermonuclear reactions and including a number of operating research devices previously used in the Commission's research program.

Conference organization. Broader in scope, the 1958 conference will be organized along the same lines as the first international meeting three years ago in which 73 governments and 8 specialized United Nations agencies participated.

Officers of the conference, as nominated through the United Nations organization, are: President, Francois Perrin, France; Vice Presidents, Dr. W. B. Lewis, Canada; Dr. Homi Bhabha, India; Prof. V. S. Emelyanov, Union of Soviet Socialist Republics; Sir John Cockcroft, United Kingdom, and Prof. I. I. Rabi, United States. Three other vice presidents are to be nominated before the conference convenes.

Direction of the conference is in the hands of the Secretary-General, Dr. Sigvard Eklund, Sweden, assisted by a staff of scientific aides drawn from the participating countries and including, from the United States, Frank Bruce, Oak Ridge National Laboratory, chemical specialist; William Okrent, Argonne National Laboratory, reactor specialist; Thomas Coor, Princeton University, thermonuclear specialist; and John Martens, Argonne, editor of the proceedings.

Each participating nation will have a delegation of up to 5 official representatives, with alternates, observers, secretariat, and a delega-

[13] The 1955 conference was described on pp. 3–27, Nineteenth Semiannual Report to Congress (July–December 1955).

tion of scientists and engineers who will participate in conference sessions. The United States conference representatives and staff will total approximately 650 persons this year, as compared with 418 in 1955. This includes, besides some 200 delegates, an exhibit staff of 180, a secretariat and information staff, plus more than 100 interpreters and similar staff to be employed locally.

Evidencing the expansion of interest in nuclear fields since the 1955 conference, the number of technical papers for the conference—2,300 in all—is more than twice the total of 3 years ago, with the largest proportionate increases among small nations. More than a fourth of the 1958 Conference papers were submitted by the United States. To accommodate discussions of the papers to be presented by all nations, the number of both plenary and parallel technical sessions was increased, about 80 plenary and technical sessions being scheduled, the latter running in five parallel series.

The exhibits will be housed in a separate exposition building, erected at a cost of $320,000 by the United Nations on the grounds of the Palais des Nations where the conference sits. It will provide 75,000 square feet of space—much more than was available for exhibits in the Palais itself in 1955. The national exhibits of the 19 nations requesting space will be shown here; the United States will be the largest single exhibitor. Construction of the building began in April and was scheduled for completion in July. The first portions of the United States exhibit were shipped in June and were to be installed before completion of the building.

Early UN preparations. The principal instrument of the United Nations for organizing the 1958 Geneva Conference was the UN Advisory Committee on the Peaceful Uses of Atomic Energy, created in 1954. By Resolution 912 (X) of December 3, 1955, the life of the committee was extended to permit it to serve as the planning body for the second international conference.

The committee has held three working sessions, the first in Geneva on May 6–8, 1957, to recommend suitable dates, location, and tentative agenda for the conference. Prior to the Geneva meeting, representatives from the United Kingdom, France, Canada, and the United States drafted a proposed agenda. Date and site of the conference were fixed at this meeting.

With only minor changes, the Advisory Committee approved the rules of procedure adopted at the 1955 conference. The proposed topical agenda was discussed item by item and revised.

Nomination of conference officers was made when the Advisory Committee met in New York on November 2, 1957. In response to the Secretary-General's request, countries represented on the Advisory

Committee subsequently submitted their nominations for vice presidents.

At the third meeting of the Advisory Committee, held in Geneva May 7 and 8, the proposed conference program prepared by Dr. Eklund's staff on the basis of abstracts submitted by the participating nations was considered for each session established in the provisional agenda. The committee established the hours during which the exhibits building will be open, approved the UN presentation of films with the multilanguage system developed for the United States film program. The Advisory Committee will hold a final meeting in Geneva August 29 to review the final conference program.

United States preparations. Preparations for United States participation in the 1958 conference were initiated formally in September 1956 when an Office for International Conference (OIC) was established by the General Manager to plan and coordinate the United States Technical Program. Edward R. Gardner, Director of the Office of Special Projects, was appointed Executive Director of OIC, and Howard C. Brown, Assistant Director for Administration of the Division of Biology and Medicine, was named Director for Administration of OIC.

During the summer and fall of 1957 a planning staff and a skeleton force, comprised of Commission personnel supplemented by technical personnel from other agencies and institutions, undertook to marshal the scientific and technical resources of industry, private institutions and the Government in a comprehensive presentation of United States accomplishments in the peaceful uses of atomic energy. The entire scientific and industrial community was invited to contribute technical papers, exhibits, and films to the United States program. To encourage, evaluate, and assemble these contributions, a scientific staff was assembled late in 1957 under the direction of Dr. L. D. P. King, a staff leader in reactor development at the Los Alamos Scientific Laboratory, which is operated for the Commission by the University of California, who was appointed Technical Director of the Office of International Conference. Under Dr. King's direction, an advisory committee and 26 review committees in various technical fields were set up to invite and review scientific contributions.

Technical papers. More than 6,000 organizations and persons were invited to submit abstracts of technical papers suitable for presentation at the conference, including staff members and employees of hospitals and educational, industrial, government and scientific institutions, and of the Commission and its contractors.

Of 1,499 abstracts received, more than 700 were recommended by

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the technical review committees, and transmitted to the United Nations for inclusion in the conference proceedings. Of these, 160 papers were recommended for oral presentation. The United Nations later scheduled nearly 200 United States papers for oral presentation. This compares with 512 United States papers submitted for the 1955 conference and 158 presented orally.

The United States submitted papers for publication or presentation in connection with all major topics to be discussed at the conference, including such subjects for plenary sessions as the future of nuclear power, experience with nuclear powerplants, other peaceful uses of atomic energy, progress in the use of isotopes, operation experience in health and safety, recent developments in fundamental physics, and the possibility of developing controlled thermonuclear reactors.

For technical sessions in series A of the five series, United States papers report work in such fields as theoretical and experimental aspects of plasma physics, controlled fusion devices and instrumentation, nuclear data and reactor theory, and the basic physics of nuclear energy.

Series B papers cover experience in the design, construction, and operation of power and experimental reactors; reactor physics and economics; and reactor fuel cycles.

Series C will include a wide variety of subjects related to nuclear chemistry. Topics to be discussed are: the basic chemistry of nuclear energy, the chemical effects of radiation, isotope separation methods, the processing of irradiated fuels, the handling of radioactive materials, and the treatment of radioactive wastes.

Series D will be concerned with the use of radioisotopes and radiological safety. There will be sessions on the production and use of isotopes in industry and research, including biochemistry, physiology and medicine; dosimetry and radiation standards, the biological effects of radiation, experience in radiological protection, environmental aspects of the large scale use of nuclear energy, and the use of isotopes in agriculture.

Series E will include a variety of topics covering the geosciences in relation to prospecting and the mining of nuclear materials, the production of nuclear materials, metallurgy and ceramics, the properties of reactor materials, the fabrication of fuels, and reactor technology.

The OIC technical review committees evaluated all abstracts and screened them for duplication, checked for completeness of coverage, and in many cases, suggested consolidation of two or more papers for oral presentation.

In addition, all papers were checked for classification and for patent involvement. The Technical Director and the Advisory Committee then weighed the recommendations of technical review committees.

Exhibits. The United States technical papers program will be complemented by the extensive technical exhibit on the Palais des Nations grounds. The United States exhibit will occupy space on the ground floor, balcony and basement of the exhibit building. Design, assembly and operation of the exhibit are in the hands of contractors—Walter Dorwin Teague & Associates, New York, and Union Carbide Nuclear Corp.

The reactor section of the exhibit will feature two working fission reactors: Argonaut, a 10 thermal kilowatt research and training reactor developed by the Argonne National Laboratory, and TRIGA, an isotope producing reactor built by General Atomic, Division of General Dynamics Corp. There also will be a full-scale model of the 38-foot-high pressure vessel and core of the Shippingport Pressurized Water Reactor, the first full-scale reactor designed exclusively to produce commercial power.

The exhibit will include panels and 10 scale models of a number of reactor types, including: the Consolidated Edison Co. Dresden plant power reactor, now under construction near Joliet, Ill.; the Enrico Fermi plant, of the Power Reactor Development Co. now under construction near Monroe, Mich.; the Engineering Test Reactor of the Commission; the Commission's Experimental Boiling Water Reactor, Experimental Breeder Reactor (EBR–2) and reprocessing plant, Homogeneous Reactor Experiment No. 2, Organic Moderated Reactor Experiment, and Sodium Reactor Experiment; the Yankee Atomic Electric Co. plant near Rowe, Mass., and the powerplant of the NS (nuclear ship) *Savannah.*

The reactor section will include also a 12-panel display illustrating the nuclear fuel cycle, from processing of uranium ore through fuel fabrication, chemical reprocessing, and waste disposal. Small operating models demonstrate recent technological developments.

Also included in the United States display are 16 exhibits concerned with basic physical sciences, 20 in the life sciences, and three operating laboratories. The latter includes a health and safety laboratory which will monitor the United States exhibit; a radiochemistry and isotope laboratory, and a third laboratory in which carbon 14 and tritium labeling techniques will be demonstrated. An electronic computer will be available for use in laboratory demonstrations.

In addition, a special exhibit will be presented on the principal research paths now being followed by the United States in quest of power from controllable sustained thermonuclear reactions. The principles being explored in United States controlled thermonuclear programs, which will be demonstrated at Geneva, are described in Part Two of this report. Devices from Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, Princeton University, and

University of California Radiation Laboratory, which are conducting Commission research in thermonuclear power, will be demonstrated at Geneva in an exhibit produced for the Commission by Union Carbide Nuclear Corp. Exhibited laboratory machines will include:

(*a*) A DCX, a scaled-down version of a thermonuclear machine developed at the Oak Ridge National Laboratory.

(*b*) The B–2 Stellerator from Princeton University.

(*c*) Scylla-G, a machine using the magnetic mirror principle and "shock" heating of the enclosed gases or plasmas, from the Los Alamos Scientific Laboratory.

(*d*) The plamsa accelerator, also from Los Alamos.

(*e*) The S–4 Perhapsatron, an operating toroidal machine which demonstrates another approach at LASL.

(*f*) A machine demonstrating the "pinch effect" principle.

(*g*) A Pyrotron exhibit, consisting of four models from the University of California Radiation Laboratory.

(*h*) The Homopolar Device, from UCRL.

(*i*) The Triaxial Pinch Machine, also from UCRL.

Film program. The United States will operate in the exhibit pavilion a motion picture theater for short technical films which will permit simultaneous running of four films, each in a separate bay. Each film will have a four-language sound track—the official conference languages, English, French, Spanish and Russian—and each member of the audience may listen through earphones to whichever language he selects.

A total of 27 films, ranging in length from 5 to 15 minutes, will be available at the theater, each covering phases of nuclear science and technology.

In addition to these short subjects, the Commission prepared 17 films of one-half hour or more in length which will be exhibited by the United Nations in two UN theaters in the Palais des Nations.

The films cover many phases of reactor construction and operation; fuel processing and reprocessing; fuel element fabrication; the use of radioisotopes in medicine, biology and industry; controlled thermonuclear research; high energy particle acceleration; the use of the bubble chamber in high energy physics research, and other allied activities.

The films made especially for the conference will be added to the Commission film libraries after the conference.

Technical information center. The wide variety of United States technical books, journals, reports, bibliographies, and other informa-

tional materials available to governments and private industry throughout the world will be displayed and distributed at the Technical Information Center in the United States exhibit at Geneva. The information center will include a library of 300 to 500 books, single copies and bound volumes of technical journals, a card catalog of all Commission technical reports, and files of microcards and filmed engineering drawings which delegates may study at their leisure. Technically qualified attendants will explain to delegates the uses of Atoms for Peace libraries and other United States technical information available to other countries. Techniques for searching technical literature will be explained and requests will be accepted for copies of the books, journals, and reports on display.

Presentation volumes. As a permanent record of the development of peaceful uses of atomic energy in the United States, sets of books comprising 13 volumes of technical information will be presented to the official representatives of each national delegation and to international organizations participating in the conference. The volumes will cover major aspects of the United States atomic energy program, including recent developments in various power reactor systems, research reactors, uranium ores, metallurgy, radiation and isotopes, controlled thermonuclear reactions, and reactor physics. In addition to the volumes on specific technical subjects, all delegates will be given a commemorative presentation volume which will describe the United States atomic energy program in general terms.

In selecting topics for the presentation volumes, comprising more than 7,500 book pages of new technical information, the Commission was able to rely heavily on manuscripts already being prepared as a part of its normal writing program. Fifteen volumes on important technical subjects by outstanding scientists at leading universities, laboratories and research organizations were near enough to completion to be considered. On the basis of subsequent progress, 11 books sponsored by the Commission were selected for the presentation set as were two other technical volumes scheduled for publication in 1958 by commercial publishers.

Contracts were signed early in 1958 with the McGraw-Hill Book Co. and Lytle Engineering Manufacturing Co. to assist in illustration and editorial work on several manuscripts. From three commercial book publishers who submitted proposals for publication of the presentation sets, Addison-Wesley Publishing Co., Inc., was awarded the contract for publishing the books.

Commercial exposition. Concurrently with the International Conference, a commercial exposition on atomic energy will be held at the

Palais de Expositions in downtown Geneva. It is sponsored jointly by the Swiss Federal Council, the State Council of the Republic and the Canton of Geneva, and the Administrative Council of the city of Geneva.

Approximately 50 United States companies will present exhibits to demonstrate the variety and quality of nuclear equipment, products, components and services available from United States industry. A special feature of these displays will be two operating research and training reactors—the 100-milliwatt, portable AGN–201, manufactured by Aerojet-General Nucleonics, a subsidiary of the Aerojet-General Corp., and the 10-watt homogeneous L–77, manufactured by Atomics International, a division of North American Aviation, Inc.

The central theme of the United States area, which will occupy approximately 32,000 square feet, will be provided by the Atomic Energy Commission. Contractor for this exhibit is the Atomic Industrial Forum, Inc., which also is coordinating the efforts of private companies participating in the exhibition. The Commission exhibit will consist of a central thematic symbol, designed by Displayers, Inc., to dramatize the cooperative effort of the United States Government and industry in making American materials and technology available for the peaceful uses of atomic energy throughout the world. Surrounding the central symbol will be an information center and an exhibit of the types of products and technology now available in the United States.

Rome Electronic and Nuclear Congress

The United States participated June 16–30 in the Fifth International Electronic and Nuclear Congress and Exhibition, held in Rome, Italy.

Eleven papers dealing with reactor technology and economics, and with the use of radioisotopes in agriculture, industry and medicine, were presented by a United States delegation of 10 representatives.

The United States exhibit at Rome presented a step-by-step explanation of peaceful uses of atomic energy.

The exhibit was in four parts, an initial introductory section on the basis of atomic energy; a second on power production which included a large site model of the Shippingport Pressurized Water Reactor and plant, of other power reactors and of the NS *Savannah;* a third on isotope production and use; and a final section, built around an operating research and training reactor, the AGN–201, emphasizing the United States program of international cooperation, particularly as it relates to Italy.

The last section, through photographs and text, told of 7,000 kilograms of nuclear fuel made available to Italy by the United States.

The technical library presented to Italy was pictured. Italian graduates of the Oak Ridge Institute of Nuclear Studies and the International School of Nuclear Science and Engineering, Argonne National Laboratory, participated in the United States exhibit.

Visits and Technical Exchanges

Active cooperation continued under United States agreements for cooperation covering exchange of specified classified information as well as unclassified information with Australia, Belgium, Canada, The Netherlands, Switzerland, and the United Kingdom.

Classified Visits and Exchanges

During the reporting period, 51 United States representatives participated in 23 classified conferences in the United Kingdom, Canada, and Australia while 86 United Kingdom and Canadian representatives visited the United States to attend 37 classified meetings.

United Kingdom. After a reactor incident at the Windscale installation in the United Kingdom occurred in October 1957 during an operation to anneal the graphite moderator, experts of the United Kingdom and United States discussed the problem of *stored energy in graphite* and methods for safely releasing the energy. Reactor safety factors, and irradiation and oxidation damages to graphite were reviewed and offsite aspects of the incident, including health and safety problems, also were discussed. A cooperative United Kingdom-United States program was planned to study the properties of graphite and its behavior under reactor conditions.

Several conferences on *controlled thermonuclear reactions research* were held in the United States with United Kingdom scientists participating. One Commission scientist from Los Alamos is spending 6 months at the United Kingdom Atomic Energy Research Establishment, Harwell, working with the controlled thermonuclear reactions research group there.

Classified exchanges and discussions also covered specific aspects of several types of reactors, including submarine propulsion, enriched gas-cooled, liquid metal-fueled, and fast reactor types, as well as graphite annealing and feed materials.

Canada. The Ninth Semiannual Joint United States-Canada Sheath Program Meeting was held at the Savannah River plant in February. Classified visits were exchanged in connection with the joint programs

on process development work on feed materials and on heavy water power reactors.

In tripartite *United States-United Kingdom-Canada* cooperation, meetings and discussions were held in connection with the hot loop and nuclear cross sections programs.

Unclassified Visits

On an unclassified basis, arrangements were made during the January–June period for 437 individuals from 42 foreign countries to visit Commission field installations. Included was a 10-man group of parliamentarians from countries of the North Atlantic Treaty Organization and a 12-man group from Japan interested in electric power productivity.

Technical Documents Exchange

During this reporting period, 83 different classified and official use only documents were received from cooperating countries, while the United States transmitted 249. The latter figure includes identical reports submitted to two or more countries in some cases.

Special Education Programs

During the reporting period, the Commission strengthened and improved existing international training and education programs and established new programs.

Puerto Rico Nuclear Center

Plans were completed for administration of the Puerto Rico Nuclear Center by the University of Puerto Rico, announcements of the Center's 1958–59 programs were distributed, and architect and design work progressed on the $3 million construction program.

Dr. Carlos Bonilla, on leave as Chairman of the Nuclear Engineering Department of Columbia University, has accepted the post as Director of Puerto Rico Nuclear Center. The facilities will be owned by the Atomic Energy Commission and a branch of the Oak Ridge Operations Office at Mayaguez administers the contracts.

The University is providing temporary facilities and space pending completion of permanent buildings. The 1 thermal megawatt pool research reactor is scheduled for operation on the Mayaguez Campus by late 1959.

The University of Puerto Rico conducted its first complete 4-week Radioisotope Techniques Training Course during the period August 19–September 13, 1957. Additional courses have been conducted and are scheduled every two months.

Instruction scheduled for the 1958–59 academic year includes a 1-year program in nuclear science and engineering leading to a master of science degree; two semesters in radiological physics leading to a similar degree to be followed by on-the-job experience at the reactor; research and training in the medical field in a cooperative program being set up by the center, the University Medical School and the Cancer Hospital at San Juan; and continuation of the training in radioisotope techniques.

Senior visiting scientists and engineers may apply to the center for temporary assignments for research in their fields. All courses are conducted in Spanish. Applications from United States citizens may be submitted directly to the center at the University of Puerto Rico. Noncitizens may apply through United States embassies in their respective countries.

In cooperation with the University of Puerto Rico, Medical School, the Commission in May sponsored a Health Physics Symposium as related to biology and medicine. Information was exchanged on health physics, and future Latin America needs for training in research use and handling of radioactive materials were discussed. Leading scientists from both Latin America and the United States attended. Papers were published in both English and Spanish.

International School of Nuclear Science and Engineering

Through June 1958, a total of 420 persons had attended the International School of Nuclear Science and Engineering: 92 United States students and 328 foreign students from 43 countries. This includes the seventh group now of 61 students now in training (5 from the United States, and 56 from foreign countries). Training under this program, begun in March 1955, is conducted in cooperation with the Argonne National Laboratory and two participating schools, North Carolina State College and Pennsylvania State University.

Members of the sixth group which completed studies in May, and those of the seventh group now in the last half of their course, made tours of private and government atomic energy installations throughout the United States. In addition to first-hand observations of various atomic energy projects, the group held seminars on the many phases of nuclear technology with scientists at the sites visited.

Enrollment of 50 to 60 students for the eighth course scheduled to begin September 15 is being completed. Applicants are selected by

a Committee on Admissions composed of representatives from the Commission, the Chicago Operations Office, Argonne National Laboratory, the Department of State, the International Cooperation Administration, and the two cooperating schools. Foreign participants must be sponsored by their respective governments.

New training courses. To assist in meeting requirements for training related to foreign reactor projects, the Commission is establishing additional training courses in 3 fields to accommodate a total of about 100 foreign nationals:

(*a*) *Reactor Hazards Evaluation* course focused on safety and control procedures related to reactor operations for personnel having the equivalent prerequisites of completion of the course of the International School of Nuclear Science and Engineering plus at least 1 year's experience in the nuclear reactor field. This will be offered semiannually with an enrollment of about 10 students per course.

(*b*) *Reactor Supervisors* course providing a variety of experience for reactor operations will include special seminars and lectures related to specific problems, and advanced problems of reactor operation. About 10 students will be enrolled in each of 2 courses per year.

(*c*) *Monitoring Techniques* course to help foreign scientists familiarize themselves with radiochemical and radiation counting procedures, and methods of sampling and analyzing for monitoring environmental conditions. This 6 weeks curriculum will be offered 4 times per year to about 15 students per course.

Oak Ridge Radioisotopes Course

During the January–June reporting period, 255 participants completed the radiosotopes techniques course conducted for the Commission by the Oak Ridge Institute of Nuclear Studies. This brings the totals through June to 2,060 participants of whom 268 have been from 49 foreign countries.

The 4-week courses begun in 1948 have since 1955 included training for foreign personnel equal to 30 percent of a year's total enrollment. Two courses have been given exclusively as part of the Atoms for Peace programs. Foreign applicants apply through United States Embassies in their countries or, if they are in the United States, through their Embassies in Washington. Selections are made by the Institute.

Due to increasing applications for this course, additional facilities were established in May to take 30 additional foreign students a year.

Program Studies and Consultants

The United States also provides consultants to atomic energy programs of other countries by arranging for the assignment of United States scientists and engineers to foreign programs for specified periods. Such United States personnel may be maintained on their regular payrolls, costs may be shared with the recipient country, or the assignment may be funded through Mutual Security or other United States funds.

Individual Training Programs

During the current 6 months, contacts have been made for 150 students from 42 nations to enter special individual training programs. This is in addition to the approximately 50 persons accepted directly under the special opportunities offered at the national laboratories.

In this supplementary program the Commission provides a service by arranging on an individual basis for education of foreign students at universities, colleges or other United States institutions, and for advanced on-the-job training at national laboratories. Such training is highly selective and primarily related to advancing a particular country's atomic energy program pursuant to an agreement for cooperation.

Atoms for Peace Libraries

A workshop for representatives of nations in Europe and the Middle East to which unclassified Atoms for Peace libraries have been presented was held May 26–30, at Geneva, Switzerland. Lectures and demonstrations were given to explain in detail the United States system of recording and making maximum utilization of technical library collections. Forty-three representatives from 20 countries and international organizations were present.

The workshop was held in response to requests for assistance from European and Middle East nations which use methods of indexing and reference that vary from United States practices. Workshops may be held in other areas if the need arises.

During the January–June reporting period, three additional unclassified technical libraries were approved for presentation to Honduras, Iran, and Poland. Atoms for Peace depository libraries now have been authorized for presentation to 54 nations, to 5 international organizations, and to the city of West Berlin.

Scientific Representatives Abroad

With establishment of a Tokyo office in November 1957, five Commission Offices of Foreign Scientific Representatives were in operation. The other four are at Chalk River (Canada), London, Paris, and Buenos Aires.

In support of the Atoms for Peace program and as Commission representatives, the services performed included (*a*) participating in conferences and negotiations abroad between United States and foreign officials on the many aspects of the Atoms for Peace program; (*b*) providing assistance to foreign atomic energy programs; (*c*) keeping Washington informed on the progress of atomic energy programs of other nations; and (*d*) serving as contact points for visiting United States officials dealing with atomic energy matters. Representative examples of their work are cited below.

The Chalk River office submitted a comprehensive technical analysis of the Canadian heavy water power reactor and research programs and covered in detail operations of the NRX and NRU reactors. The London office reported on technical developments of the Windscale incident and participated in the ensuing conferences related to graphite research. The Paris office held numerous meetings with officials of the newly developing regional atomic energy authorites. The Buenos Aires scientific representative provided assistance to the biological, chemical and medical aspects of the Argentine program and traveled extensively in South America to advise and assist the atomic programs of various Latin American countries. The Tokyo representative held numerous conferences with personnel of the Japanese Atomic Energy Commission and made special reports on nuclear developments in that country. He also participated in the Commission's New Zealand and Australian missions and visited Thailand and the Republic of Korea, providing technical assistance to these countries in developing their newly proposed nuclear programs.

U. N. Scientific Committee on Radiation Effects

At its Fifth Session held at the U. N Headquarters, New York, from June 9–13, the United Nations Scientific Committee on the Effects of Atomic Radiation unanimously approved adoption of a report to the General Assembly on the biological effects of radiation arising from the natural background, medical radiography, industrial uses of radioisotopes, and fallout from nuclear explosions.

The committee voted down a Soviet proposal which would have put the committee on record as favoring an immediate cessation of

nuclear weapons testing. The report was submitted to the Secretary General and later will be made available to the public.

Commercial and Isotope Development

During the past 6 months, the Commission has taken further steps to increase private commercial participation in Federal atomic energy programs, to encourage independent growth of a private atomic energy industry, and to increase the contributions which use of radioisotopes and radiation sources can make to the economy.

The Commission's establishment last December of the Office of Industrial Development, with the specific mission of continuing the encouragement of commercial and isotope development, was reported previously.[14] During this reporting period, new programs in these fields have been evolved and launched. Highlights of the January–June reporting period include:

As a result of growing industrial capability in the atomic energy field, the Commission authorized its field managers of operations under specified conditions to procure from private industry certain Commission requirements for processing and fabrication services.

The Commission announced that it will no longer accept requests from the public for gamma irradiation services which are available from private industry.

Charges were established for the conversion of uranyl nitrate to uranium hexafluoride and plutonium nitrate to plutonium metal, thus completing for reactor operators the cost pattern under interim Commission contracts for chemical processing of used fuel elements. Charges for the sale of depleted uranium were published.

The Commission continued a study of the problem of public liability in connection with reactor sales abroad.

Industrial organizations were queried on their interest in large quantities of lithium 7 at lower prices.

As of June 30, 1,415 permits for access to restricted data on the civilian applications of atomic energy were in effect.

The Commission entered contracts with academic and industrial organizations for research to develop increased use of radioisotopes and radiation sources, and to augment training in industrial applications.

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[14] See p. VIII and p. 305, Twenty-third Semiannual Report to Congress (July–December 1957).

Prices were cut to an average of less than 10 percent of former prices on a series of key radioisotopes.

The responsibility of the Commission for encouraging peaceful uses of atomic energy enters into decisions made in nearly all program areas. The steps taken in these areas are described throughout this report, particularly in the sections on Raw Materials; Reactor Development; Military Applications; International Activities; Licenses, Regulations, Indemnity; Information Services, and Education and Training.

Commercial Development

New Commercial Services

Thorium and uranium materials. The Spencer Chemical Co. was issued a special nuclear materials license in January for the recovery of enriched uranium from scrap and the preparation of uranium compounds from uranium hexafluoride. The Mallinckrodt Chemical Co. was issued a special nuclear materials license in March for recovery of enriched uranium from scrap. Baker & Co.. Newark, N. J., Nuclear Materials & Equipment Corp., Apollo, Pa., and Davison Chemical Co., Erwin, Tenn., were licensed previously to recover unirradiated enriched scrap.

The Davison Chemical Co. has indicated that it now carries thorium oxide and thorium metal in stock. Davison is one of six companies licensed as processors and suppliers of thorium compounds and of thorium metal on a commercial basis.[15]

Gamma irradiation services. On February 18, the Commission announced that, as of March 31, no new requests for gamma irradiation service would be accepted from the public unless private industry cannot readily provide the requested service. A recent Commission survey showed that at least 16 academic and industrial organizations were prepared to provide gamma irradiation service on a commercial basis.

Commercial processing and fabrication. In recognition of the growing industrial capability for processing and fabricating unirradiated nuclear materials, the Commission has authorized its 10 operations office managers to purchase these services and materials from commercial sources in connection with requirements for power and test reactor programs whenever commercial sources are available at reasonable prices.

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[15] See pp. 148–149, Twenty-third Semiannual Report to Congress (July–December 1957).

Prior to the Atomic Energy Act of 1954, the Commission fulfilled its needs from its own plants. In 1955, the Commission initiated purchase of Materials Testing Reactor fuel elements from commercial manufacturers. Fuel elements for the Engineering Test Reactor and those to be used in a reactor safety experimental reactor (SPERT–3) also are being obtained from commercial sources. The recent action extends this policy to procurement of uranium compounds and metal, and of uranium scrap recovery.

The Commission, upon request to managers of operations offices, will furnish prospective commercial processors with samples of scrap that can be used to evaluate shop capabilities and to develop costs for proposals on recovery of uranium scrap.

Large scale sales of lithium 7. The Commission began a survey to determine the extent of interest in use of lithium 7 at a price considerably lower than the catalog price for this stable isotope. Letters were sent to a number of Commission contractors and access permittees engaged in reactor studies requesting estimates of quantities that might be used, the degree of enrichment in lithium 7 required, and the possible delivery date considered. Based on replies, the Commission will determine the desirability of initiating large-scale, lower-priced sale of lithium 7 for civilian uses.

Establishment of Charges

Chemical processing of fuel elements. On March 12, the Commission established the charges it will make for converting the chemical products of processing used fuel elements into the products for which it has announced purchase prices,[16] that is, for converting uranyl nitrate into uranium hexafluoride, and plutonium nitrate into plutonium metal.

These charges would apply to chemical processing services on irradiated fuel elements which, as announced on February 18, 1957,[16] the Commission will provide for an interim period under contracts with reactor licensees in this country, and under agreements for cooperation for foreign reactor operators using United States fuels.

The charges announced this March 12 round out the pattern of the costs of chemical processing. These charges are:

(*a*) Conversion of purified low-enrichment uranyl nitrate (5 percent or less by weight of uranium 235 in total uranium) into uranium hexafluoride, $5.60 per kilogram of contained uranium.

(*b*) Conversion of purified high-enrichment uranyl nitrate (more than

[16] See pp. 41–43, Twenty-second Semiannual Report to Congress (January–June 1957).

5 percent by weight of uranium 235 in total uranium) into uranium hexafluoride, $32 per kilogram of contained uranium.

(*c*) Conversion of purified plutonium nitrate into plutonium metal $1.50 per gram of contained plutonium, as announced on February 18, 1957.

Other charges. The Commission, in the *Federal Register* of June 28, announced the following base charges for depleted uranium, as uranium hexafluoride, f. o. b. Paducah, Ky.:

Assay weight fraction U-235	*Charge per kg. U*	*Assay weight fraction U-235*	*Charge per kg. U*
0.0036 and lower	$5.00	0.0060	26.90
0.0040	8.15	0.0062	29.00
0.0050	16.65	0.0064	31.25
0.0052	18.65	0.0066	33.50
0.0054	20.65	0.0068	35.75
0.0056	22.65	0.0070	38.15
0.0058	24.75		

This material will be sold, on an unclassified basis, for nuclear and nonnuclear purposes, to Commission license holders and, under the relevant laws and regulations, to friendly foreign nations.

Foreign Liability

A major problem facing United States manufacturers of reactors and related equipment who offer their products for sale abroad is public liability in case of reactor accidents. In the United States, the Price-Anderson Act requires reactor operators to show proof of stipulated financial protection up to a maximum liability of $60 million against public liability claims and the Federal Government additionally provides an indemnity up to $500 million.[17] This arrangement covers both reactor operators and suppliers.

Some United States reactor manufacturers have expressed their reluctance to enter into contracts in other countries unless those countries indemnify the suppliers. The Commission, the Department of State, and private groups including the Atomic Industrial Forum, have under study steps which might be taken to assist in this problem. The Commission sent a questionnaire to companies concerned asking them (*a*) to set out their actual experiences with the foreign liability problem, (*b*) to describe any steps taken to ameliorate this situation, and (*c*) to offer any suggestions for United States Government actions that might be helpful.

The answer to the questionnaire confirmed the concern of manufacturers particularly in respect to export of power reactors.

[17] See pp. 177–179, Twenty-third Semiannual Report to Congress (July–December 1957), and later section of this report on Licensing, Regulation and Indemnity.

Provision of Information

Statistics. The Commission has arranged for the Bureau of Census to include atomic energy products in its regular Census of Manufactures for 1958 which will be carried out in 1959. The Bureau of Census this year is conducting a special survey of 1957 manufactures by such classes of atomic energy products as reactor fuel elements, radiation instruments, and radioisotopes. This survey will serve as a test for the regular census questionnaire and the definitions for the various new products involved.

Technical information meetings. During this reporting period, the Commission sponsored five technical information meetings designed to help industry keep abreast of the latest developments in various fields of interest: February 7, Princeton, N. J., "Briefing on Controlled Thermonuclear Processes" (classified); February 12 and 13, Los Angeles, "Forum on Sodium Reactor Experiment and Organic Moderated Reactor Experiment" (unclassified); April 7–9, Baltimore, "Symposium on the Industrial Utilization of Radioisotopes" (unclassified); June 18–20, East Lansing, Mich., "Reactor Fuel Measurement Techniques" (unclassified); and June 26–27, New York City, "Workshop Meeting," on availability and use of technical information (unclassified).

Access permits. During this period an average of 17 permits was granted each month to private individuals and concerns seeking access to restricted data related to civilian applications of atomic energy. As of June 30, a total of 1,415 permits was in effect, 598 for access to confidential restricted data and 817 for access to secret and confidential restricted data.

The number of permits issued for access to secret information continued to increase during the reporting period, and was 11 percent above June 30, 1957.

Access permits are issued for periods of 2 years. Of the 880 permits due to expire at the end of June, 702 or 79 percent have been renewed.

The distribution of permits by geographic area, industry, and field of interest is given in appendix 8, with comparative data for the permits in force as of June 30 and December 31, 1957.

Patent Policy

The Commission has initiated a review of its patent policies and practices during the reporting period. Written comments were invited from contractors of the Commission and a public hearing to

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review and discuss comments was held April 15 in Washington, D. C. The information obtained has been submitted for study to the Patent Advisory Panel of the Commission; discussions have been held with the Panel members and others will be scheduled.

Isotope Development

The Commission inaugurated last December[18] a program designed to accelerate the widespread use of radioisotopes and radiation sources in industry and to encourage their production by private industry.

New Isotope Program

The new Isotope Development Program emphasizes four major areas: Radioisotope Applications, High Level Industrial Radiation, Isotope Technology, and Radioisotope Production and Pricing.

Radioisotope applications. Of the many potential applications of radioisotopes to industrial problems, three basic techniques—gaging, industrial radiography, and oil well stimulation—account for the largest fraction of the estimated annual savings to industry.[19]

The Commission initiated a program of research to develop new techniques and to make more effective use of existing techniques. It contracted for studies as follows:

(*a*) *Armour Research Foundation.* Development and production of isotopic sources of X-rays from secondary radiation in the energy region of 5 to 200 kev from beta emitting radioisotopes.

(*b*) *Tracerlab, Inc.* Development of a radiochemical analyzer for nonradioactive gases.

(*c*) *General Atomic, Division of General Dynamics Corp.* Study of the Szilard-Chalmers process for the production of short-lived, high specific radioisotopes.

(*d*) *Radiation Applications, Inc.* Study of the technology and application of large fission product beta sources.

(*e*) *Battelle Memorial Institute.* Development of radioactive tracer quality control systems.

(*f*) *Nuclear-Chicago Corp.* Exploration of radiometric methods for industrial processes and controls.

(*g*) *Nuclear Science and Engineering Corp.* Development of devices and techniques for industrial applications of radioisotopes.

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[18] See p. 11, Twenty-third Semiannual Report to Congress (July–December 1957).

[19] Devices and techniques in industrial processes were described on pp. 25–34, Twenty-third Semiannual Report to Congress (July–December 1957).

High level industrial radiation. Since successful applications of high level radiation in industry would have national economic significance, the Commission has undertaken a program to accelerate development of this field. Initial activities include the following contracts:

(*a*) *Emerson Radio and Phonograph Co.*, representing the CEM group (chemical-electronic-metals) which also includes General Aniline and Film Corp. and Revere Copper and Brass, Inc. Analysis of existing world technology on industrial radiation and identification of the technical, economic, and managerial factors stimulating or deterring its development.

(*b*) *Atomics International*, a division of North American Aviation, Inc. A feasibility study on using for industrial radiation purposes the sodium 24 in the coolant of the Consumers Public Power District's projected Hallam (Nebr.) Nuclear Power Facility, which will use a sodium-graphite reactor.

(*c*) *Battelle Memorial Institute.* Fundamental research to investigate the feasibility of using inclusion compounds for production of specific isomers, and to provide an understanding of radiation effects on molecules in a state of restricted motion. The formation of branched-chain structures from straight chain hydrocarbons through recombination or rearrangement of free radicals would be of great significance in industrial radiation processing.

(*d*) *Curtiss-Wright Corp.* The proposal submitted by the company for design, construction, and test operation of a 2-megacurie cobalt 60 High Intensity Food Irradiator (HI-FI) at Sharpe General Depot, Lathrop, Calif., for use by the Army Quartermaster Corps in its radiation preservation of foods project, has been accepted as a basis for negotiations.

The availability of megacurie sources of gamma radiation may make possible new techniques in process industries. Improved plastics can be produced, chemical reactions induced, and drugs, and medical supplies, sterilized for storage by high-level radiation. Possible radiation sources for these uses include cobalt 60, cesium 137, unrefined fission products from reactors, and gamma radiation from reactors.

Isotope Technology

The numbers of industrial personnel presently trained in radioisotope technology are inadequate and must be significantly increased if a greatly expanded use of these materials is to be achieved and maximum benefits are to accrue to the national economy. The Commission has initiated a program to broaden the availability of isotope tech-

nology training throughout the United States. As the initial step, a prototype course in industrial applications of radioisotopes is to be developed and offered by the Oak Ridge Institute of Nuclear Studies. Simultaneously, universities and educational institutes will be encouraged to expand facilities for undergraduate and postgraduate training in radioisotope technology. Under a contract with W. H. Johnston Associates, a series of experiments and demonstrations suitable for advanced undergraduate and graduate courses in basic and applied high-level radiation technology is being developed. This company is also conducting a comprehensive research study on fundamental principles and applications of high-level radiation phenomena and technology.

In order to evaluate properly the economic aspects of the growth of isotope technology, assessment of the economics of industrial applications of radioisotopes has been undertaken through a contract with the National Industrial Conference Board.

Medical applications of radioisotopes provide a large and growing market for industrial processors of radioisotopes and manufacturers of associated equipment. Under contract with Stanford Research Institute, the factors contributing to future medical demand will be evaluated. Economies accruing to patients through the use of isotopes also will be assessed.

Radioisotope Production and Pricing

Prices were greatly reduced April 1 for five long-lived radioactive fission products: cerium 144, cesium 137, promethium 147, strontium 90, and technetium 99. The new prices, averaging less than 10 percent of those formerly in effect, are based on estimated costs of large-scale production from the new Multicurie Fission Product Pilot Plant at the Commission's Oak Ridge National Laboratory, Oak Ridge, Tenn. (See section on Physical Research.)

Reduction in prices, designed to encourage widespread use of these radioisotopes, was announced in advance of actual plant operation to give research institutions and industry an opportunity to plan for large-scale use of fission byproducts.

Cesium 137 is being used in medical therapy, and for industrial radiography, density gages, and liquid level gages. It is a potential radiation source for such industrial operations as induction of chemical reactions, polymerization, and sterilization of drugs and surgical supplies. Promethium 147 and strontium 90 have a number of industrial applications, such as in self-luminous sources and atomic batteries. Strontium 90 also is employed in industrial thickness gages and in medical applicators for treatment of certain eye diseases.

Cerium 144 and technetium 99 have not previously been used extensively because of limited availability and high cost.

Licensing, Regulation, Indemnity

The Commission's licensing operations during the reporting period reflected increasing activity among both public and private organizations interested in nuclear research and training programs.

Permits were issued for the construction of 23 research and training reactors, and licenses were issued for operation of 10 research reactors, including the first licensed for use for medical therapy as well as other purposes. Some 60 new licenses were issued authorizing the use of special nuclear material for research purposes. A construction permit also was issued for a large testing reactor to be used for developmental work in the design of fuel elements and other reactor components.

Indicating further growth in uses of radioisotopes for medical and industrial applications, the total number of licensees increased from 3,335 as of November 30, 1957 to 3,750 as of May 31. Licensees for medical uses accounted for 39 percent of the increase.

The Commission is preparing amendments to the temporary regulation published in September 1957 (10 CFR Part 140—"Financial Protection Requirements and Indemnity Agreements"). Amendments will include a revised formula for computing the amounts of financial protection for public liability which reactor licensees are required to obtain, a proposed form of indemnity agreement, and regulations dealing with acceptability of forms of nuclear energy liability insurance policies submitted as proof of financial protection. In the preparation of the proposed amendments, industry advisory groups have been consulted. When completed, the amendments will be published as notices of proposed rule-making, and public comment will be invited.

Minor amendments were issued for some previously issued regulations.

Licensing

Licenses Issued

Production and utilization facilities. During this reporting period the Commission issued a construction permit authorizing General Electric Co. to construct a 30 megawatt test reactor at its Vallecitos Atomic Laboratory in Alameda County, Calif., for developmental work on fuel element fabrication and other reactor components.

Permits were issued authorizing the construction of 23 additional

research reactors, 21 of which are being constructed by one manufacturer for sale. Five research reactors completed by this manufacturer were licensed for operation.

Five facility export licenses were issued, two authorizing shipment of materials testing reactors to The Netherlands and to Sweden, the others approving shipment of three pool research reactors to Republic of China, Israel, and Venezuela.

Four licenses were issued for completed critical experiment facilities.

Applications were filed for licenses to construct and operate a total of 14 research reactors, 10 of which are of the same design to be built by one company for sale to licensed institutions. Applications were filed by 3 educational institutions for licenses to acquire and operate reactors constructed by this manufacturer.

Seven applications were filed for the proposed export of research reactors, one each to Austria, Republic of China, Israel, Spain, and Switzerland, and two to Italy.

One application was filed to construct a critical experiment facility at Greendale, Wis.

Operators' licenses. During this 6-month period 111 reactor operators' licenses were issued bringing to 259 the total number of such licenses issued through June 30.

Special nuclear material. Sixty-three licenses were issued for possession and use of special nuclear material. These were chiefly for small quantities of material for research purposes and do not include special nuclear material for fuel in licensed reactors.

Source material. Source material licenses issued, including renewals, totalled 1,046 and comprised 259 to producers, 18 to processors, 71 to distributors, 334 to consumers, and 364 to exporters.

A description of applications filed and licensing actions taken is given in Appendix 8.

Byproduct material (*radioisotopes*). During this reporting period, 1,241 new licenses were issued in addition to 1,128 amendments to previously issued licenses. As of May 31, a total of 5,687 licenses was in effect for the use of radioisotopes.

Many other users received small quantities of material under the provisions of the general license (CFR 10, Part 30, sec. 30.21). Users of these generally licensed quantities are not included in the figures given here.

During the 6 months period through May 31, the Commission's primary radioisotope distributor, the Oak Ridge National Laboratory,

made 7,412 shipments. This brings to 110,802 the total number of shipments from the Laboratory since 1946. Fewer, but more specialized shipments are made from the Commission's Argonne National Laboratory, Brookhaven National Laboratory, and Mound Laboratory, and the National Reactor Testing Station. In addition to those for Commission facilities, many shipments are made each month by commercial suppliers who purchase bulk quantities of radioisotopes and reprocess them for sale to licensed users.

The total export shipments of radioisotopes reported as of May 31, amounted to 9,038, an increase of 1,637 since November 1957.

Appendix 4 lists the types of radioisotopes for which licenses were issued and also the number of users by class and location, and the shipments made in this country and abroad.

Medical uses of radioisotopes continued to expand. A total of 1,713 medical institutions and physicians was licensed as of May 31, of which 162 were new during this reporting period. Several medical procedures involving radioisotopes are approaching a state of routine application. These uses include diagnosis of thyroid function, and determination of blood and plasma volume with radioiodine-labeled compounds; diagnosis of pernicious anemia with cobalt 60-labeled vitamin B–12; and the measurement of red cell survival time and mass with chromium 51-labeled sodium chromate. Additional clinical procedures involving radioisotopes which are receiving widespread acceptance by physicians include fat absorption studies, evaluation of kidney function, and determination of cardiac output using radioiodine labeled compounds. More than 187 radioisotope teletherapy units now are licensed. In February 1958 the first license was issued for a cesium 137 teletherapy unit using 2 opposing sources.

Waste disposal. As of June 30, seven new applications had been received for commercial waste disposal licenses specifically authorizing commercial concerns to dispose of packaged radioactive waste by burial at sea. Four licenses had been issued previously.

The Commission has sponsored monitoring surveys of major sea disposal areas in both the Atlantic and Pacific Oceans. In addition the work of the Committee on Oceanography in the National Academy of Sciences on related problems is partially sponsored by the Commission.

Formal Hearings on License Applications

Power Reactor Development Co., Detroit, Mich. The Commission heard oral arguments on May 29 on a permit authorizing construction of a 90,000 net electric kilowatt fast breeder power reactor near Monroe, Mich.

The permit was granted August 4, 1956. Petitions for leave to intervene were granted October 8, 1956 to the International Union, United Automobile, Aircraft, and Agricultural Implement Workers of America, the International Union of Electrical, Radio, and Machine Workers, the International Union, United Paper Workers of America, AFL–CIO. A hearing was ordered on the application for a license, the record of hearing was certified by the Hearing Examiner to the Commission, and the oral arguments then were heard.

General Electric Co., San Jose, Calif. A hearing on application of the General Electric Co. for license to construct and operate a 30,000-kilowatt pressurized water test reactor at the company's Vallecitos Atomic Laboratory was held January 17. No petitions for intervention were received. On conclusion of the hearing, the Hearing Examiner handed down an intermediate decision on February 26, and ordered that a construction permit be issued on or before March 24, unless exceptions were filed pursuant to 10 CFR Part 2.752 (Rules of Practice) or the Commission chose to review the application. The Commission, on March 7, waived its right to review the matter and upon motion of the license applicant to issue the permit forthwith, ordered that the construction permit be issued. On March 11, General Electric was granted a construction permit.

National Advisory Committee for Aeronautics, Washington, D. C. The hearing on proposed construction by the National Advisory Committee for Aeronautics of a 60 megawatt pressurized water test reactor at Sandusky, Ohio, commenced January 16. No petitions for intervention were received. On June 24, the Hearing Examiner ordered that a construction permit be issued, effective July 21, unless exceptions to his decision are filed on or before July 18, or the Commission reviews his decision on its own motion.

Reactor Safety

During this reporting period, the Commission's technical and scientific staff performed safety evaluations of some 21 licensed reactor projects and 30 Government-owned reactor projects to determine that their operation would not constitute an undue risk to public health and safety. The evaluations included projects planned for construction, those being constructed, and those scheduled to commence operations. They also included projects on which modifications to design or operating procedures presented new safety considerations not involved in a previous evaluation of the facility.

In addition to the review by its technical and scientific staff, the

Commission obtains from the Advisory Committee on Reactor Safeguards, a statutory committee since September 1957, advice on the safety aspects of reactor projects referred to it. During the last 6 months, the Advisory Committee held 4 meetings to consider 13 reactor projects referred to it. These included 2 reactors for licensing—the General Electric Boiling Water Reactor and the Massachusetts Institute of Technology Research Reactor. Eight Commission-operated reactors and 3 reactor projects operated by the Department of Defense also were reviewed.

Similarly, safety evaluations were made by the Commission staff for each license application for the use of radioactive materials received during this period. Review included an appraisal of the applicant's qualifications and the adequacy of his facilities to assure safe use of the material. As necessary, prelicensing visits were made to the applicant to supplement the review of the application. In the development of safety criteria in the licensing of byproduct material, the advice of the Commission's Advisory Committee on Isotopes Distribution has been of great value and assistance.

Amendments to Regulations

Amendments to regulations issued during the first half of 1958 comprised:

(*a*) *Amendments to various regulations* published in the *Federal Register* February 21, effective upon publication, to eliminate the former address of the Atomic Energy Commission and substitute therefor the new mailing address for Germantown, Md., headquarters. They also provide that communications and papers may be delivered in person either at 1717 H Street NW., Washington, D. C., or at Germantown. The amendments further provide for appropriate recognition of the Division of Licensing and Regulation and the Office of Industrial Development, established upon dissolution of the former Division of Civilian Application.

(*b*) *10 CFR Part 50—Licensing of Production and Utilization Facilities,* amendment was published in the *Federal Register* May 10, to be effective June 10, 1958 increasing the number of copies of facility license applications which must be filed with the Commission.

(*c*) *10 CFR Part 70—Special Nuclear Material,* an amendment published in the *Federal Register* March 11, effective upon publication, which eliminates the requirement that applications for licenses and statements must be signed under oath or affirmation.

(*d*) *10 CFR Part 40—Control of Source Materials*, an amendment published in the *Federal Register* June 28, effective immediately, which removes prohibitions instituted in 1947 on the use of uranium as a coloring agent in the manufacture of ceramics, glass products, and photographic films, negatives and prints.

Text of amendments is given in Appendix 7.

Insurance and Indemnity

Activities Relating to Licensees

Regulation 10 CFR Part 140, "Financial Protection Requirements and Indemnity Agreements," [20] published by the Commission September 11, 1957, after enactment of Public Law 85–256 (Sept. 22, 1957), was designed as a temporary measure to be replaced by more definitive regulations as soon as practicable.

During January, the Commission conducted the last of a series of five industry advisory conferences convened to consider a draft revision of the financial protection provisions of Part 140. The fifth conference, attended by representatives of the insurance industry, followed four meetings held in December 1957 with groups of representatives of electric utilities, equipment manufacturers, fuel fabricators, and research organizations likely to be affected by the proposed regulations.

Appropriate amendments are being prepared based on continuing staff studies which have weighed the views and suggestions of the industry advisory groups. A revised method for calculating financial protection is expected to be published in the *Federal Register* as a notice of proposed rule-making and interested persons will be given full opportunity to submit comments.

The Commission also expects to invite public comment on two other matters of interest to persons engaged in reactor design, construction and operation.

The first is a proposed form of indemnity agreement.

The second concerns whether the Standard Nuclear Energy Liability Policy, developed by the stock and mutual nuclear energy liability pools, should be accepted by the Commission as proof of financial protection under Public Law 85–256 and Part 140.

Provision of insurance. Of the 25 licensees required by the regulation to furnish proof of financial protection, 16 have submitted insurance

[20] For a report on Public Law 85–256 and 10 CFR Part 140, see pp. 177–179, Twenty-third Semiannual Report to Congress (July–December 1957).

binders, 1 has elected to rely on its own resources, and 8 claim immunity from public liability.

The Commission has not exercised its authority to require reactor licensees who are agencies of a State to waive any immunity they may possess under State law. Such a requirement would result in shutting down most of these reactors since the licensees presently are without authority to waive their immunity. Some of these licensees also are without authority to purchase insurance.

The Commission is working with various State groups, including the Council of State Governments, to reach a satisfactory solution of this problem. Currently the Commission is considering other means of dealing with the problem, including the possibility of amending the indemnity provisions of the Atomic Energy Act of 1954 as given in Public Law 85–256.

Indemnification of Contractors

The Commission altered its policy on indemnity agreements with major contractors during this reporting period when it offered to extend to them the statutory indemnity provided for in Public Law 85–256 to protect contractors and the public against losses arising from nuclear accidents.

The indemnity provisions in the offered agreements cover not only any incidents for which the operating contractors are responsible, but also nuclear incidents caused by fault or negligence of other persons, including subcontractors or suppliers.

The net result of the various changes is to provide much broader protection to the public.

Commission prime contractors and their suppliers, who accept agreements covering operating nuclear reactors or other operating facilities such as gaseous diffusion plants or chemical separation plants, will be indemnified up to $500 million against claims resulting from nuclear accidents. Other contractors engaged in activities involving the risk of occurrence of a substantial nuclear incident also may be granted indemnity.

Design and engineering contractors and suppliers of component parts will be given contractual assurance that they will receive protection as suppliers under the statutory indemnity granted to the prime contractor who will operate the facility when it is completed.

Contractors are not charged a fee for the indemnity covering their contracts since all costs involved would be included in the cost of the work performed under the contract and therefore normally would be reimbursable by the Commission.

Cooperation With State Agencies

Interest of States in licensed atomic energy activities conducted within their boundaries is expanding with the growth of the Commission's licensing program. The Commission supplies information about licensing actions affecting each State, including actions taken in enforcement of regulations.

State legislative committees and regulatory bodies have consulted with the Commission staff in many instances on proposed laws and regulations, and members of the staff have participated upon invitation in State hearings on proposed legislation.

As described, the Commission also is working with the Council of State Governments and the National Association of Attorneys General on the problem of immunity from liability of State institutions licensed to operate reactors.

These cooperative actions and exchanges of information have been mutually beneficial both to the States and to the Federal atomic energy program.

Inspection

Inspection of Privately Owned Reactors

Commission staff during the January–June reporting period made more than 25 inspections of privately owned reactors, authorized for construction or licensed to operate, to determine whether licensees were in compliance with appropriate rules and regulations and, in general, conducting a safe operation. Headquarters staff, experienced in the design and operation of reactors, and familiar through study and review of each new reactor project and its possible hazards carry out these inspections.

The total number of inspections exceeds 65, and included critical experiment facilities, research and training reactors, specialized test and power reactors, both during and after construction and during initial and routine operation. Review of operations and equipment has resulted in a number of voluntary changes in design or in method of operation to improve safety.

Licensed Materials Inspection

Decentralization of responsibilities for inspections of licensed material users under 10 CFR 70 (Special Nuclear Material) was essentially completed during the reporting period with the assignment of this

duty to field operations offices. Standards, policies and procedures relating to inspection were improved on the basis of field experience so as to provide for selective scheduling of inspections and preparation of reports. As a result, those licenses which could involve substantial radiological health hazards have been inspected first, and inspections of recently issued licenses of this type have high priority. A program of periodic reinspection has been established on a tentative basis.

As of March 31, approximately 26 percent of the facilities and methods of all licensed materials operations had been inspected. Inspection reports revealed the following:

(*a*) Of total inspections performed, about 56 percent indicated that operations were in compliance with license conditions and with Commission regulations.

(*b*) Of the remaining 44 percent of the inspections performed, approximately 87 percent revealed some noncompliance such as failures of the licensees properly to label, post, or maintain adequate records. The remaining 13 percent involved failures to maintain proper procedures or equipment that have direct bearing on the safety of operations.

(*c*) Of the total inspections conducted, approximately 5 percent revealed potential or actual radiation hazards, but many of the cases in this group involved relatively minor deviations from prescribed standards on the part of the licensee.

Licensees have undertaken promptly to correct conditions when noncompliance was called to their attention. Followup inspections are made of all potential or actual radiation hazards to assure prompt corrective action.

The program of Federal-State cooperation in inspection of Commission licensees continues to expand in those states interested in the control problem.

Radiation Incidents

During 1957 approximately 28 licensees experienced abnormal operations which resulted in personnel exposures or levels of radiation in excess of the standards prescribed by regulation. Prompt action by licensees and advice and assistance from the Commission avoided serious consequence or injury as a result of these incidents.

Commission and Contractor Activities

Appraisals of 38 major cost-reimbursable contractors of the Commission were completed in the fiscal year ended June 30 under the

program for making periodic assessments of performance. Review of headquarters divisions' inspection programs continued.

Foreign Activities

Methods were developed for assisting execution of the safeguard provisions of agreements for cooperation between the United States and individual nations. Initial visits were made under this program.

Reactor Development

Substantial progress was made during the January–June reporting period on the Commission's programs to advance the technology of civilian and military power reactors.

Seven power reactor experiments were operating and the Shippingport Atomic Power Station, which was dedicated by the President on May 26, was operating at its full power of 60,000 net electric kilowatts.

Major construction was started on the Experimental Breeder Reactor No. 2, the last of the experimental power reactors in the 5-year program approved by the Congress in 1954. Results of design studies were sufficiently promising to warrant continuing the development program on the liquid metal-fueled reactor, with construction planned to start in 1959. A design study was initiated to evaluate the potential of gas-cooled power reactors using moderately enriched uranium. Facilities were under construction and others were planned to advance the work on using plutonium as a reactor fuel.

The fifth contract was signed in the industry-Government cooperative program calling for design and construction of prototype power reactors. Contracts for construction of two other reactors were being negotiated under the Power Demonstration Reactor Program, and bases of agreements on two others were before the Congress. Development work continued on a tenth reactor. One project was cancelled after studies showed it was not promising in the size proposed.

The keel was laid for the first nuclear-powered merchant ship, fabrication of its propulsion plant went forward, and other work was continued aimed at assisting introduction of nuclear-powered ships into international commerce.

General engineering and development continued in support of the reactor industry. After an extensive testing program, the Engineering Test Reactor began operating at its full design power. In the reactor safety program a 50 kilowatt test reactor reached a momentary power level of more than 500,000 kilowatts without sustaining damage.

Development and construction continued on reactors required for

various military applications, including production of power and heat at remote bases, and propulsion of naval vessels and of manned and unmanned aircraft. Three nuclear-powered submarines were operating and have steamed a total of 182,000 miles, 133,000 miles while submerged; one made a transatlantic voyage submerged throughout the trip. An additional nuclear-powered submarine was launched and 18 were being built. In addition, a guided missile cruiser and an aircraft carrier utilizing eight reactors were being built.

Civilian Power Reactors

Civilian power reactor work in the United States reached a new level of maturity during the last 6 months with experimental operation of seven reactor experiments, routine power operation of the Shippingport Atomic Power Station, and continued progress in the private and cooperative programs for construction and operation of full-scale nuclear powerplants.

The seven experimental reactors which operated are: Experimental Boiling Water Reactor (EBWR), Boiling Reactor Experiment No. 4 (BORAX–4), Homogeneous Reactor Experiment No. 2 (HRE–2), Experimental Breeder Reactor No. 1 (EBR–1), Sodium Reactor Experiment (SRE), Organic Moderated Reactor Experiment (OMRE), and the Vallecitos Boiling Water Reactor (VBWR). The Vallecitos reactor was built and is owned by General Electric Co; the others were wholly or primarily Commission financed.

The civilian power effort has definitely advanced to much firmer ground as a result of this encouraging operating experience and the direction of development required to achieve economic nuclear power can now be charted with more certainty.

Experimental Reactors

Shippingport Atomic Power Station. The Shippingport Atomic Power Station, the nation's first large-scale nuclear powerplant to generate electricity for civilian purposes, was dedicated on May 26 at Shippingport, Pa., the proceedings being carried on a nationwide television network.

President Eisenhower from the White House used a neutron source to send an impulse to Shippingport which opened the main turbine throttle valve of the plant to generate electricity from the 60,000 kilowatt plant for homes, stores, and industrial plants of the Pittsburgh area.

In his remarks, the President said, "It is with pride in what has been accomplished at Shippingport—and with equal confidence in

the future—that I now dedicate this Shippingport Atomic Power Station to the cause of scientific progress—the cause of peace.

"The plant represents what can be done, not only in America but throughout the world to put the atom to work for the good of mankind, not its destruction * * * It represents the hope of our people that the power of the atom will be able to open up a vast new world of peaceful development; that atomic power will ease mankind's burdens and provide additional comfort for human living."

In an address at the reactor dedication, Chairman Strauss said, "As the years pass, nuclear powerplants of greater size and even more sophisticated technology than this great plant will be completed. Some of them are far along in construction. Nevertheless, this Shippingport plant will always hold the proud title as the first of the world's large-scale nuclear power stations built and operated exclusively for peaceful purposes. The Duquesne Light Company, the Westinghouse Electric Corporation, and those who direct those great enterprises have performed a signal service to the nation. Their courage and their enterprise have made American industrial history."

The reactor first achieved criticality on December 2, 1957, 15 years to the day after the first experimental atomic pile built by Enrico Fermi and his associates attained a chain reaction. The Shippingport plant first produced electricity on December 18, and on a test basis it delivered 60,000 net kilowatts of electricity on December 23.

During the first 3 weeks of January, this pressurized water reactor plant was maintained in a subcritical condition but at operating temperature and pressure while various tests involving the performance of the core and plant systems were carried out. During the last week in January and the first week in February the plant was shut down for routine maintenance and to perform minor modifications.

Critical operation was resumed on February 5 for the performance of core physics tests. The plant was brought to power on February 10. During the remainder of February and the first 2 weeks of March the plant was operated at various power levels up to 60,000 kilowatts net electrical output, supplying power to the system of the Duquesne Light Co., which is operating the plant under contract to the Commission. Valve operating system tests, response of the plant to variation in load, neutron flux measurements, instrument calibration, and other operational and physics tests were successfully conducted in conjunction with power operation.

The third week of March was devoted to physics and control rod drive tests which involved both subcritical and critical operation. During the remainder of March and until April 28 the plant was again operated at various power levels supplying the Duquesne Light Co.



Shippingport dedication. Admiral H. G. Rickover, Chief of Naval Reactors Branch, Atomic Energy Commission; Lewis L. Strauss, Chairman, U. S. Atomic Energy Commission; Honorable Henry Dworshak, U. S. Senator (Idaho); James E. Van Zandt, U. S. Representative from Pennsylvania; Philip A. Fleger, Chairman of the Board, Duquesne Light Co. at the Shippingport Atomic Power Station during dedication ceremonies May 26, 1958.

system. Physics tests which required continuous high power operation were performed during the week of April 28.

As of June 30, the plant had delivered nearly 38 million net kilowatt-hours of electricity to the Duquesne system.

Boiling water reactors. Since the first *Boiling Reactor Experiment* (*BORAX–1*) demonstrated the basic stability of boiling water systems in 1953, the Commission has continued development of the BORAX series and BORAX–4 is presently in operation at the National Reactor Testing Station. Late in 1956, the *Experimental Boiling Water Reactor* (*EBWR*), a pilot-plant boiling water power reactor complete with turbine generator, began operation at Argonne National Laboratory. This was about a year and a half after start of construction.

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Recent operating results from the EBWR and BORAX–4 have been most encouraging. Among major results are the following:

(*a*) The EBWR was operated stably at 62 thermal megawatts, more than 3 times its nominal design rating of 20 megawatts, without major modification. It is planned to operate this plant at still higher power levels after installation of a larger core and additional heat removal equipment. This large increase in power has been possible because the natural circulation of water in the core has been much greater than was once thought possible, and because the increasing amount of steam in the reactor core caused by the high power operation has not resulted in instability as was originally expected. In this connection, BORAX–4 operated stably with more than 7 percent of its total reactivity contained in steam voids—the highest level yet achieved in a boiling water reactor.

(*b*) Turbine maintenance in the EBWR has proved to be routine in spite of the fact that saturated steam is fed directly from the reactor to the turbine. There has been little or no pitting of the turbine blades and residual radioactivity in the turbine has been so low that direct maintenance is possible. Even under the severe test of experimental operation of EBWR and BORAX–4 with the ruptured oxide fuel elements, radioactivity carryover to the turbine was small. During routine experiments in early May, excessive vibration was detected in the EBWR turbine. A subsequent examination of the turbine revealed that one turbine blade and its shroud were broken loose from the rotor. This is believed to have been a fatigue failure which is not related to the nuclear portion of this plant. The necessary repairs have been made and operation of the plant has resumed.

(*c*) Experiments in BORAX–4 have demonstrated that boiling reactors can operate stably with uranium oxide or thorium oxide fuels. There had originally been some concern that the poorer heat transfer characteristics of oxide fuels as compared with metallic fuels would adversely affect reactor stability. Among the advantages of oxide fuels is their ability to withstand very high exposures at high operating temperatures. In event of a failure of protective cladding on fuel elements, they also are much less reactive with the water coolant than are metallic fuels.

These encouraging operating results have pointed the way to additional methods of improving boiling water reactor systems. Modifications in core geometry promise to increase the natural circulation of coolants beyond the high levels already attained and thereby increase their heat output. Forced circulation of the coolant is a

possible but yet unproved method of increasing power and aiding in reactor control. Operation with heavy water will increase the conversion ratio of boiling reactor systems—that is the percentage of fuel generated to fuel burned—but heavy water is expensive and its leakage must be carefully controlled. Superheating the steam by nuclear heat may make it possible to obtain steam temperatures approaching those prevailing in modern steam plants. Experiments on these and other improvements are planned.

Work was discontinued on the *Argonne Boiling Reactor* (ARBOR), which had been planned as a flexible boiling water test facility. Based on on further studies by the Argonne National Laboratory, including preliminary design by United Engineers and Constructors, it was determined that the flexibile facility required to accomplish all the objectives of the project would cost considerably more than was first estimated.

Anticipated results did not appear to warrant the expenditure in view of the schedule delays and the competition of other projects for funds.

Homogeneous reactors. Following dismantling of the *Homogeneous Reactor Experiment No. 1* (*HRE–1*) in 1954, the *Homogeneous Reactor Experiment No. 2* (*HRE–2*) was undertaken on the same reactor site at Oak Ridge National Laboratory. The HRE–2 is a two-region forced circulation aqueous homogeneous reactor: a central region consisting of a zirconium tank containing enriched uranium fuel in the form of uranyl sulfate dissolved in heavy water, and a surrounding region containing heavy water and acting as a reflector. HRE–2 is designed for a thermal output of 50 megawatts. A small amount of heat produced is supplied to the same turbogenerator used with HRE–1 to produce 300 gross kilowatts of electrical power. The remaining heat is dumped to air-cooled condensers.

The use of fluid fuel permits continuous removal of fission products and plutonium, avoids the expense of fabricating fuel elements, and leads to desirable control characteristics. Fluid fuel reactors, now being developed, employ fuel in the form of a solution or slurry.

The HRE–2 achieved criticality December 27, 1957. After critical and low power-level experiments, the reactor was gradually brought up to its full design power of 5,000 thermal kilowatts, which was attained on April 4. Shortly after the reactor reached full power, instruments indicated that some fuel from the main core region was transferring to the heavy water reflector region. The reactor was thereupon shut down. Before the shutdown occurred, the plant had produced about 326 megawatt-hours of nuclear heat and had operated

in a stable manner at design conditions. At no time during the entire operation did any radioactivity escape from the reactor system. Examination after the shutdown determined that an internal leak in the zircaloy core vessel was responsible for the transfer of fuel from the core to the reflector region. Until the cause of the core vessel failure has been determined, and a decision made on whether or not to replace the core vessel assembly, the HRE–2 will be operated as a single-region reactor.

The long-term objective of the program for development of aqueous homogeneous reactors continues to be the development of a thermal breeder reactor system for the thorium-uranium 233 cycle.

Oak Ridge National Laboratory also is exploring the technical and economic feasibility of using molten salts of uranium fluoride and thorium fluoride in homogeneous reactors. Molten salt systems could operate at high temperature and low pressures. Results in out-of-pile loop experiments have demonstrated the exceptionally high resistance of the container materials to corrosion and to extended mass transfer.

A smaller development program on homogeneous reactors utilizing uranyl phosphate fuel is being completed at Los Alamos Scientific Laboratory. The first small experimental reactor in this program, *Los Alamos Power Reactor Experiment No. 1* (*LAPRE–1*), was abandoned because of excessive corrosion. The second reactor, *Los Alamos Power Reactor Experiment No. 2* (*LAPRE–2*), will be assembled and operational tests will be conducted before the program is terminated.

Fast reactors. Development of fast breeder reactors has been pressed from the start of the civilian power reactor program because of their ability to breed more fissionable material than they consume in the uranium-plutonium cycle. Reactors of this type operate with neutrons at high velocities instead of using moderators to slow down neutrons to thermal velocities. The United Kingdom also has an extensive fast reactor program and there has been a free exchange of information in this field for the past 3 years.

One of the most important experimental facilities in the fast reactor program is the *Experimental Breeder Reactor No. 1* (*EBR–1*) at the National Reactor Testing Station, which produced the world's first electric power from atomic energy in December 1951.

Undesirable operating characteristics were observed during 1955 after a second core was installed, and in experiments investigating these characteristics, a partial meltdown of the core occurred.[21] Studies indicated that the cause was "bowing" or distortion of the

[21] See pp. 45–46, Twentieth Semiannual Report to Congress (January–June 1956).

core components because of temperature differences within the core. A third core was designed to control this "bowing" by using tightly clad fuel elements and tightening and supporting devices, both inside and outside the core. Preliminary operation of the EBR–1 with the third core during late 1957 and 1958 indicates that the new core design has eliminated the prompt positive temperature coefficient, that is, the tendency of a small increase in temperature to increase reactivity and thus cause a further increase in power and temperature. The third core also showed no evidence within the design power rating of the reactor of the other undesirable characteristic previously observed—oscillations of power without external cause when the reactor reached a certain power level.

Major construction is under way on the *Experimental Breeder Reactor No. 2* (*EBR–2*), a fully integrated experimental power reactor station with its own chemical processing plant. The station will have 16,500 kilowatts net electric output. The EBR–2, being built at the National Reactor Testing Station, is designed with operating characteristics similar to those of a full-scale powerplant. It will, for example, utilize components of such design that they can be scaled up to a size or capacity required for a full scale plant.

Several other major developmental facilities pertaining to fast reactor technology are in operation or are planned. Now that successful operation of the EBR–1 is demonstrating basic stability, the major area of fast reactor safety that remains to be demonstrated is the possible effects of extreme operating conditions. Two facilities are planned which will investigate these effects, namely, the *Transient Reactor Test* (*TREAT*) and the small *Nevada Fast Reactor Safety Testing Station.*

The TREAT reactor, scheduled for operation in early 1959 at the National Reactor Testing Station, will have a special test hole to study dynamics of fuel meltdowns. In this test hole, a sample fuel element can be heated to and beyond melting temperatures without overheating the reactor itself.

The Nevada facility, located at the Nevada Test Site, and scheduled for completion in July 1959, will provide a remote site for test of fast reactor cores under extreme conditions.

The Zero Power Reactor No. 3 (ZPR–3), a fast critical assembly at the National Reactor Testing Station, Idaho, is utilized for fast reactor physics work. The Zero Power Reactor No. 6 (ZPR–6) facility planned for construction at Argonne National Laboratory will permit an extension of these studies.

Sodium Reactor Experiment (*SRE*). The sodium graphite power reactor program was formally initiated in 1954 with start of construc-

tion of the Sodium Reactor Experiment. The sodium-cooled, graphite-moderated SRE began operation in April 1957 at Santa Susana, Calif. Although several problems with components and fuel limited its output to about one-third design power during early tests, operation has been generally satisfactory. During this report period, the SRE reached its design power of 20 thermal megawatts for the first time.

Initial experience with reactor control and maintenance has been particularly gratifying. Reactor stability was such that negligible control rod motion was required at constant power. Routine maintenance and modifications of the system have been carried out without difficulty and in a relatively short time. On one occasion, a fuel element, accidently broken during insertion, was removed during a single day with grappling tools devised for this purpose.

Early difficulties with the pumps and cold traps in the coolant system have been largely overcome by minor modifications to the system. Operation of the intermediate heat exchanger and steam generator at low capacity has revealed some difficulties which now are understood and can be eliminated in future designs. Because of potentially high thermal stresses during scrams (instantaneous shutdowns) of the reactor, initial operation was restricted to one-third design power until early 1958 after eddy current brakes had been installed in the sodium circuits to control coolant flow. Subsequent full power operation has been entirely satisfactory in this regard.

Although the fuel elements presently installed are operating satisfactorily, evidence has accumulated that the life of these elements will be much shorter than originally estimated. This is partly because the excess reactivity of the reactor, required to overcome fission poisons buildup, is low and would diminish as poisoning increased. A second factor is that the swelling of metallic uranium at high temperatures, partially a result of fission product gases, may cause failure of fuel elements. A loading of thorium-uranium alloy fuel elements is being fabricated and will be installed during 1958.

The attainment of full power operation of the SRE on May 21 is a noteworthy achievement. Even more significant, however, is the fact that a year of operation, including the difficulties encountered, has pointed the way toward major improvements in design. Planning is under way on modification to demonstrate improved sodium-graphite designs.

Invitations were issued May 8 to industry for design, development, manufacture and test operation of major nonnuclear components for use in all reactor systems which use liquid sodium as coolant. Fifteen proposals were received for development of intermediate heat exchang-

ers and steam generators of advanced design and improved performance, and the Commission has selected the Griscom Russell Co., Alco Products, Inc., and Combustion Engineering to carry out preliminary design and analysis. In response to an invitation for proposals for development of flow control mechanisms, 11 proposals were received, and are being evaluated.

Liquid metal fuel reactor. Experimental work and design studies on liquid metal fuel systems were continued by the Brookhaven National Laboratory and The Babcock & Wilcox Co. A conceptual design and preliminary research and development for a large liquid metal fuel reactor were completed with sufficiently promising results to warrant continuation of the development program. The basic facility in the development program will be a 5 thermal megawatt Liquid Metal Fuel Reactor Experiment (LMFRE–1).

The LMFRE–1 will use a fluid fuel of uranium dissolved in molten bismuth in a moderating structure of unclad graphite. The reactor heat will be dissipated by an air-blast heat-exchanger with no generation of electric power. Reactor construction is scheduled to start in 1959 with completion in 1961. Babcock & Wilcox will design, construct, and operate the reactor.

Organic Moderated Reactor Experiment (OMRE). Investigation of organic moderated and cooled reactors was initiated in 1955. The noncorrosive nature of the organic coolant, the low level of radioactivity created in the coolant by neutron bombardment, and the low pressure of the organic coolant at operating temperature, are advantages of this type of plant. However, organic coolant decomposes under radiation, and there was some concern that the decomposed organic material might foul fuel element and heat transfer surfaces as well as lower the heat transfer properties of the organic. In order to determine the rate of organic decomposition and to evaluate possible fouling, construction of the *Organic Moderated Reactor Experiment (OMRE)* was undertaken at the National Reactor Testing Station.

The OMRE, which began operation late last year, is a relatively simple and inexpensive reactor experiment. During initial operation there has been no evidence of fouling of heat transfer surfaces. Preliminary results of decomposition studies indicate that the cost of replacement of the decomposed organic coolant would not be prohibitive in a power reactor of this type. Extensive experiments are planned with the OMRE to study long-term irradiation effects, and to try to develop improved organic materials.

Plutonium program. The Commission has under way a major program to develop the technology and techniques of utilizing plutonium as fuel in civilian power reactors. Use of plutonium as a fuel is essential to the long-run conservation of uranium fuel resources and may reduce the cost of nuclear fuel in power reactors. Uranium as it occurs in nature is made up of less than 1 percent uranium 235, which is fissionable, and more than 99 percent uranium 238, which is relatively nonfissionable. Uranium 238 can be converted into fissionable plutonium, however, by exposure to neutron irradiation in a reactor.

In most reactors, uranium 238 is converted into plutonium at a rate slightly lower than that at which fissionable uranium or plutonium is consumed. Fast reactor designs, however, can provide for breeding plutonium, more rapidly than uranium or plutonium is consumed. In either case, the energy output of naturally occurring uranium can be greatly extended if the plutonium which is produced is utilized as fuel.

The use of plutonium as a reactor fuel involves many problems not encountered with uranium. Plutonium is highly toxic, more radioactive than uranium, more likely to ignite in air and also has many undesirable metallurgical characteristics. Much more needs to be learned about special handling and fabrication techniques before the full potential of plutonium as a reactor fuel may be realized. The Commission is building new developmental and fabrication facilities to carry out the work.

The *Plutonium Recycle Program* at the Commission's Hanford Works is designed to assist in developing technology applicable to the use of plutonium as fuel in thermal heterogeneous power reactors. The technology can be applied to several types of reactors.

Recycling plutonium in thermal reactors is particularly important to nations possessing supplies of natural uranium but without facilities for enriching uranium. Natural uranium can be used as the basic fuel and "enriched" with recycled plutonium. This will make possible compact, high performance and relatively inexpensive enriched reactor systems.

The *Plutonium Recycle Test Reactor (PRTR)* under construction at Hanford will be used to test plutonium-bearing fuel elements. A Plutonium Fabrication Laboratory also is being built to manufacture cores for the PRTR, and to develop and fabricate a variety of experimental fuels for use in power reactors.

A *Fuels Technology Center,* on which construction is scheduled to begin in July at Argonne National Laboratory, will provide a considerable expansion in facilities for basic research on plutonium and other fuels. A Plutonium Fabrication Facility, scheduled for completion early in 1959, will be used for experimental fabrication of plutonium

core loadings for the Experimental Breeder Reactor. Much of the basic work on plutonium fuels for fast breeder reactors will be performed in these facilities.

The Los Alamos Scientific Laboratory also has a large basic program on plutonium metallurgy which includes development of molten plutonium alloys as fuels for fast reactors.

Heavy water reactors. Research and development on heavy water-moderated reactors continued during this reporting period chiefly at the Commission's Savannah River plant. As a result of this work, and of evaluation of design criteria, two conclusions have been reached:

First, although a heavy water power reactor could be built by the original target date of June 30, 1962, such a schedule would require premature and undesirable compromises in design. Relaxation of the target date therefore is being considered to permit more research and development and further design and evaluation studies.

Second, as part of the continuing research and development program, a Heavy Water Components Test Reactor would be desirable and is planned.

The original proposal was to design a heavy water power reactor using natural uranium fuel. The program was altered during this reporting period toward developing instead a plant which can take some advantage of enriched fuel as a means of reducing nuclear power costs, but which also will be operable, with reasonable performance, on natural uranium fuel. Heavy water moderated reactors are still believed to offer the best promise for use of natural uranium as a power fuel.

Gas-cooled power reactors. A series of studies on gas-cooled graphite-moderated civilian power reactors was completed during the 6-month reporting period by Kaiser Engineers, ACF Industries, Oak Ridge National Laboratory, and General Electric Co. These studies, reported in April to the Joint Committee on Atomic Energy,[22] indicate that reactors of this type using natural uranium as a fuel are rapidly approaching their ultimate potential as power producers because of the limitations imposed by the ability of metallic fuel elements to withstand temperature and exposure. With fuel elements of partially enriched uranium, the situation is substantially improved. Enrichment of the uranium permits use of uranium oxide elements and cladding materials that will resist higher temperatures. Reactors using enriched fuel are also much more compact and hence cheaper to build than natural uranium reactors. The studies indicate that gas-cooled,

[22] Pursuant to the Authorization Act for 1958 (Public Law 85-162); see also the earlier section of this report on Production of Special Nuclear Materials.

graphite-moderated reactors using enriched uranium oxide fuels have considerable promise for production of competitive nuclear power.

Construction of a prototype reactor, and a comprehensive research and development program, are believed necessary to develop a realistic basis for evaluating the potential of the gas-cooled power reactor. Accordingly, under Commission contract, Kaiser Engineers-ACF Industries initiated design of a reactor of approximately 40,000 electrical kilowatts to operate on partially enriched fuel with outlet gas temperature of 1,000° F.

Investigation of the relative merits of carbon dioxide and helium as coolant gases continued. Supporting research and development continued at Oak Ridge National Laboratory and at the Hanford Works. A program of design studies and development work on advanced gas-cooled reactor concepts was initiated at Oak Ridge.

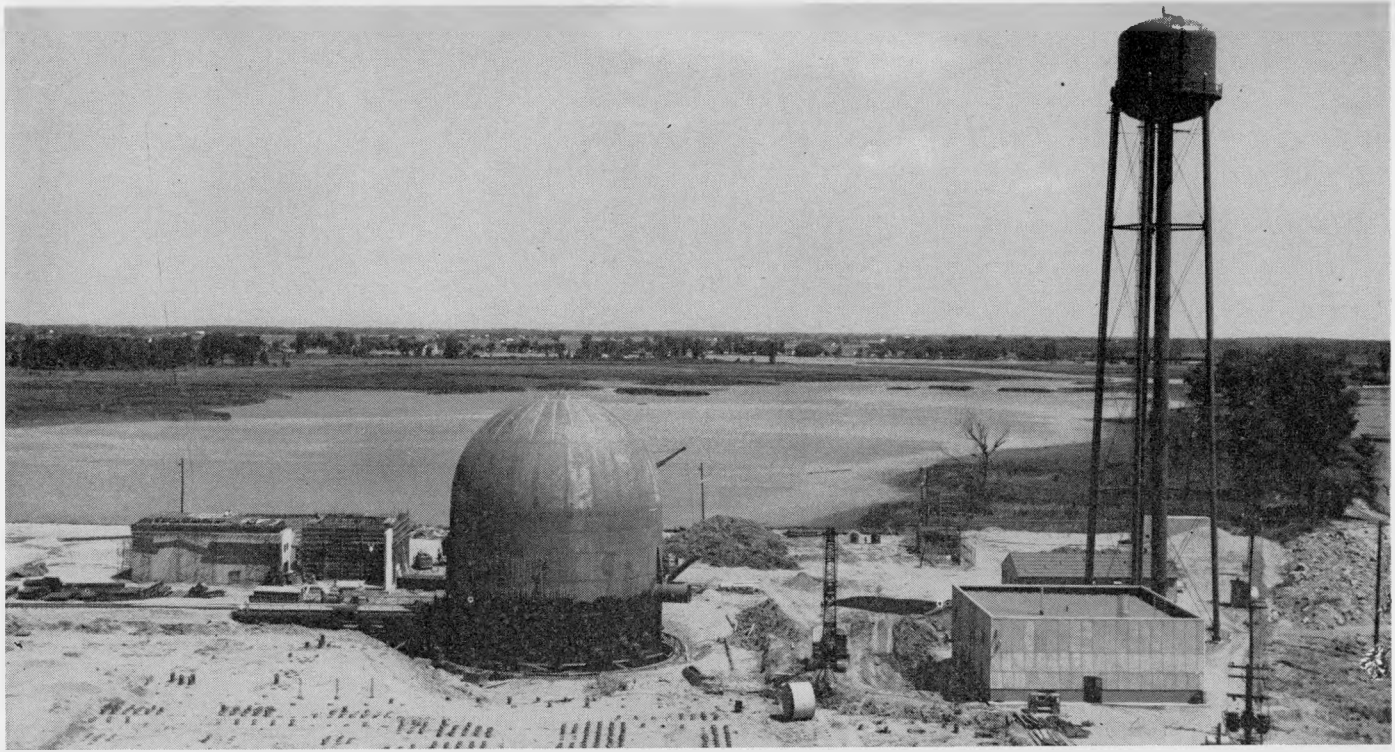
Prototype Nuclear Powerplants

Parallelling the successful operation of reactor experiments, heavy construction went forward on four large-scale nuclear powerplants ranging from 90,000 kilowatts to 255,000 kilowatts net electric output. These four large-scale plants, being built by *Commonwealth Edison Co.*, *Consolidated Edison Co.* of New York, *Yankee Atomic Electric Co.*, and *Power Reactor Development Co.* (*PRDC*), are scheduled to go on stream in 1960 and 1961, joining the Shippingport plant in feeding large blocks of power into the nation's electrical grids. These four are being constructed exclusively with private funds, but the Yankee and PRDC plants will receive assistance from the Commission under its Power Demonstration Reactor Program of Government-industry cooperation to develop nuclear powerplants. The Commission will carry out specific research and development work for these reactors and will waive charges for use of the fuel.

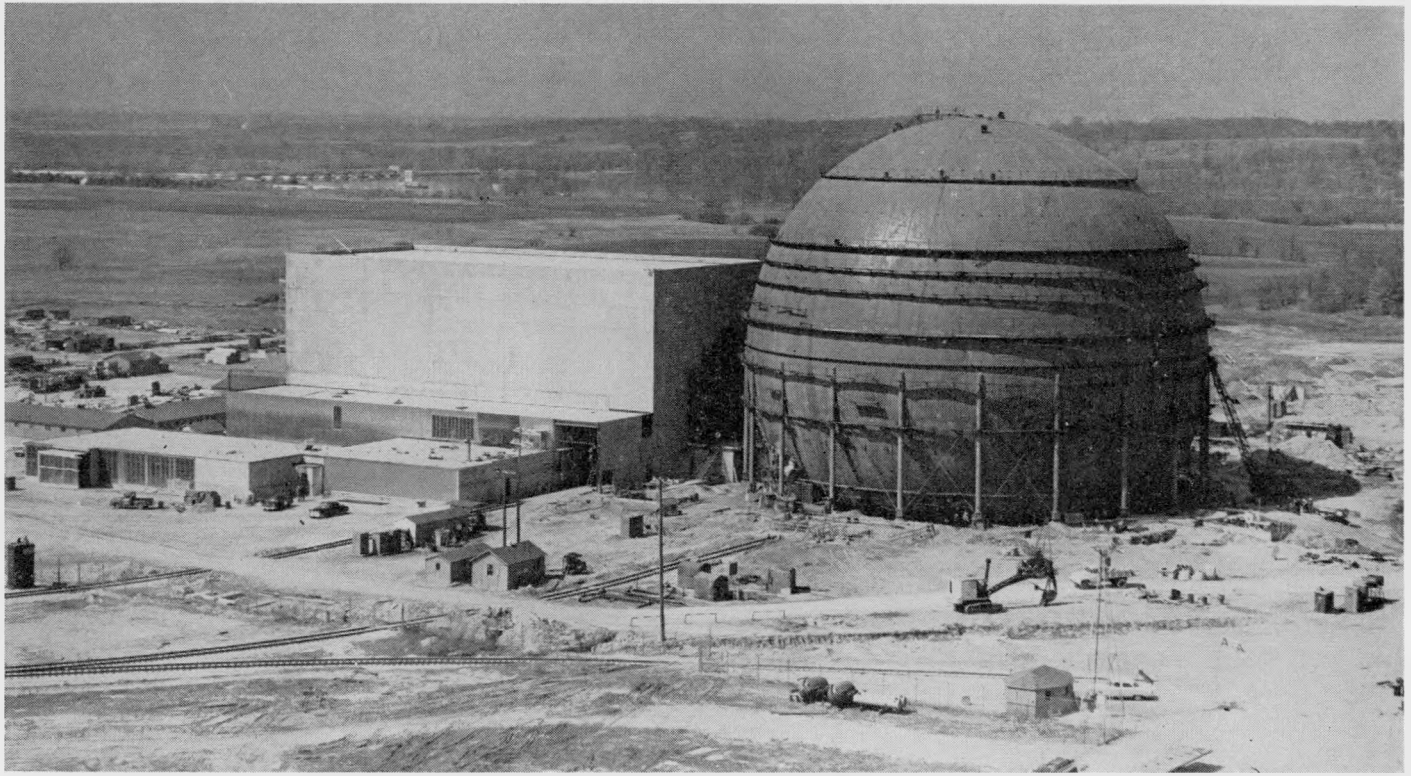
A cooperative arrangement was approved during this reporting period on one power reactor proposal. Contract negotiations were nearing completion on two additional power reactor proposals, and two others were awaiting specific legislative authorization. Development studies were continued on another proposed reactor. These plants will range in net electric output from 10,000 kilowatts to 150,000 kilowatts. Those scheduled would be placed in operation between 1961 and 1963.

The *Pacific Gas & Electric Co.* 50,000 to 60,000 net electric kilowatt powerplant, to be financed entirely with private funds, also is scheduled for completion during this period.

Including the privately financed and cooperatively planned and Government reactors, there are 15 prototype reactors proposed for



Enrico Fermi Plant. Progress in construction as of June of the fast reactor prototype powerplant being built by the Power Reactor Development Co., near Monroe, Mich.



Commonwealth Edison Dresden Plant. Progress in construction as of April of the power reactor plant being built near Joliet, Ill.

full-power operation by 1963. Adding in the federal power reactor experiments, there would be 21 reactors operating by 1963 with a total electrical capacity of more than 1.3 million kilowatts. The reactors are listed in table I.

TABLE I. EXPECTED ELECTRIC POWER OUTPUT FROM CIVILIAN NUCLEAR POWER-PLANTS AND REACTOR EXPERIMENTS [1]

[Net output in electrical kilowatts]

PLANT	END OF CALENDAR YEARS						
	1957 (Actual)	1958	1959	1960	1961	1962	1963
Shippingport Atomic Power Station	60,000	60,000	60,000	60,000	100,000	100,000	100,000
Boiling Reactor Experiment (BORAX-4)	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Experimental Boiling Water Reactor (EBWR)	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Vallecitos Boiling Water Reactor	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Experimental Breeder Reactor No. 1 (EBR-1)	100	100	100	100	100	100	100
Sodium Reactor Experiment (SRE)	.....	5,000	5,000	5,000	5,000	5,000	5,000
Experimental Breeder Reactor No. 2 (EBR-2)	.....	.....	.....	16,500	16,500	16,500	16,500
Yankee Atomic Electric Co	.....	.....	.....	110,000	134,000	134,000	134,000
Commonwealth Edison Co. Dresden Station	.....	.....	.....	180,000	180,000	180,000	180,000
Consolidated Edison Thorium Reactor [2]	.....	.....	.....	.....	255,000	255,000	255,000
Enrico Fermi Plant	.....	.....	.....	.....	90,000	140,000	140,000
Rural Cooperative Power Association [2]	.....	.....	.....	.....	22,000	22,000	22,000
City of Piqua, Ohio	.....	.....	.....	.....	11,400	11,400	11,400
Consumers Public Power District (Hallam)	.....	.....	.....	.....	.....	75,000	75,000
Chugach Electric Association	.....	.....	.....	.....	.....	10,000	10,000
Northern States Power Co. [3]	.....	.....	.....	.....	.....	62,000	62,000
Carolinas-Virginia Nuclear Power Associates	.....	.....	.....	.....	.....	17,000	17,000
Pacific Gas and Electric Co. [3]	.....	.....	.....	.....	.....	50,000	50,000
Gas-Cooled Power Reactor	.....	.....	.....	.....	.....	.....	40,000
Pennsylvania Power and Light Co. [4]	.....	.....	.....	.....	.....	40,000	150,000
East Central and Florida West Coast Nuclear Power Groups	.....	.....	.....	.....	.....	.....	46,000
Total	71,600	77,600	77,600	384,100	826,500	1,130,500	1,326,500

[1] Output is shown for each plant beginning in year of first full power operation. These are not always the same years as shown for startup (criticality) in app. 9.

[2] Output shown for these plants includes some conventionally fired superheat.

[3] Output may be as much as 60 mw.

[4] Present plan is to build 150 mw. plant but development results may cause later change to a 70 mw. plant.

Since inception of the Power Demonstration Reactor Program after passage of the Atomic Energy Act of 1954, contracts have been executed relating to 5 proposals made under this program for cooperative industry-Government development of power reactors. Details of 4 contracts have been given in previous reports as noted

in the following section. One additional contract entered into during this reporting period is described in the following pages. The status of the individual projects, as of the end of January–June reporting period, was as follows:

Yankee Atomic Electric Co. Construction of the Yankee Atomic Electric Co. pressurized water nuclear powerplant at Rowe, Mass., was under way. Supporting Commission-financed research and development by Westinghouse Atomic Power Department pursuant to the contract [23] was more than half completed and was progressing satisfactorily. Fabrication was started on a large in-pile loop to be installed in the Commission's Materials Testing Reactor at the National Reactor Testing Station to test the Yankee fuel element design. The initial core is designed for an output of 110,000 net electric kilowatts. Subsequent cores are expected to produce 134,000 net electrical kilowatts.

Power Reactor Development Co. Heavy construction continued on the fast breeder reactor of the Power Reactor Development Co. at Monroe, Mich.[24] Operation is scheduled for August 1960 and will be followed by a year of low-power nuclear testing before full-power operation is undertaken. The initial thermal output of the reactor is to be 300 megawatts with an electrical output of 100,000 kilowatts gross and 90,000 kilowatts net. In anticipation of increasing the thermal output of the reactor at a later date, the electric power generation and auxiliary equipment are designed for 140,000 kilowatts net electric capacity.

Consumers Public Power District. Design and development of a 75,000 net electric kilowatt sodium-graphite reactor for the Consumers Public Power District at Hallam, Nebr., was continued by the Atomics International Division of North American Aviation, Inc., under contract with the Commission. The Bechtel Corp. was selected by the Commission to participate with Atomics International and provide general architect-engineering services for the more conventional portions of the reactor and steam generator plants. The Consumers Power District is responsible for design and construction of the turbine-generator facility.[25] Construction at the site is planned to begin early in 1960, with December 1961 the target date for plant completion.

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[23] For contract details, see pp. 39–40, Twentieth Semiannual Report to Congress (January–June 1956).
[24] For contract details, see pp. 55–56, Twenty-second Semiannual Report to Congress (January–June 1957).
[25] For details of contract, see pp. 113–14, Twenty-third Semiannual Report to Congress (July–December 1957).

Rural Cooperative Power Association. The Commission on June 16 signed a contract with the Nuclear Products—Erco Division of ACF Industries, Inc., Washington, D. C., to develop and construct a demonstration nuclear powerplant at Elk River, Minn.

The Commission signed a contract on June 27 with the Rural Cooperative Power Association at Elk River under which that organization would provide a site for the nuclear plant, the conventional turbogenerator and related facilities, operate the entire plant for 5 years as part of its electric power system, and purchase from the Commission the steam produced by the reactor.

The agreement with ACF Industries covers design, development, fabrication, construction and test operation of a closed-cycle boiling water nuclear reactor and conventional fuel-fired superheater with a combined capacity of 22,000 net electrical kilowatts. The reactor would use water as a moderator and coolant, and a mixture of thorium and uranium oxides as fuel.

The total estimated cost to the Commission would be about $11.45 million. This includes the cost of development, construction, training, and test operation of the reactor, to be performed by ACF Industries under a cost-type contract with a ceiling of $9.269 million, including fixed fee. The total also includes operating costs to be borne by the Commission. The conventional turbogenerator facilities would be provided by the Rural Cooperative Association at an estimated cost of about $1.750 million.

It is expected that the reactor will be completed by October 1960. Title to the entire reactor plant, fuel elements, and superheater, would be retained by the Government. Since the plant would be built and operated under contract to the Commission, construction or operating licenses probably would not be issued, but authority to operate the plant would be granted only after the Commission's safety standards were fully complied with.

City of Piqua, Ohio. Contract negotiations continued during this reporting period with the city of Piqua, and Atomics International, concerning the design, development, construction and operation of an organic moderated reactor to be located at Piqua, Ohio. Research and development pertaining to the reactor has been initiated by Atomics International. Construction is scheduled to begin in 1959 with completion scheduled for 1961.

Chugach Electric Association. The Nuclear Development Corp. of America continued development and preliminary design of the Chugach Electric Association project. A definite decision whether or not to construct the reactor, planned for the utility's system at

Anchorage, Alaska, will be made after the results of this work are evaluated.

Northern States Power Co. A site for the 62,000 net electric kilowatt boiling water reactor plant of the Northern States Power Co. was selected on the Big Sioux River, about 6 miles northeast of Sioux Falls, S. Dak. Site surveys and test borings were begun. Determinations were made on several elements of design. The research and development program, and establishment of the reference design, are progressing satisfactorily.

A contract between the Commission and Northern States was signed November 22, 1957.[26]

Pennsylvania Power & Light Co. Research and development on a single-region, slurry-type aqueous homogeneous power reactor of 70,000 to 150,000 kilowatts electrical capacity was initiated more than two years ago by Pennsylvania Power and Light Co. and Westinghouse Electric Corp. with their own funds. As a result of a proposal by the two organizations, the Commission placed before the Congress the basis of a proposed cooperative arrangement. Inasmuch as the arrangement would cover only initial research and development, with the decision to construct and operate a reactor contingent upon results, special legislative action was requested to approve use of funds authorized by Public Law 85–162 for reactor development and construction under the third invitation of the Power Demonstration Reactor Program. If authorized, the Commission contract would call for continued research and development during 1958 and 1959.

Carolinas-Virginia Nuclear Power Associates, Inc. Agreement was reached during this reporting period on the major features of a contract which would provide for the development, design, construction, and operation at Parr Shoals, S. C., of a heavy water-moderated and cooled, low enrichment uranium oxide-fueled power reactor plant which, with the aid of an oil-fired superheater, will generate 17,000 net kilowatts of electrical energy. Research and development work has been initiated under provisions of a letter of agreement.

East Central Nuclear Group-Florida West Coast Nuclear Group. The Commission submitted to the Congress the basis of cooperative agreements negotiated between the Commission and the Florida groups for the development, design, construction, and operation of a heavy water-moderated, gas-cooled reactor having a net electrical capacity of 50,000 kilowatts. The proposal is awaiting specific legislative

[26] See pp. 109–10, Twenty-third Semiannual Report to Congress (July–December 1957).

authorization. Completion of construction is estimated to be June 1963, whereas the criteria of the third invitation issued by the Commission under its Power Demonstration Reactor Program provided for a completion date no later than June 1962. In addition, a waiver of the heavy water use charge was requested, and the prototype reactor will use slightly enriched uranium instead of normal uranium, as was specified in issuance of the third invitation, and in the authorization act for fiscal 1958 (Public Law (85–162).[27]

Wolverine Electric Cooperative. Detailed construction and operating cost analysis on a 10,000 electric kilowatt aqueous homogeneous nuclear powerplant proposed by the Wolverine Electric Cooperative for location at Hersey, Mich., were undertaken for the Commission by its staff and by Oak Ridge National Laboratory. Results indicated there was little or no economic promise for this type of reactor in a small-scale powerplant. It was therefore determined that it would be in the best interests of the Government and of Wolverine to discontinue any further action with respect to the proposed project.

Maritime Reactors Program

Nuclear merchant ship. Mrs. Richard Nixon, wife of the Vice President, placed a segment of the keel of the NS *Savannah*, first nuclear-powered merchant ship, in formal ceremonies at Camden, N. J., on May 22, Maritime Day, which commemorates the 1819 Atlantic crossing of the SS *Savannah*, the first by a United States steamship.

Preparation of shop drawings and working plans for the ship by the New York Shipbuilding Corp. is about 20 percent complete.

Subassembly work has started on many ship components and structural members, and work on the reactor containment vessel and secondary reactor shield will start shortly. Keel, inner bottom, tank tops, and base structural members already are in place on the ways. All major component orders have been placed for such items as the steering gear and main electrical switchboard, and subcontract work is largely under way.

The schedule calls for launching the ship in May 1959, achievement of reactor criticality early in 1960, and sea trials in the spring of 1960.

The Babcock & Wilcox Co. has completed about 50 percent of the detailed design of the nuclear part of the pressurized water powerplant. Fabrication is under way on the reactor pressure vessel, steam generators, and pressurizer. Subcontractor work has started on control rod drive mechanisms, primary pumps, and all long lead-time main propulsion equipment items.

[27] See pp. 54–55, Twenty-second Semiannual Report to Congress (January–June 1957).

The program of critical nuclear measurements on uranium or oxide fuel rods for the reactor is proceeding rapidly at the Babcock and Wilcox facility at Lynchburg, Va. The initial core loading will comprise pelletized uranium oxide, enriched to approximately 4 percent uranium 235, as the fuel material in 0.5 inch stainless steel tubes.

Engineering development work started on a second core for the *Savannah* which would be used for replacement and standby purposes. The work, leading to a start of core fabrication early in fiscal year 1960, is being performed by General Electric Co.

A program of general support was established at the Oak Ridge National Laboratory to assist the Maritime Reactors Program in health physics studies, metallurgical development, and special consultation services.

Maritime gas-cooled propulsion system. Alternative reactor systems have been under study to determine which ones give greatest promise of producing economic nuclear power for merchant ship propulsion. Design feasibility studies, completed during the previous reporting period, showed that a gas-cooled reactor with a closed-cycle gas turbine would provide a compact plant of relatively light weight and offer promise of eventual economic operation. Consequently, the Commission and the Maritime Administration contracted on June 26 with General Dynamics Corp. to perform research and development on a high-temperature (1,300°–1,600° F.) system of this type. This program is expected to lead to fabrication and test of a prototype reactor within 5 to 7 years, the time depending upon technical success in various developmental phases. The General Atomic and Electric Boat Divisions of General Dynamics Corp. are performing initial work on key technical problems involving metallurgy, fuel element design, heat transfer, development of seals, and system analysis.

Experimental fuel elements, moderator material, and coolant will be tested in a recirculating gas loop being fabricated by General Electric Co. in a Hanford reactor. Development by General Electric of compressor bearings lubricated by the process gas stream, which would eliminate lubricant contamination and leakage of process gas, is progressing satisfactorily.

Other program developments. Assurance of maximum safety is important to the successful introduction of nuclear-powered merchant ships into normal channels of foreign and domestic commerce. Precautions to prevent a nuclear incident aboard the *Savannah* will include the use of reinforced shielding and protection against the impact of collisions. The Coast Guard and American Bureau of Shipping, marine safety regulatory bodies, are carrying out a detailed

review to ensure maximum practical safety in compliance with appropriate regulations. The naval architect firm of Gibbs & Cox, Inc., New York, began safety design studies aimed at achieving maximum safety at minimum cost in future nuclear-powered ships.

A study of shore facilities and equipment required to service nuclear-power merchant ships was initiated by the Electric Boat Division of General Dynamics Corp. following a preliminary study by Ralph M. Parsons Co., Los Angeles.

A study by American Radiator and Standard Sanitary Corp. has shown that oil tankers, ore carriers, and general cargo vessels operating on long trade routes at relatively high speeds offer the best chance for a relatively early economic application of nuclear power to merchant ships.

In line with these findings, preliminary engineering work was undertaken during this reporting period on possible conversion to nuclear power of a prototype T–5, 22,500 ton, 20-knot tanker now under construction. Current plans propose use of a 20,000 shaft horsepower boiling water reactor system—the first application of this reactor system to ship propulsion. The date when the ship probably could be ready for initial operation will depend on what design features are incorporated. The earliest date is estimated to be 1961. Preliminary design work on the reactor propulsion plant was undertaken by the General Electric Co. under a Commission contract, and overall marine engineering by George G. Sharp, Inc., under a Maritime Administration contract.

General Engineering and Development

Chemical Processing

Development of techniques and processes for aqueous, volatility, and low decontamination systems of chemical separation and decontamination of unburned fuel from irradiated fuel elements was advanced during the reporting period.

Aqueous processing. The Commission continued emphasis on development of processes which would be suitable for broad classes of fuel types.

The *Darex* headend process, in which stainless steel fuels are dissolved in dilute *aqua regia*, followed by distillation separation of the highly corrosive chloride, continues to be of major interest. At Oak Ridge National Laboratory continuous dissolution was demonstrated on a cold engineering basis, and an integrated loop test is in progress that involves dissolution, chloride stripping, rectification, and nitric

acid evaporation for feed preparation. Extensive investigations have also been conducted at Idaho Chemical Processing Plant and at the Hanford Works.

In the *Zircex* headend process, applicable to preparation of zirconium-niobium types of fuels for aqueous separation, anhydrous hydrogen chloride is reacted directly with metallic fuel constituents. Data on unit operations obtained with *Zircex*, both in dejacketing of uranium oxide fuels and on the integral attack on alloy metallic fuels, has proved this approach to be feasible. Removal of heat from this highly exothermic reaction continues to present severe engineering problems. The most promising application of the technique appears to be in the decladding operations.

Nautilus fuel process. Processing of a variety of highly enriched irradiated fuels was accomplished at the Idaho Chemical Processing Plant. The zirconium-uranium alloy, zirconium-clad fuel from the *Nautilus* was processed routinely using a process involving hydrofluoric acid dissolution and tributyl phosphate extraction. Recovery efficiency for uranium was in excess of 99.6 percent. Miscellaneous changes were incorporated into the plant to improve the performance of the process and to reduce operating costs. Highly enriched fuels of the uranium-aluminum alloy type were handled in the continuous dissolving extraction process with routine, high recovery efficiency. Included among these fuels were various Materials Testing Reactor types such as the Aircraft Shield Test Reactor fuel.

Other methods for the treatment of highly irradiated fuels expected from power reactors prior to decontamination of the source and special nuclear material by extraction are under investigation at Commission installations of Hanford, Savannah River, Oak Ridge, and Idaho.

Volatility processing. Considerable progress was made on developing the fluoride volatility process of chemical separation at Oak Ridge and Argonne National Laboratories. Irradiated fuel from the Aircraft Reactor Experiment (ARE) was successfully processed through the Oak Ridge National Laboratory volatility pilot plant with satisfactory product recovery, excellent decontamination, and low loss of the product in wastes. This operation demonstrated the feasibility of the molten salt volatility approach to chemical processing, using Oak Ridge techniques which involves use of sodium fluoride as an absorption-desorption medium.

Development continued at Argonne National Laboratory on a volatility process for separating plutonium from fission product residues. A development program was also initiated at Argonne to

investigate the application of fluoride volatility processes to recovery of fuel of the type to be used in the Liquid Metal Fuel Reactor Experiment.

Integrated low decontamination processing. The *Pyrozinc* process under development at Argonne continued to show promise of effecting adequate fission product separation for low decontamination processing. In this process, uranium is dissolved in molten zinc and an intermetallic uranium-zinc compound is formed which can be separated by filtration.

Low decontamination (pyro) chemical processing methods are of interest in that they remove fission product poisons, thereby restoring reactor reactivity. When integrated with a fuel element design amenable to remote fabrication, this method makes possible a potential reduction in fuel cycle cost.

Argonne continued development and testing of components in an equipment mockup of the Experimental Breeder Reactor No. 2 processing facility. Melt refining studies have shown zirconium oxide to be better than magnesium oxide as a crucible material for removal of fission products.

At Atomics International emphasis was placed on development of low decontamination methods for processing future Sodium Reactor Experiment cores of uranium oxide. A technique which involves cycling through multiple stages of oxidation-reduction has yielded promising results. Equipment has been assembled to allow testing and mockup on an engineering scale.

Treatment and Disposal of Reactor Residues

Research continued on safe, practical methods for handling, treatment, and disposal of radioactive residues from chemical reprocessing of irradiated reactor fuels.

Waste treatment development. The development of a process for calcination of radioactive chemical processing plant waste materials was continued. In this process, highly radioactive liquid waste is reduced to dryness, forming a less hazardous, noncorrosive solid product. Preliminary conceptual design of an engineering scale pilot plant for the fluidized bed calcination of radioactive wastes from the Idaho Chemical Processing Plant was completed, and detailed design was initiated.

Laboratory and cold pilot plant development was continued at the Idaho plant and radioactive tracer pilot plant operations were carried out at Argonne National Laboratory.

A contract between the Commission and the Arthur D. Little Co. initiated a survey of the present day market potential for the sale of mixed and separated fission products. Design of prototype facilities for the large scale packaging of separated fission products was nearing completion at Hanford.

Waste disposal development. Work on *direct disposal* of highly radioactive residues with or without treatment, into selected, isolated geologic formations is in the beginning stages. Core drilling in a salt formation at the Naval Air Station, Hutchinson, Kans., has been performed in order to compare this location with other possible sites for conducting field experiments. Detailed calculations indicated the maximum heat built up from the wastes will be in the range of hundreds of degrees centigrade, instead of tens of thousands of degrees, as was first believed likely. An advisory committee has been established by the American Petroleum Institute to assist the Commission in this work.

Immobilization of the radioisotopes by fixation into inert media such as glass, ceramics, or synthetic minerals is being studied at Oak Ridge National Laboratory, National Reactor Testing Station, Los Alamos Scientific Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, and Massachusetts Institute of Technology. Mixtures for forming ceramic materials to bind the radioactive materials in the ceramic structure include varying amounts of lime, borax, and sand. After firing, leaching tests of solidified mixtures incorporating simulated mixed fission product residues showed it is possible to make ceramics that are essentially nonleachable.

Specific separation of the radioactive fission products, cesium 137 and strontium 90, to reduce the toxicity of reactor residues and shorten the total life of the residues' radioactivity is being studied at Oak Ridge National Laboratory and Johns Hopkins University. Removal of cesium and strontium would reduce the effective radioactive life of the remainder to some tens of years instead of hundreds of years, and would reduce also the long term heat generation. The long lived isotopes that are removed then would be available for industrial uses. However, it has been found necessary to separate these two elements to a very high degree (a factor of approximately 1 million) in order to make possible simpler disposal of the remaining wastes. Electrolytic cells employing moving mercury cathodes are being developed which fulfill the high specification for decontamination.

Development work continued on *disposal of low-level wastes,* especially in studies of the effects of these wastes on the environment. During January–June 1958, under the direction of a group at Northwestern University and in cooperation with all State and Federal

authorities having related responsibilities, large scale tracer studies were run in the Chicago Sanitary and Ship Canal to determine the dispersion and dilution capabilities of the stream. The latest of these studies consisted of an injection of approximately 1,000 curies of tritium and 20 curies of scandium 46, which enabled the scientists to follow the activity for several hundred miles. Once injected into the canal, these tracers were rapidly diluted to levels which presented no hazard.

Arrangements are being made with the United States Public Health Service to conduct a survey of the wastes resulting from uranium milling operations and their effects on stream environments.

A special subcommittee working under the auspices of the National Academy of Sciences' Committee on Oceanography is examining the feasibility of establishing a limited number of *new sea disposal sites* in the Atlantic Ocean and Gulf of Mexico for use in commercial disposal of low-level radioactive wastes. If feasible, new sites will be established closer to the coast-line than the presently recommended 100 miles or more offshore.

An interdivisional Atomic Energy Commission Waste Disposal Working Group was established to review and coordinate Commission operations.

Testing Reactors

Engineering Test Reactor (ETR). After initial criticality of the Engineering Test Reactor was achieved in September 1957, an extensive testing program was conducted to determine the reactor's operating characteristics. At the outset, primary coolant pump deficiencies were observed. These were corrected by the manufacturer. In addition, both out-of-pile and in-pile hydraulic tests on the brazed fuel elements designed for ETR operation showed buckling at less than design water coolant flows (35 ft./sec.). These tests indicated that the brazed elements stood up at roughly one-half design power and the ETR was accordingly operated with these elements at 80 megawatts for approximately 3,000 megawatt-days.

Of several new designs investigated, two warranted procurement of full core loadings. In both cases, the fuel plates are held in the side plates by means of pins rather than brazing which caused objectionable softening of the metal. In one case, the element sideplates were slotted to relieve pressure differentials across fuel plates.

On April 19 the ETR began operating at full power, 175 megawatts, with the pinned, solid sideplate elements. Operation at full power with the slotted plates followed. Both types performed satisfactorily.

Materials Testing Reactor (MTR). Operation of the Materials Testing Reactor on fuel of 20 percent enrichment was completed in November 1957. A total of 646 megawatt-days, 550 at the 30 megawatt level, was achieved from the full core loading to demonstrate that, from both nuclear and engineering points of view, 20 percent enriched fuel is satisfactory for a high flux testing reactor. Operation showed that it is possible to manufacture an element using 20 percent enriched fuel which will contain enough uranium 235 per element to produce a satisfactory operating cycle time and which still will be able to withstand the conditions in a high flux reactor. The resonance escape probability for neutrons proved somewhat higher than predicted, but this actually made possible a longer life for the fuel charge than would be needed in usual MTR practice.

Work was completed on the velocity selector and associated equipment for installation at the Materials Testing Reactor to facilitate the study of mechanisms of neutron scattering in the range below 0.1 electron volts. The information is important to calculation of leakage, control rod effectiveness, temperature coefficients, and other data for thermal neutron reactors.

Advanced Engineering Test Reactor (AETR). A final report was received from Internuclear Co. on its study contract dealing with the proposed Advanced Engineering Test Reactor.[28] Progress reports were received from American Radiator and Standard Sanitary Corp.-Atomic Energy Division on its similar contract, with the final report due in July.

The AETR is intended for testing fuel assemblies cooled by water, gas, and liquid metal. The design now under study consists of a group of seven separately cooled and controlled reactors, each capable of producing an unperturbed thermal neutron flux of 1 to 1.5 x 10^{15} neutrons per square centimeter per second in the test sections. It would provide an effective tool for the civilian nuclear power industry's use in testing a variety of fuel assemblies under optimum conditions.

The advantage of the multiple core facility is that testing of an element in one test hole may be carried to the point of destruction of the element without causing perturbations of neutron flux distributions in other test holes.

Privately financed test reactors being built by Westinghouse Electric Corp. near Pittsburgh and by General Electric Co. near Pleasanton, Calif., were well along in construction. Industrial Test Reactors, Inc., Charlotte, N. C., also plans construction of a test reactor.

[28] See p. 130, Twenty-third Semiannual Report to Congress (July–December 1957).

Control Rod Materials Program

On March 12, the Commission invited expressions of interest from firms qualified to perform a research and development program to provide information on materials which reactor designers may utilize in control rods. The program is expected to encompass initially a comprehensive survey of existing data and developments in this field, to be followed by reactor physics calculations, determination of nuclear specifications for materials development, procurement, fabrication, and irradiation of selected materials in nuclear reactors.

Twenty-two proposals were received. The proposal by General Electric Co. to perform the work at their Vallecitos Atomic Power Laboratory in California was accepted as a basis for contract negotiations.

Reactor Safety

The experimental reactor safety program of the Commission includes three broad areas of research and development: (*a*) reactor kinetic and transient studies, (*b*) chemical aspects of reactor safety, and (*c*) containment of reactor systems. These programs are designed to gain such understanding of the behavior of reactors and reactor components that plants can be designed and operated, with virtual certainty of safety.

Besides continuing work during this reporting period on the Special Power Excursion Reactor Test (SPERT) programs at the National Reactor Testing Station, the Kinetic Experiment on Water Boilers (KEWB) at Santa Susana, Calif., and the other safety programs,[29] two additional investigations dealing with metal-water reactions were undertaken at Argonne National Laboratory and at the Vallecitos Laboratory of General Electric Co. The reactor safety program at the Oak Ridge National Laboratory was expanded, particularly in fuel element melting studies and in reactor controls and instrumentation.

In a test with KEWB on April 14, the reactor momentarily reached a power level of more than 500,000 kilowatts without sustaining any damage. The reactor, rated at 50 kilowatts, was subjected to severe operating conditions when more fissionable uranium than is required for normal operation was added to a homogeneous solution of fuel and the control rod rapidly withdrawn. The reactor responded by increasing its power output to 530 thousand kilowatts in less than a second and then shut itself off.

[29] See pp. 125–129, Twenty-third Semiannual Report to Congress (July–December 1957).

KEWB was designed to study the behavior of homogenous reactors when the power is accidently increased beyond normal operating levels. The latest series of tests demonstrated the inherent ability of the reactor to shut itself down when an abnormal operating condition occurs. The power surge was so brief that the temperature of the fuel solution was raised only slightly, not enough to cause it to boil. Only moderate pressure lasting for one-thousandth of a second was generated within the reactor vessel. The power was prevented from rising further by the sudden expulsion of fuel solution into an overflow chamber which prevented the nuclear chain reaction from continuing. The expulsion of the fuel solution in turn was caused by the generation of gas within the fuel, a characteristic of solution type reactors under high power operation.

Rate of power rise of the KEWB reactor was faster than any similar experimental reactor has been able to withstand without being damaged. The peak power reached was more than 10 times the design power.

Military Reactor Development

Army Reactors Program

The Army Reactors Program involves the development of reactor systems to meet specific military requirements for the production of electricity and heat, and for other special applications not involving aircraft or ship propulsion. Current projects are described in the following items.

Army Package Power Reactor (APPR–1). The Army Package Power Reactor No. 1 at Fort Belvoir, Va., continued to operate successfully at its rated power of 1,855 net electrical kilowatts. The contract with Alco Products, Inc. for construction and test operation of APPR–1 was completed with Government acceptance of the plant on January 24, 1958. Alco will continue to operate the plant through June 30, 1959, under a Commission contract funded in part by the Army.

During the reporting period, continued research and development work aimed at improving plant reliability, extending the life of reactor system components, and increasing knowledge of reactor performance characteristics. Alco has completed design of a bimetallic tube steam generator which is not susceptible to chloride stress corrosion. It will be installed later in the APPR–1.

Argonne Low Power Reactor (ALPR). Construction was virtually completed during this reporting period on the Argonne Low Power

Reactor, a package boiling water reactor of smaller size and lower power than the APPR–1. It will serve as the basis for design of field units which might be used in small military installations in arctic areas. The prototype at the National Reactor Testing Station in Idaho is designed to produce about 200 kilowatts of electricity and 400 kilowatts of space heat. The ALPR hazards summary report was approved by the Advisory Committee on Reactor Safeguards, which concluded that the reactor could be operated up to 3 megawatts (heat). Fuel element and core fabrication were completed, and attainment of criticality is scheduled in the near future.

Gas-Cooled Reactor Experiment (GCRE). The Gas-Cooled Reactor Experiment, under construction at the National Reactor Testing Station under Commission contract, is intended to develop engineering data and provide experience for design and construction of mobile powerplants for military use and small stationary powerplants for civilian use.

During this reporting period, the critical assembly work and the engineering core test were completed. Final specifications for fuel elements were established and their components will be furnished by Metals and Controls Corp. Fabrication of the core assembly is under way, and is scheduled to be completed by December 1958.

Design and fabrication of several test loops continued. The reference test loop at Battelle Memorial Institute began operation in February.

Advanced reactor studies. The Department of Defense has repeatedly expressed interest in reactor systems of moderate power rating, extreme compactness, and low weight, particularly for use in mobile units. Under Commission contracts, Curtiss-Wright Corp., General Electric Co., and Nuclear Development Corp. of America began preliminary studies related to the selection of reactor concepts most promising for mobile use.

The Commission contracted with Convair Division of General Dynamics for a complementary study to survey all information available on light weight shield development, and to arrive at the detailed requirements for an experimental program necessary for the development of appropriate shielding for compact reactors.

To provide information pertaining to the relative practicability of mounting nuclear powerplants on extensible piers and barges, an investigation was begun by Moran, Proctor, Mueser & Rutledge and Gibbs & Hill, Inc., under a Commission contract initiated in March. This method of mounting might greatly reduce the cost and time required to construct nuclear powerplants to meet military power

requirements at arctic riparian installations. Concurrently a canvass of the industry was initiated to determine which reactors, nearly or fully developed, would be best suited for such an application.

Naval Reactors Program

Naval reactor projects in operation or completed. Three nuclear-powered submarines were in operation as of June 30. In total, as of May 31, they had traveled some 182,300 miles on nuclear power, 133,000 while submerged, distributed as follows:

Submarine	Miles traveled	
	Total	Submerged
USS *Nautilus* (SS (N) 571)	112, 000	78, 000
USS *Seawolf* (SS (N) 575)	48, 500	36, 000
USS *Skate* (SS (N) 578)	21, 800	19, 700

The USS *Skate* satisfactorily completed her sea trials during this reporting period. On March 28 she completed a totally submerged trans-Atlantic crossing from Portland, England, to New London, Conn., in 7 days and 5 hours.

Throughout the first half of this reporting period the S1W plant at the National Reactor Testing Station remained shut down for refueling and routine maintenance. On March 31 the second replacement core was installed in the plant.

Naval Reactor Projects Under Development

Design and development work on the *Small Submarine Reactor S1C* prototype reactor plant continued under Commission contract at the Nuclear Engineering Laboratory of Combustion Engineering, Inc., Windsor, Conn. Construction of the hull which will house the prototype nuclear propulsion plant was completed in December 1957 and installation of plant components started. The reactor pressure vessel, propulsion load absorber, and other major nuclear propulsion plant components have been installed in the prototype hull.

An S1C type of nuclear propulsion plant will be installed in the submarine *Tullibee* (SSN597). This submarine was authorized for construction in the Navy's fiscal year 1958 shipbuilding program.

The *Submarine Advanced Reactor (S3G)*, a prototype of a high-performance submarine nuclear propulsion plant for the radar picket submarine *Triton* is being constructed at West Milton, N. Y., under Commission contract. It consists of a section of a submarine hull containing one reactor with primary coolant system and related control, auxiliary systems, and steam-producing equipment. The reactor will be pressurized, light water-cooled and moderated.

Two S3G-type reactors will be installed in the submarine *Triton* (SSR (N) 586). This submarine was authorized for construction in the Navy's fiscal year 1956 shipbuilding program. The *Triton* will be the largest submarine the United States Navy has ever built, and the first to be powered by two nuclear reactors. It is being designed to be fast enough to operate in conjunction with a fast carrier task force and to provide radar information. Construction of the *Triton* is proceeding at Electric Boat Division, Central Dynamics Corp., Groton, Conn.

The *Large Ship Reactor* (*A1W*) project provides for design and construction of a land-based prototype dual pressurized water reactor plant at the National Reactor Testing Station in Idaho. The A1W prototype plant will consist of the machinery for one shaft of a large surface ship, including the nuclear reactors. Construction of the prototype plant by Westinghouse Corp. under a Commission contract is approximately 70 percent completed.

Eight A1W-type nuclear reactors will be installed in the aircraft carrier *Enterprise* (CVA (N) 65). The keel of the *Enterprise* was laid February 4 at Newport News, Va., where the ship is being constructed by the Newport News Shipbuilding and Dry Dock Co.

Construction of *Destroyer Reactor* (*D1G*) a land-based destroyer reactor prototype plant at West Milton, N. Y., was authorized by Congress in May. The destroyer nuclear propulsion plant will be of an advanced pressurized water type constructed by General Electric under a Commission contract and will be located in the sphere which formerly housed the *Seawolf* prototype reactor plant at West Milton. Advance architect engineering designs are under way for modification of the West Milton off-hull facilities and utilities for the D1G project.

Design and development of the D1G reactor plant is under way at Knolls Atomic Power Laboratory. The Navy has included in its 1959 shipbuilding program a destroyer type of ship that will utilize two D1G-type reactors.

Guided Missile Cruiser Reactor (*C1W*). Design and development continued on the nuclear propulsion plant for the guided missile cruiser, USS *Long Beach* (CG (N)–9), at the Commission's Bettis Plant in Pittsburgh. Construction work progressed on the ship at Bethlehem Steel Co.'s Fore River Shipyard, Quincy, Mass.

High Speed Submarine Reactor (*S5W*). The first of the nuclear powered, highspeed, single screw attack submarines, the USS *Skipjack* (SSN585) was launched on May 26 at Groton, Conn. This submarine will utilize an S5W type nuclear propulsion plant which was designed and developed at the Commission's Bettis Plant.

The primary purpose of the *High Temperature Test Facility (HTTF)* at the Commission's Bettis Plant, Pittsburgh, Pa., is to obtain basic physics information on pressurized water reactors at high temperatures. All systems descriptions and flow diagrams have been received from the architect-engineer. Preliminary design work is completed. The contract has been awarded for the reactor vessel, and the reactor bridge crane has been placed on order.

Construction of the *Expended Core Facility (ECF)* continued at the Naval Reactor Facility, Idaho. Administrative quarters have been completed. The water pits, fluid systems, hot cells, and radiochemistry laboratories are about 65 to 75 percent complete. Completion of the facility by Westinghouse under Commission contract is expected in the summer of 1958.

Aircraft Reactors Program

The Department of Defense and the Atomic Energy Commission are cooperating in a joint Aircraft Nuclear Propulsion Program which includes the development and testing of nuclear propulsion systems for both manned and unmanned vehicles.

In the *manned aircraft propulsion program*, investigations are going forward on two basic systems. In the *direct-cycle approach*, air from a turbojet engine compressor is heated in the reactor core itself before being exhausted through the engine turbine and exhaust nozzle. In the *indirect-cycle approach*, the compressed air is heated as it passes through a heat exchanger system, containing liquid-metal coolant from the reactor.

The General Electric Co. at Evendale, Ohio, is under contract to the Commission to develop a reactor for the direct-cycle system.

Development of the indirect-cycle approach is being conducted under contract to the Commission by Pratt & Whitney Aircraft Division of the United Aircraft Corp. at the recently completed Air Force facilities of the Connecticut Aircraft Nuclear Engine Laboratory (CANEL) at Middletown, Conn. Criticality of the first critical experiment to be run at the laboratory was achieved in March.

The Oak Ridge National Laboratory provides general support for both the direct and indirect cycle Aircraft Nuclear Propulsion Programs, with particular emphasis on theoretical and applied shielding problems.

Reactors under development for use in *unmanned vehicles* include those to propel rocket and ramjet types of missiles (Projects ROVER and PLUTO), and to provide a source of nuclear auxiliary power (SNAP) for space satellites. A nuclear rocket system might be useful for propelling space vehicles as well as intercontinental ballistic

missiles. A ramjet, which is an air-breathing engine, would be useful in propelling essentially unlimited range missiles operating in the earth's atmosphere. The Commission work in this area is directed towards determining the feasibility of reactors for each of these systems and involves materials development, reactor component testing, and fabrication and testing of experimental high temperature reactors.

During the reporting period experiments continued at the *Aircraft Nuclear Propulsion Site* of the National Reactor Testing Station related to the testing of reactors necessary for nuclear operation of direct air-cycle turbojet engines for manned vehicles. The components for these experiments are designed and produced by the General Electric Co. at Evendale, Ohio, under its contracts with the Commission and the Air Force.

New facilities were placed in operation at the site, including two reactor critical cells in the *Low Power Test Facility* (*LPTF*), four high level hot cells, and a large cold shop area. The LPTF will be used for criticality and low power testing of assemblies so that other facilities can be kept available for test operations at power. Construction scheduled to be finished in August 1959 will provide new propulsion system testing facilities and a facility for performing basic shielding experiments.

Construction started in March on the *Shield Test Pool Facility* (*STPF*). This facility will contain a two-compartment pool for submerged tests required in designing aircraft reactor shielding.

Nuclear rocket propulsion (*Project Rover*). The program to determine the feasibility of utilizing nuclear energy for rocket vehicle propulsion continued at the Los Alamos Scientific Laboratory. The scope of research on reactor materials was increased and results are encouraging. The design, development, and fabrication of the initial test reactor progressed with a static test scheduled for late 1958.

Information gained in this and other static tests at the Nevada Test Site is expected to help in formulating more advanced design concepts which may lead to construction of prototype nuclear propulsion engines for rockets. Construction of test facilities continued at the Nevada Test Site. The initial phase is approximately 80 percent complete. All roads, utilities, supporting facilities, and the control building have been completed and work is well under way on the assembly-disassembly building and test cell.

Nuclear ramjet propulsion (*Project Pluto*). Experimental and theoretical work to determine the feasibility of applying heat from a reactor to ramjet engines was continued at the University of California Radiation Laboratory.

Contracts for construction work at the Nevada Test Site to accommodate the extension of these efforts have been awarded.

Atomics International made significant progress in its research on reactor materials.

Classification and Declassification

Commission representatives met with officials of the United Kingdom in October 1957 to undertake further studies of declassification of information on research in the field of controlled thermonuclear reactions. As a result of these discussions, the Commission announced in January that a new Joint Declassification Guide had been approved by the United States and the United Kingdom. This new declassification guide makes it possible to declassify almost all fundamental scientific work on research, development, and operation of devices in this field. (See Part Two of this report, Progress Toward Producing Power from Controlled Fusion.)

In April, the Commission declassified information on the existence of depleted uranium with an assay of 0.22 (plus or minus 0.02) weight percent of uranium 235. In addition, the Commission declassified the schedule of charges for depleted uranium and a schedule of prices to be paid for uranium bought or credited for leased material returned. (See earlier section of this report on Commercial and Isotope Development.)

As a part of the Commission's continuing program to declassify as promptly as possible all reports and records eligible for declassification under current policy, special review teams from the Division of Classification were established to review the classified documents held by 82 former Commission contractors whose contracts have now expired. Of approximately 10,000 documents on file, 5,500 documents in 18 facilities had been reviewed as of June 30 and 4,500 of these have been declassified. The program will continue until all the documents at the 82 facilities have been reviewed.

Information Activities

Atoms for Peace Exhibits

As of the end of the January–June reporting period, 9,281,173 persons had viewed the traveling atomic energy exhibits made available by the Commission for nonprofit display throughout the United States, 2,390,699 during the last 6 months. The exhibits were in-

augurated in February 1956. Six different types and sizes of displays, suitable for a large variety of exhibit arrangements and sites, now are being circulated for the Commission by the American Museum of Atomic Energy, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn.

For display in large population centers, at state fairs, and at similar sites, there are 3 large, 86-panel *Atoms for Peace* exhibits. Five mobile vans contain scaled-down, walk-through *Atoms for Peace* exhibits suitable for briefer showings in smaller communities. Six demonstrators travel with equipment enabling them to present *This Atomic World* demonstrations to high school assemblies. Ten new 18-panel units—*Summary of Atomic Energy*—packaged for shipment without an attendant, meet the needs of small cities and county fairs. Three 8-poster package exhibits titled *The Useful Atom* have been developed as library displays to increase reader interest in atomic energy. A booth exhibit explains the nuclear power program.

The five walk-through exhibit vans maintain an intensive, state-by-state, town-by-town schedule developed 6 months in advance of showings under the cosponsorship of the National University Extension Association and the United States Junior Chamber of Commerce. The other exhibits are scheduled by the Oak Ridge museum on a first-come, first-served basis, with some units already booked as far ahead as September 1959.

Since establishment and through June 30, the large Atoms for Peace units had been shown in 34 States to 4,695,718 persons; the mobile Atoms for Peace units in 1,679 communities in 34 States to 1,092,024 persons; the 14 package units in 283 communities to 2,260,330 persons; and *This Atomic World* at 1,601 schools before 1,233,101 students. For the 6-month period ending June 30 the totals for the large Atoms for Peace units were 13 States, 364,564 persons; mobile Atoms for Peace units, 581 communities in 13 States, 426,577 persons; package units, 115 communities, 1,014,920 persons; and *This Atomic World*, 615 schools, 584,638 students.

Technical Information

Technical Progress Reviews

Three series of unclassified *Technical Progress Reviews* were issued during this reporting period to supply industry with concise summaries of current atomic developments. The Reviews, inaugurated November 1957, are issued each quarter. Experts in specific areas of

nuclear science and technology, under Commission contract, digest and evaluate latest findings in their respective fields. The technology of military reactor and other classified Commission programs is reported to the extent that the technology can be dissociated from military and production data which must be safeguarded. The three Reviews currently published are:

Power Reactor Technology.[30] Walter H. Zinn and associates, General Nuclear Engineering Corp.

Reactor Fuel Processing,[30] Stephen Lawroski and associates, Chemical Engineering Division, Argonne National Laboratory.

Reactor Core Materials,[30] covering solid material developments, R. W. Dayton, E. M. Simons, and associates, Battelle Memorial Institute.

Technical Progress Reviews for other areas of nuclear science and technology will be issued as needed.

New Technical Data

The Commission surveyed the adequacy and effectiveness of contractor systems of reporting on technological advances and developments. It established a monitoring system to insure that significant reports are made promptly available for industrial use.

Translations

The Commission's program for producing translations of foreign scientific literature was expanded during this reporting period. Some 20 monographs by technicians in the Union of Soviet Socialist Republics on subjects such as "Heat Transfer Problems," "Tagged Atoms in the Study of Plant Nutrition and Use of Fertilizers," "Lithium and Its Alloys," "Hyperons and K-Mesons," "Many Particle Theory," and "Reviews of Radiobiology" were translated from Russian into English. Abstracts of translations are published as available in the Commission's *Nuclear Science Abstracts.* Full texts will be offered for sale, as soon as published, by the Office of Technical Services, Department of Commerce.

The Commission also continued its support of the joint translation program with the National Science Foundation to improve the availability of foreign scientific periodical literature in the United States.

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[30] Available by subscription (domestic, $2 a year, foreign, $2.50 a year) or by individual issue ($0.55), Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Rewriting Program

In its program for editing, rewriting, and publishing reports on military reactors which could be published as declassified documents after deletion of some material, the Commission has rewritten and issued about 175 of a total of 200 reports. They are available through normal Government channels for unclassified atomic energy reports.

Technical Information Workshop

The third of a series of regional meetings with access permittees was held June 26–27 in New York to explain Commission technical information services and to demonstrate their efficient use. An information workshop also was held in Geneva May 26–30 to assist European and Middle-East librarians in utilizing Atoms for Peace libraries donated to their countries and organizations (see earlier section of this report on International Activities). Arrangements were improved for transmittal to this country of unclassified scientific and technical publications.

Distribution of Reports

During this reporting period 58,127 classified and unclassified reports were sold to United States business and industry and others holding access permits, and 1,737 new unclassified reports were placed on sale[31] to the scientific community and the general public.

Increasing number of Commission-produced scientific and technical reports also are being distributed to laboratories and offices of other Government agencies and their contractors. These groups receive about 44 percent of all unclassified reports sent out under the Commission's standard and automatic distribution systems to supply technical and scientific personnel working for the Government, including the Commission, or for Federal contractors. They also received about 46 percent of all classified reports distributed by this system.

Access permittees purchased from the Commission during the past 6 months, 2,993 secret technical reports and 3,756 confidential reports. Cumulative purchases as of June 30, 1958 and December 31, 1957 are:

	Confidential reports	*Secret reports*
Total Dec. 31, 1957	27,416	8,561
Total June 30, 1958	32,172	11,554

[31] Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Proceedings of Technical Symposia

The Commission published during the last 6 months 7 collections of papers presented at scientific and technical meetings, conferences, and symposia so as to make this information more widely available to industry and the scientific community. Publications were:

Symposium on Fuel Element Fabrication, held at Paris, France, November 18–23, 1957. Paperbound, (Two Parts), $7.[32]

Symposium on the Shorter-Term Biological Hazards of a Fallout Field, reprint of a paper of a meeting held December 12, 1956, in Washington, D. C. Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Paperbound $1.75.

Reactor Safety Conference, sponsored by American Nuclear Society, Atomic Industrial Forum and United States Atomic Energy Commission, held in New York City, October 31, 1957. Paperbound, (Two Parts), $1.75.[32]

Fifth Air Cleaning Seminar, Harvard University, June 26–27, 1957. Paperbound $2.[32]

Report of Working Meeting on Fixation of Radioactivity in Stable, Solid Media, Johns Hopkins University, June 19–21, 1957. Paperbound $2.50.[32]

Minutes of the Fifth Tripartite Instrumentation Conference, Brookhaven National Laboratory, October 22–26, 1956. Paperbound $3.[32]

Sodium Reactor Experiment-Organic Moderated Reactor Experiment Information Meeting, Los Angeles, February 12–13, 1958. Paperbound $3.[32]

The second edition of the *Sourcebook on Atomic Energy*, written for the Commission by Dr. Samuel Glasstone, was published in March by D. Van Nostrand Co., Inc. Other special Commission publications are listed in appendix 6.

Education and Training

Surveys sponsored by the Commission have provided the first detailed estimates of technical manpower requirements in nuclear science and technology in industry, in universities and colleges, and in Commission and Commission contractor activities.

In these categories, a total of 34,700 technical personnel was reported in the fall of 1957 including 18,750 engineers, 13,500 scientists, and

[32] Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

2,550 technical managers. It is estimated that additional workers in organizations not surveyed or not responding to questionnaires would raise this total to almost 38,000.

Of the 34,700 actually reported, the Commission and its contractors employed about 68 percent; private industry employed some 18 percent, and the remaining 14 percent were in college and university atomic energy activities.

Although there were shortages in many scientific and engineering fields, none of these was believed to be sufficiently serious at present to delay important undertakings.

The Commission continued, during the January–June reporting period, its support of industrial and academic efforts to assure a broad base of present and future technical manpower for the continuing rapid development of the atomic energy industry and of Government programs.

Results of Surveys

Colleges and universities will have an estimated 5,700 scientists and engineers devoting at least part of their teaching and research time for the 1960–61 academic year to atomic energy activities, according to final results from the Commission's survey of academic manpower requirements.[33] This will represent an increase of about 1,000 or 21 percent over the 4,700 scientists and engineers in these fields during the 1956–57 academic year. For the 1957–58 semesters, the total was estimated at 5,400 or nearly 15 percent over 1956–57.

The survey also indicates that more than 86 percent of technical people in educational atomic energy activities are scientists, and 14 percent engineers. Twenty-four percent of all persons reported, or 1,059, were in chemistry and biochemistry; with 22 percent, a total of 967, in physics and biophysics. Chemical and mechanical engineering accounted for almost 50 percent of all engineers reported. Shortages of scientists averaged only about 6 percent of the total number required, but in engineering the deficiencies ranged up to 15 percent in some fields. The fields with the largest shortages are nuclear, electrical and mechanical engineers, physicists, chemists and biophysicists.

The data obtained from the survey of scientists and engineers in university atomic energy activities, when combined with studies of similar needs for the Commission and its contractors and for private industry,[34] presents the first broad picture of technical manpower

[33] Preliminary results were reported in the Twenty-third Semiannual Report to Congress (July–December 1957) pp. 306–307.

[34] These two studies, conducted by the Atomic Industrial Forum and Atomic Energy Commission staff, respectively, are available from the Division of Information, Technical Information Service, AEC, Washington 25, D. C., on request.

requirements for the entire atomic energy industry. A fourth survey designed to examine the requirements of Federal agencies other than the Commission itself will not be conducted because the studies already completed are believed to present sufficient general information. An analysis based on the three completed studies is being prepared.

To verify estimates and to keep the Commission currently informed, 22 Commission contractors employing 50 or more scientists and engineers each prepared an analysis of its 1958 supply and demand for scientific and engineering personnel. As of February there was no extensive shortage of scientists and engineers at the college graduate and masters degree levels, nor of men with little work experience. Virtually all contractors reporting, however, emphasized a continuing unfilled need for a small number of highly qualified personnel in such fields as theoretical and experimental physics, metallurgy, applied mathematics, physical chemistry and ceramic engineering. Turnover among technical people has lessened due to trends in general business activity.

Most companies report that they anticipate no difficulty in meeting their recruiting goals for junior and intermediate technical personnel and that they can be more selective in current hiring. Recruiting for those with doctorates continues difficult.

Assistance to Colleges and Universities

To assist development of expanded nuclear technology curricula at colleges and universities, the Commission continued during the reporting period to support programs of assistance in faculty training, fellowships, and provision of laboratory equipment for instructional purposes.

Laboratory equipment grants. The Commission contributed $6.2 million in grants to 120 educational institutions during the January–June reporting period, in addition to loans of equipment and materials. To date, $9.8 million has been distributed in grants to 131 schools.

In the life sciences, the Commission in the last 6 months has made grants of $827,442 to 64 institutions for equipment to be used in instruction. This brings the total awards to $1,167,480 to 73 schools since establishment of the program in August 1957.

To assist curricula in physical sciences and engineering, the Commission either by grants or under contracts contributed $5.4 million to 87 institutions during the last 6 months. In less than 2 years since initiation of this program, $8.7 million has been granted to 95 colleges and universities, including funds for 23 training and research reactors and 26 subcritical assemblies.

In many cases schools have received grants under both life and physical science programs.

Since January 1 the Commission also approved the loan without charge of neutron sources and special nuclear materials to 28 colleges and universities for use in educational programs. Sixty institutions now have received loans of nuclear materials under this program.

The grants for nuclear laboratory equipment have encouraged educational institutions to establish new programs of nuclear instruction and to expand courses already being offered. Most of the schools have not yet had time to report on actions taken subsequent to receipt of grants. The seven schools reporting so far have indicated that, in total, 6 nuclear curricula have been expanded, 5 universities or colleges have provided new or modified space for nuclear laboratories, and 3 new faculty positions have been added providing an increase of capacity in fields of nuclear instruction of approximately 400 student-course units, equivalent to 100 students enrolled in 4 nuclear technology courses.

Examples, drawn from university reports, include the following:

The *University of Florida* received a grant of $95,000 on March 6, 1957 toward the purchase of a teaching reactor. The university is constructing a permanent building costing $252,000 to house the reactor, a classroom and laboratory. A department of nuclear engineering was approved by the university's Board of Control in October 1957. An optional program in nuclear engineering, in which approximately 50 students are enrolled at the present time, is offered undergraduate students in electrical, mechanical and chemical engineering. Plans are under way to offer a degree of master's in nuclear engineering in the fall of 1958.

Stanford University was granted $9,950 by the Commission on March 6, 1957 to purchase nuclear electronic instruments for its subcritical assembly. The university moved its nuclear equipment to a larger building to provide sufficient space for instruction. A graduate nuclear engineering laboratory course, was offered in the 1958 spring quarter, for 20 students. Stanford has added another faculty member to its staff to assist in the teaching activities of the nuclear program.

The *University of Notre Dame* was awarded $13,400 on March 6, 1957 for nuclear equipment. Within the past year the university established a nuclear engineering sequence in its engineering college. Eight students were participating in this program in the fall of 1957.

Faculty training. For the third consecutive year, faculty members from engineering institutions will participate in a summer institute program sponsored jointly by the American Society for Engineering

Education and the Commission. It provides an opportunity for college teachers to improve their background in the basic or advanced levels of nuclear science and engineering.

This year there will be four institutes providing basic courses for engineering school faculty as follows: Cornell University with Brookhaven National Laboratory; Purdue University with Argonne National Laboratory; University of California (Berkeley) with University of California Radiation Laboratory; and North Carolina State College with Oak Ridge National Laboratory.

An institute of basic studies also is provided for the faculty of schools which offer 2-year technical courses, rather than full engineering training. This institute will be conducted through the cooperative efforts of Pennsylvania State University and Argonne National Laboratory.

Advanced institutes are offered in nuclear metallurgy at Ames Laboratory, in reactor physics at the University of Michigan, in chemical processing at the Hanford plant, and in instrumentation and control at Argonne National Laboratory.

Some 190 faculty members are expected to take part in the nine basic and advanced institutes, bringing the total for the 3-year program to 330 participants.

Fellowships. To attract outstanding students to the fields of nuclear science and engineering the Commission offered 164 fellowships for the 1958–59 academic year. A comparable number will be offered for the 1959–69 year.

The 1-year special fellowships in nuclear science and engineering, administered for the Commission by the Oak Ridge Institute of Nuclear Studies are offered at graduate levels. The fellowship students for 1958–59 comprise about 60 percent first year graduate students, 35 percent in the second year, and 5 percent in the final year.

Other special fellowships supported in fields of particular interest to the Commission included, during the period of this report, 94 special fellowships in radiological physics, 8 special fellowships in industrial hygiene, and 8 special fellowships in industrial medicine—the last group administered by the University of Rochester.

Other Domestic Programs

In addition to assisting colleges and universities in developing programs in nuclear science and engineering, the Commission supports other activities designed to interest young people in these fields or

provide specific training or experience to individuals with preliminary background in other areas.

Courses for high school teachers. Training courses in radiation biology for high school science teachers will be offered this summer at 12 universities. The courses are supported by the Commission in cooperation with the National Science Foundation. The Commission provides funds for special equipment and operational costs and the Foundation provides stipends, family allowances, and travel costs to the high school teachers. Teachers completing the course will be given kits of equipment supplied by the Commission for use in performing experiments and demonstrations in radiation physics and biology in high school classes. Since its initiation in 1956, these institutes have trained 400 high school science teachers.

Visiting lecturers, symposia and conferences. Through a program started by the American Institute of Biological Sciences in May 1957 the Commission provided 18 scientists for visiting lecturers in the field of radiation biology to 19 colleges and universities. As a part of their 3-to-5-day visits, the scientists hold interviews and consultations with students.

Short courses. A special 8-week course in health physics fundamentals was offered at Oak Ridge National Laboratory in February and March. It included formal classroom work concurrent with applied health physics training.

Work experience program. Agreements were signed during this reporting period to place 6 scientists and engineers in national laboratories where they will gain specialized work experience in nuclear technology. Under this work experience program, initiated in March 1957, agreements have been signed for 11 technical personnel, 4 of whom have completed their training.

Information for atomic energy study. During the first 5 months of the reporting period, 17,816 *kits of published material* dealing with various aspects of atomic energy were distributed to elementary, high school and college students in both this and other countries, as well as to teachers, adult study groups and other interested organizations. This represents an increase of nearly 75 percent over the same period of 1957, when 10,285 kits were distributed, and of 500 percent over the 3,067 distributed during the same period of 1954.

The kits are provided in response to requests for information on such subjects as the role of atomic energy in agriculture, medicine and industry; the food irradiation program; the nuclear power program;

basic research; uranium prospecting; weapons development; how to construct a cyclotron; how to build a Geiger counter; radiation effects; the Atoms for Peace program; the controlled thermonuclear program; and careers in atomic energy.

During the January-June reporting period, there were 17,124 screenings of atomic energy *loan films* for a total audience of 743,646. Of these screenings, 11,272 were in high schools. The 12 film libraries of the Commission contain some 70 titled unclassified subject films, available for loan upon request at 12 installations including Commission headquarters. Each library is responsible for servicing the areas nearest the library.

From the nearly 6,000 unclassified *photographs* in the Commission's picture library at Commission headquarters, an average of 800 prints is provided each month, upon request, to national news media, to schools, and for exhibit purposes.

Student visits to installations. Ten of the Commission's key laboratories and production facilities provided tours of unclassified areas for more than 3,000 selected high school students in a second annual observance of Thomas Alva Edison's birthday on February 11. Facilities visited were: Ames Laboratory, Ames, Iowa; Argonne National Laboratory, Lemont, Ill.; Brookhaven National Laboratory, Upton, Long Island, N. Y.; Hanford Works, Richland, Wash.; Knolls Atomic Power Laboratory, Schenectady, N. Y.; Los Alamos Scientific Laboratory, Los Alamos, N. Mex.; National Reactor Testing Station, Idaho Falls, Idaho; Oak Ridge National Laboratory, Oak Ridge, Tenn.; Sandia Laboratory, Albuquerque, N. Mex.; and Savannah River Plant, Aiken, S. C.

More than 2,000 high school science students visited the University of California Radiation Laboratory, Berkeley, between September 1, 1957 to May 1, 1958, as part of the cooperative program conducted with Northern California high school science classes.

The Brookhaven National Laboratory held two Visitors Days, one for junior and senior high school students which was attended by 5,677 students and one for the general public which was attended by 3,632 persons.

At Oak Ridge, a student educational tour program is carried out weekly under which high school and college student groups visit the American Museum of Atomic Energy and unclassified facilities at the Oak Ridge National Laboratory. During the past academic year, 42 tours were conducted for about 3,300 students and sponsors representing 111 schools in 14 States.

The Hanford Operations Office also conducts tours of unclassified facilities on a regular basis for small groups of science students.

Twenty-seven tours were conducted during the past 6 months for a total of 825 students and teachers.

The Argonne National Laboratory conducts frequent tours of its unclassified facilities. Ninety-five tours for college and high school students and faculty were conducted during the past academic year for a total of 2,085 students and 141 faculty members representing 59 colleges and 54 high schools.

International Educational Programs

As part of its Atoms for Peace program, described earlier in this report, the Commission sponsored courses for foreign students as well as domestic students. These include the curricula of the International School of Nuclear Science and Engineering at Argonne National Laboratory and associated universities and training courses in the uses of radioisotopes at the Oak Ridge Institute of Nuclear Studies. Among other activities, the Commission is preparing to open additional courses at the Argonne School, is helping to arrange for entrance of foreign students into colleges and universities for courses related to nuclear training, and is working with the University of Puerto Rico to establish a Spanish-language Puerto Rico Nuclear Center.

Physical Research

Research in high energy and nuclear physics, chemistry and metallurgy continued during the January–June reporting period to contribute basic knowledge to help advance nuclear science and technology. In addition to sponsoring research in Federal laboratories and through contracts with university and industry organizations, the Commission contributed to the design and construction of the large experimental machines required for this research.

During the last 6 months, among other developments, the new high-flux Oak Ridge Research Reactor went critical; construction and design advanced rapidly on Brookhaven National Laboratory's Alternating Gradient Synchrotron; Argonne National Laboratory successfully tested a scale model magnet for its proton-synchrotron; intensive design studies were carried by the Midwestern Universities Research Association on a 15-billion electron volt accelerator using colliding beams in a fixed field alternating gradient configuration. Both new heavy-ion linear accelerators, at Berkeley, Calif., and at New Haven, Conn., were in operation. The nation's two most powerful accelerators, the Cosmotron and the Bevatron, went out of service because of breakdowns; the Bevatron is operating at less than maxi-

mum efficiency while repairs are made; the Cosmotron will be shut down until about December 1958 while redesign and repairs are carried out.

In high energy physics research, among other recent projects, the properties of the recently identified particle, the neutrino, were further analyzed; the basic interactions of antiprotons with ordinary matter were studied; and tools and techniques were devised for advancing experiments with the so-called "strange" nuclear particles. Physicists continued to test the ramifications of the new Yang and Lee theory of nonconservation of parity in weak interactions.

In addition to chemical studies on special nuclear materials and on newly created elements at the upper end of the atomic table, chemical research has devised new methods of nuclear spectroscopy, and among other projects, has worked with molten salts. In metallurgy, studies supporting reactor work on liquid metal fuels were carried out, and oxidation, self-diffusion of metals, radiation effects, and powder metallurgy were investigated.

At the request of the Joint Committee on Atomic Energy, Subcommittee on Research and Development, the Commission presented testimony in public hearings during the first 2 weeks of February on the status and progress of research in physics, chemistry, metallurgy and materials, and on controlled thermonuclear reactions. The Commission also reviewed for the committee its administration of the total research program and gave estimates of requirements for financial support.

Research Equipment

The Oak Ridge Research Reactor, a high-flux instrument for research, was being tested during this reporting period, and two other major research machines, the heavy-ion accelerators at University of California Radiation Laboratory, at Berkeley, and Yale University were in service. Progress in design of new high energy accelerators by Argonne National Laboratory and by the Midwestern Universities Research Associations is described in this report, and details are given on construction of the alternating gradient synchrotron at Brookhaven National Laboratory. Causes of Bevatron and Cosmotron breakdowns, and plans for repairs, are reported.

Oak Ridge Research Reactor Critical

The Oak Ridge Research Reactor (ORR) went critical March 21. Authorized in 1954, the reactor has cost approximately $5 million. The reactor operated at its design power level of 20,000 kilowatts of

heat on May 29. It is a high flux reactor immersed in a pool and is moderated and cooled with demineralized water. The ORR is designed to operate at a power level of 20 to 30 thermal megawatts with an average flux greater than 1 x 10^{14} neutrons per square centimeter. The reactor will be used primarily in reactor development, physical research, and biology and medicine programs, and for fundamental research and engineering studies on the effects of nuclear radiations on reactor materials, particularly fuel elements and structural materials.

Major emphasis in design was placed on flexibility of use to permit many kinds of experiments close to the reactor core, and on accessibility to the core itself for numerous experiments within the high flux region. Entire fuel systems as well as individual samples may be placed easily in the area of high flux.

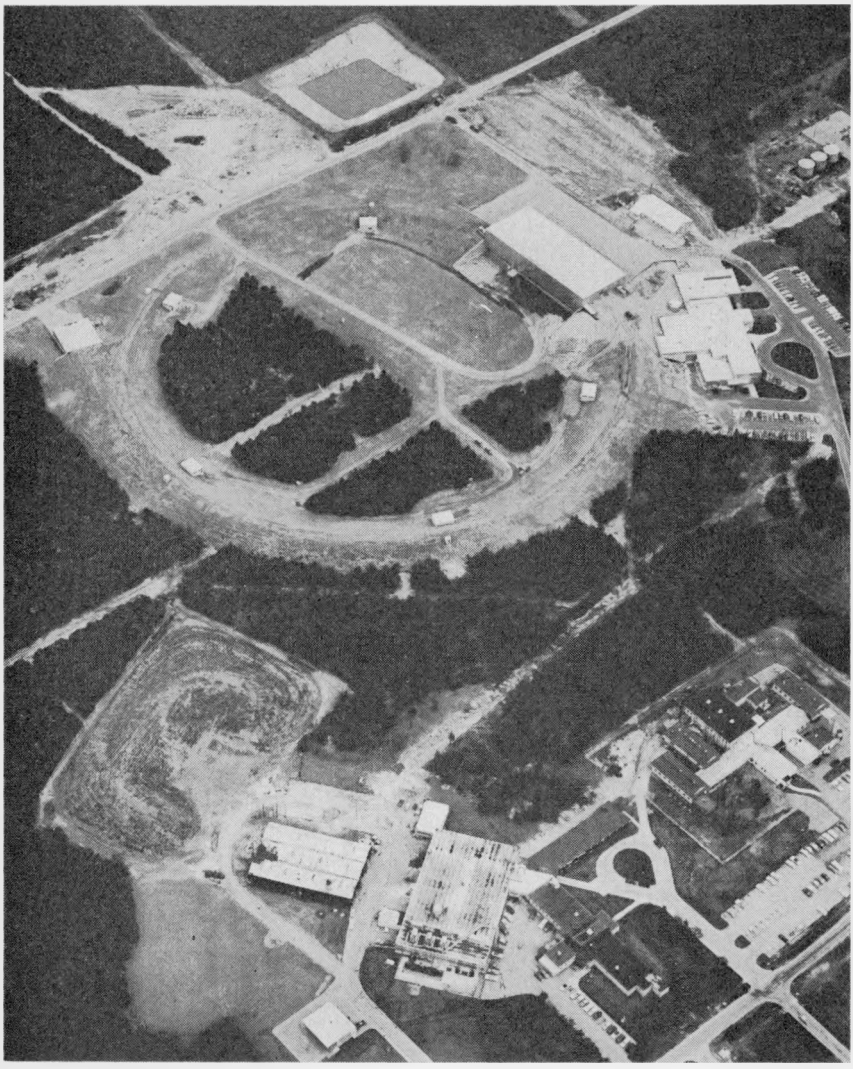
Progress on Brookhaven Alternating Gradient Synchrotron

The building complex of the Alternating Gradient Synchrotron (AGS) was completed during the reporting period at Brookhaven National Laboratory. (See photograph.) Design of the AGS magnet has been completed, and testing of sample cores and design studies of other smaller magnet units are under way. The injection system of the AGS comprises a 50 million electron volt (Mev) linear accelerator, on which work is on schedule, and a 750 kilovolt (kv.) Cockroft-Walton preaccelerator which has been delivered and tested. Final design on power amplifiers for the AGS radiofrequency system has been established, and details on the synchrotron vacuum chamber have been largely completed.

The controls for the AGS will be designed at the time that the mode of desired operation of component systems has been established. At present, detailed circuit drawings have been prepared for the main synchrotron water control system and a communications system. Preliminary work has started on the vacuum control system.

Authorized under the Second Independent Offices Appropriation Act of 1954, construction began on the AGS in March 1954.[35] It will be an enormous machine, the magnet ring that controls the particle beam within the vacuum chamber has a diameter of 842 feet, and a circumference of about a half-mile. Protons will be injected into the vacuum chamber with velocities of some 50 Mev and, in the course of some 300,000 revolutions, are expected to attain a maximum energy of 25 to 30 billion electron volts (Bev). During these revolu-

[35] See p. 34, Fourteenth Semiannual Report to Congress (January-June 1953), and p. 37, Fifteenth Semiannual Report to Congress (July-December 1953).



Brookhaven's AGS accelerator. The photograph above is an aerial view of the 30 billion electron volt Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory, Upton, Long Island, N. Y., now under construction and expected to become operational in 1960.

The large ring in the upper center portion of the photograph is the half-mile track of the AGS magnet enclosure covered with earth. At the extreme left of the magnet ring is the building that will house the 50 Mev linear accelerator injector for the machine. On the right side of the ring is the Target Building and Experimental Areas. The large building to the right is the Service Building. Around the magnet ring are five air-conditioned stations necessary to provide the constant temperatures for the machine's operation.

At the top of the photograph is the AGS diffusion basin for the machine cool-

tions, the particles must be maintained in a circuit within lateral displacements of the order of 1½ inch from the ideal orbit. Tolerances of the order of about 0.02 inch over the distance of one-half mile for the placement of magnets have required extremely exacting engineering and design work.

Building progress. With the buildings for the accelerator completed, auxiliary building services were installed, fabrication of magnets and the linear accelerator was begun and a large part of the detailed design of other components was finished.

Supplementary contracts were awarded for the building complex, including installation of equipment and piping in the pump room; excavation of a suitable foundation for the main magnet power supply, and completion of the power room wing of the synchrotron service building. Sections of the Target Building and Linac Building are now occupied, and machine equipment was moved into position.

The section of the synchrotron ring which passes through the Target Building will be covered with 14,000 tons of high density concrete shielding blocks. The pouring of these blocks is nearing completion.

Progress on magnets. With design of the AGS magnet completed, a contract for fabrication of the cores was awarded to Baldwin-Lima-Hamilton Corp. and a contract for the magnet exciting coils was awarded to National Coil Co. After intensive tooling preparations, Baldwin-Lima-Hamilton ordered its steel requirements from Allegheny-Ludlum Steel Corp., and at present has 1,000 tons on hand. The average magnetic properties of this material have been tested and will be satisfactory for use in the AGS magnet.

Before a production release can be given for the 240 magnet cores needed for the synchrotron, the contract requires that three pilot units be assembled and submitted to the Laboratory for measurement and approval. Measurements on the first unit completed indicated that, while the core did not meet the specifications in all respects, it came encouragingly close. The experience gained on core No. 1 resulted in some modifications to the fabrication plan, and pilot core

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ing system. At the lower right half of the photograph is the Cosmotron External Beam Trap Dike. The Cosmotron Building which houses the Cosmotron and the Nuclear Engineering Department are in the lower center of the photograph. The diameter of the Cosmotron is 70 feet, while the diameter of the AGS is 842. The photograph provides a dramatic comparison between the sizes of the new AGS and what is presently the second highest energy accelerator in the United States, the 3.2 Bev Cosmotron.

No. 2 was assembled. Preliminary measurements on this unit indicate that it meets specifications, and work has started on pilot core No. 3.

At Brookhaven, preparations have been made for a magnetic measurements program that will determine the parameters of the pilot magnets as well as the 240 production units to follow. Final adjustments on the test instrumentation and calibration of all search coils have been concluded.

National Electric Coil also has completed its tooling program. The contract with this firm requires that 14 pilot magnet exciting coils be fabricated and submitted to the Laboratory for inspection and approval before a production release can be given. All the pilot coils have been completed and are undergoing engineering evaluation.

Design has started on the quadrupole and sextupole correcting magnets. A theoretical study was made to determine the influence of coil and pole shapes on the magnetic field patterns, and to give a rough estimate of the stored energy, inductance, and saturation behavior of the multipole magnets. A model sextupole magnet has been constructed with removable pole tips of two designs. Two model quadrupole magnets are under construction. These scaled models will be used to study power supply requirements and the shape parameters of the magnetic fields.

Detailed design and engineering is nearing completion for the main magnet power supply which will provide 4,600-volt, 6,526-ampere direct current at full load. Preliminary drawings for the power control system have been prepared and reviewed, and final design is expected to be completed shortly.

The first phase of the synchrotron surveying program has started. Two precise leveling circuits were run connecting marks on pile caps in the magnet enclosure to permanent bench marks on site. Work is in progress on the closure of the polygon defined by the 24 permanent surveying monuments which have been spaced around the magnet ring.

Progress on injection system. Work on the 50 Mev linear accelerator injector is progressing on schedule. A contract has been awarded to Lukenweld, a division of Lukens Steel Co., for fabrication of the 11 sections of the 110-feet long linear accelerator tank. The bending, forming, and welding on five of the 11 units has been completed and they have been shipped to a subcontracting firm for final machining.

Drawings have been prepared for the linac drift tubes which accelerate particles in the machine, and templates defining the contours of these components have been completed. These templates will be used with an automatic contour cutter to machine the final shapes

of the drift tubes. The necessary copper forgings for the drift tube bodies have been received as have the special copper clad stainless steel supports, and production of these complex assemblies has commenced.

The 750-kev Cockcroft-Walton preaccelerator was delivered to Brookhaven, and set up temporarily so that it could be tested and a number of circuit modifications incorporated into the system. Recently, upon completion and acceptance of the Linac Building which which will house the injection system, the Cockcroft-Walton set was moved to its final location. Work is continuing on the auxiliary equipment for this unit, including the accelerating tube, ion source and mechanical supports.

An analysis and preliminary design of the AGS injection system continued. An array of bending and focusing lenses has been proposed and is being studied in detail. The system will also include a beam chopper, debuncher, and momentum analyzer. The chopper will be used to form the injector linac beam into pulses of variable length to facilitate beam observation and operation of the low-level radiofrequency system. The debuncher will reduce the energy spread of particles in the beam from the linac; the momentum analyzer is a magnet used to determine the momentum distribution of particles in the beam.

Design of radiofrequency system. The final design of the AGS radiofrequency power amplifiers has been established. A prototype of the last stage of the power amplifier has been built and tested. The original test model was converted and used to drive the new prototype through 1,600 feet of connecting coaxial cable, thus simulating the proposed final arrangement in which the driver would be located in the AGS power room and the 12 amplifiers will be distributed around the magnet ring. Full voltage was developed across the accelerating gaps of a ferrite-loaded cavity over a frequency spectrum of 1.4 million to 4.5 million cycles per second.

A bench set-up of the overall low-level radiofrequency system, utilizing a multiple heterodyning principle, was tested. These circuits will use information derived from the proton beam itself to generate the required low level signal varying from 1.4 to 4.5 million cycles per second. The heterodyning of the signal, and insertion of appropriate amounts of time delay in the proper place in the circuit, is necessary to eliminate the inherent differential shift of phase that accompanies a changing frequency transmitted over long cable runs.

Initial tests of the system pointed to some improvements that could be incorporated in the equipment, and a stable, highly selective, self-tracking amplifier was developed. Work on the low level system is

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continuing as various circuit refinements and modifications are designed.

Vacuum chamber. Details of the synchrotron vacuum chamber (with the exception of the various special straight sections) has been completed. The size and shape of the chamber as it passes through each magnet gap have been established and the tolerances on these dimensions have been fixed. Solicitations for bids for the fabrication of the vacuum chamber have been forwarded to interested firms.

Five production models of the Evapor-ion pumps have arrived on site. These units presently are undergoing engineering evaluation before an order for the additional pumps is placed—approximately 20 for the linear accelerator and 48 for the synchrotron ring.

Heavy Ion Accelerator at Yale University

The new heavy-ion linear accelerator went into operation at Yale University on March 14. The machine represents, in part, a joint project between the University of California and Yale University. Scientists from both institutions worked together in developing the design. The Commission authorized and supported the construction of two accelerators of the same design, one at Berkeley for chemical research, and the other at New Haven for physics experiments.

The first run of the Yale machine with helium beams supplied the necessary radiofrequency calibrations. On March 15, nitrogen ions were accelerated and subsequent runs were made using a foil stripper, pulse rates of 3 a second and a new radiofrequency system with separate amplifiers and driver chains for the two tanks. Beam intensities were of the order of 1 microampere at the peak of the pulse but faraday collections could not be accuratly determined due to electron collection and loss. A schedule of running experiments 1 week, and making improvements on the machine in alternate weeks has been established.

Progress on Argonne's Proton Synchrotron

Work with an accurately scaled magnet model for the 12 Bev proton synchrotron being designed at Argonne National Laboratory was successful, and a more advanced model designed for pulsed operation is being built to investigate further details of construction and operation. Machinery to produce a large power supply for the new model has been purchased. The recording of data has been largely automatized and analysis of results was accomplished with a digital computer. A fast converter to prepare material from analog com-

puters for use on a digital machine has been delivered and is undergoing initial adjustment.

Investigation of the economics and feasibilities of various methods of fabricating and assembling the final magnet has been carried out in cooperation with several steel companies; test plates and groups of plates have been produced and assembled in different manners for this evaluation. The problem of coil construction has been studied and a contract has been let to carry on development work with test sections.

Much of the development and construction of a prototype accelerating unit has been completed; testing awaits delivery of special ceramic components. Design work on the 50 Mev injector has begun and experimental programs are under way to seek solutions to the problems of certain individual components.

Theoretical studies have continued on many phases of particle orbit dynamics and orbit stability, as well as in analyzing the required accuracy of the radiofrequency programing. Much of this work has been done with the aid of digital computers.

Rehabilitation work was begun on an old warehouse to act as temporary laboratory and office space.

MURA Accelerator Design Work

Design studies have been carried out on a 15 Bev colliding beam Fixed Field Alternating Gradient accelerator (FFAG), which would produce two beams that would collide to produce very high energy reactions. Detailed design was described in a revised proposal made by the Midwestern Universities Research Association (MURA) to several government agencies. The colliding-beam FFAG accelerator was suggested by the MURA group.

An accelerator model for the larger machine to accelerate electron beams in both directions to 40 Mev, or in one direction to 50 Mev, is being constructed. It is expected that assembly will be completed by August. It is expected that it will be possible to accumulate circulating currents of the order of 50 amperes or more in this accelerator. This model will be used to study beam stacking, to demonstrate experimentally the acceleration of two opposite beams in one accelerator, and to study the properties of relativistic plasmas, that is, plasmas approaching the speed of light.

Digital computer studies of problems in the theory of radiofrequency acceleration have given encouraging results. Studies of orbit theory and of the magnet have been continued.

The 120 kev spiral-sector electron accelerator, completed and put into operation on August 15, 1957, has been used for many orbit

studies. A survey of resonances over a wide tuning range has been completed, with results in close agreement with theory. The theory of misalignments has been verified. A radiofrequency system has been built to accelerate the beam over the critical transition energy in this accelerator.

The studies which have demonstrated the validity of the fundamental principles of beam stacking and radiofrequency acceleration of particles in the 400 kev radial-sector accelerator have been continued. A radiofrequency system has been built which will accelerate particles all the way from injection to output energy.

Cosmotron Breakdown

Major overhaul and repairs on the Cosmotron at Brookhaven National Laboratory will require that the machine remain shut down until about December 1958. The Cosmotron underwent an emergency shutdown on November 5, 1957, similar to the earlier one that occurred in January of that year when a short circuit in a magnet coil caused a fire that damaged magnet insulation.[36]

At the time of the first emergency shutdown, it was recognized that the coil configuration in combination with small motions of the magnet unit due to the cyclic pulsing of the magnet resulted in very high stress concentrations within the coils. A number of other magnet coil conductors in the same quadrant of the Cosmotron as the conductor that had failed exhibited fatigue cracks. In order to restore the Cosmotron to operation as quickly as possible, cracked conductors were replaced, minor changes in design to help relieve the stress were made to all conductors in the quadrant, and clamping arrangements were improved in all quadrants, in the hope that fatigue cracks in the other three quadrants had not progressed too far. Because of the long time that would have been required to complete repair of the entire machine, and because of the increasing backlog of high energy experiments for the Cosmotron, it was decided not to remove the copper bars in the other three quadrants.

The second breakdown was a clear indication that the fatigue cracking observed earlier was not an isolated occurrence and that major modification of the coil design was required. It is expected that the new design will avoid all known difficulties of the present coil and will be considerably easier to install. The total amount of time the Cosmotron will have to be shut down will be minimized by the fact that repairs can be carried on simultaneously with a large part of the construction work to expand the target area. This work was approved

[36] See pp. 86-87, Twenty-second Semiannual Report to Congress (January-June 1957).

by Congress during the current fiscal year ended June 30 to provide additional shielding and to expand the experimental area around the machine. It would have required additional shutdown time had it not been possible to dovetail this work into the repair of the machine.

Bevatron Breakdown

A breakdown of 1 of the 2 motor generators which power the magnet coils of the Bevatron at University of California Radiation Laboratory, Berkeley, occurred on April 23. Repairs are expected to take 3 months.

The head of a retaining bolt in the rotor sheared off, cut through the generator coils, and caused a short circuit which grounded through and badly scorched one of the main bearings. Failure of the bolt head is as yet unexplained, especially as no known heavy stresses were acting on it. Metallurgical examinations are in progress and similar bolts will be examined in the twin generator.

While the generator is being repaired, the machine will be able to operate on one generator with reduced capability. Both the maximum energy for the accelerated protons and the rate of repetition of pulses of protons will have to be decreased. Protons probably can be accelerated up to 4 Bev at 8 pulses per minute by the single generator, compared to normal 2-generator operation at 6.3 Bev and 10 pulses per minute. Operation at these energies will preclude antiparticle experiments such as those with antiprotons and antineutrons.[37]

Before Bevatron operations with one generator can begin, the undamaged generator will undergo preventive maintenance as well as a complete check.

Bevatron addition. A new research building directly adjacent to the Bevatron was completed during this reporting period. The addition provides space for testing experimental equipment and allows performance of more complex experiments.

Several electronic circuits were developed and installed in the Bevatron control system. As a result, more stable operation will now be possible. A number of thin windows were installed in new and existing target areas to increase the number of useful beam stations.

A thin-foil technique was developed to make beam pulses of arbitrarily selected duration (0.01 second to 2 seconds) and arbitrarily selected energy (10 Mev to 6.25 Bev). Automatic equipment was developed to measure and record the internal beam intensity.

Additional focusing and bending magnets were acquired to permit

[37] See pp. 233-34, Twenty-third Semiannual Report to Congress (July–December 1957).

operation of several simultaneous experiments, and more complex experiments. Power supplies for these magnets were installed.

Radiation Laboratory Cyclotrons

Additional shielding was placed around the *60-inch cyclotron* at the University of California Radiation Laboratory to reduce the amount of radiation in areas occupied by personnel. New safety devices were added to prevent irradiation of persons who might accidentally gain access to regions where beams emerge from the cyclotron.

The *184-inch cyclotron* is used primarily to accelerate three types of particles-ions of ordinary hydrogen (protons), ions of heavy hydrogen (deuterons), and ions of helium (alpha particles). In the past, several hours were required to switch operation from one type of particle to another. Range-changing capacitors have been installed so that the switch can be made in about 15 minutes, thus increasing experimental use of the machine. Several new magnets were acquired for use in planned experiments.

Heavy-ion Linear Accelerator

The pulse rate of injected particles for the heavy-ion linear accelerator at the University of California Radiation Laboratory was increased from 2 pulses to 10 pulses per second by alterations completed during this reporting period. A buncher and focusing magnets have been installed on the injector beam. As a result the beam intensity is now 25 times as great as previously.

A steering magnet to allow several experiments to be set up at the same time was placed at the beam-exit end of the accelerator. A fourth radiofrequency amplifier installed will increase the reliability of the machine. In addition to the types of ions accelerated previously, carbon 13 and argon ions have been successfully accelerated during the past few months. (Experiments with this machine are reported in the later section on chemistry.)

Transfer of UCRL Linear Accelerator

The 32 Mev proton linear accelerator at the University of California Radiation Laboratory was dismantled and shipped during May to the University of Southern California, as authorized by the Commission last spring.[38]

[38] See p. 86, Twenty-second Semiannual Report to Congress (January-June 1957).

Isotope Process Development

The isotopes production and distribution program continued to provide larger quantities and additional products for use in research, medicine, agriculture and industry. Satisfactory operational tests were run on the completed Fission Product Pilot Plant at Oak Ridge National Laboratory and large-scale separation of fission products from waste solutions is expected to begin this summer. Process improvement studies for the Fission Product Pilot Plant resulted in improved recovery of cerium 144, the development of cerium oxide sources, and a more efficient procedure for purification of promethium 147.

Production and distribution of short-lived radioisotopes has expanded markedly in the past year. Rapid processing has permitted distribution of high specific-activity products with half-lives as short as 12 hours. Irradiations in the new Oak Ridge Research Reactor should assist in developing methods of processing radioisotopes with even high specific radioactivities (activity per unit) and shorter half-lives.

Studies are under way on obtaining higher specific activity radioisotopes by electromagnetic separation, thermal diffusion, chemical separation and electromigration in molten salts.

Electromagnetic separation of stable isotopes at Oak Ridge has produced for research 2,000 samples comprising 216 isotopes of 51 elements, totaling 15 kilograms of enriched isotopes. The isotopes of erbium (118 grams) were inventoried for the first time. With the use as charge material of uranium and plutonium products that already had put once through the separators, operations yielded the highest purity uranium 234, uranium 236 and plutonium 240 ever achieved by calutron processing.

High resolution calutron components are being used for the current "first pass" separations of vanadium and ytterbium to produce highly enriched samples. A model magnet study indicated the practicality of dividing a calutron track of 36 calutrons into four small tracks consisting of 6 or 8 tank units per track, thus permitting the simultaneous processing of a number of elements.

Physics

Although research in high energy physics was hampered during this reporting period by shutdown of the Cosmotron and Bevatron, physicists continued their analyses of results obtained earlier on neutrinos and "strange" particles. Research on fisson and nuclear reac-

tions, and mathematical and theoretical studies on digital computers are described.

High Energy Physics

In their continuing effort to add to knowledge and understanding of nuclear forces and particles, physicists have determined relation of the spin to direction of flight of the *neutrino*—one recently identified particle—has improved their technique for working with *antiprotons*, and with "strange" particles.

Brookhaven National Laboratory. Emulsion exposures and bubble chamber photographs of reactions obtained before shutdown of the Cosmotron still are being analyzed at Brookhaven National Laboratory. Some high energy counter work is being continued at the University of California Bevatron by Brookhaven physicists. Construction of a large bubble chamber is continuing, and will include equipment for automatic analysis of particle photographs.

The Van de Graaf accelerator has been used for fundamental studies of the *energy levels in nitrogen 14 and oxygen 16.* With the 18-inch Cyclotron, proton-neutron and neutron-neutron reactions have been studied, using a neutron time-of-flight method. Tritium targets were used to produce monochromatic neutrons (neutrons of uniform energies).

Another result in nuclear physics was the determination of the *helicity of the neutrino*—that is, the direction of the spin as related to direction of flight. The new concept of beta-decay, for which Lee and Yang received the Nobel Prize last year,[39] has shown that the neutrino must have its spin aligned either along, or opposite to, the direction of its flight.

The neutrino is the most elusive elementary particle. It is emitted simultaneously with an electron in beta-decay of radioactive atoms. Only by designing a very ingenious experiment was it possible to determine that the neutrino has a "left-handed screw," with its spin opposite to the direction of flight. In the antineutrino the situation is reversed. The neutrino is emitted when the beta particle is positive (a positron), and and antineutrino when the beta particle is negative (an electron).

A fast neutron chopper (a machine that interrupts a beam of neutrons to produce monochromatic bunches) has recently been installed at the high flux Chalk River reactor in Canada, for cooperative work with physicists of that laboratory.

[39] See pp. 91-93, Twenty-second Semiannual Report to Congress (January-June 1957).

University of California Radiation Laboratory. Until the breakdown of the Bevatron in April, studies continued on the *interaction of antiprotons* with ordinary matter. One major difficulty in these experiments is that the relatively rare antiprotons are produced in company with a tremendous number of other particles—about 1 antiproton per 100,000 other particles. The problem is either to identify the antiprotons in the presence of this very large background, or else to separate the antiprotons physically from the other particles. A physical separation scheme was devised that utilizes the fact that antiprotons of a certain momentum generally have a different velocity from other particles of the same momentum. By employing a device that will transmit preferentially particles of a desired velocity (the antiprotons), antiprotons were partially separated from the other particles in a momentum-analyzed beam. Several "velocity selectors" based on this principle have been built, tested, and successfuly used in these antiproton-interaction experiments. The detection of the antiprotons has been accomplished in several ways—electronic counters, photographic emulsions, and bubble chambers.

The experiments have greatly furthered understanding of the nature of these basic interactions. The predictions of physicists engaged in a study of the theoretical description of the interaction of antiprotons with ordinary matter so far have been quite well confirmed by experiment.

About 10 distinct types of *strange particles* have been found to date. These can be divided into two main categories according to the masses of the particles—the heavy strange particles with a mass greater than a proton are called hyperons and particles lighter than protons are called heavy mesons. Toward the end of 1957, a 30-inch-long bubble chamber filled with liquid propane, at present the largest of its type in the world, was successfully put into experimental operation at the Bevatron. So far it has been used to study strange particles and antiprotons. The first observation of artificially produced negative *xi* particles—hyperons heretofore observed only in cosmic rays—was made in this bubble chamber.

A 10-inch liquid hydrogen bubble chamber has been used in studying production and decay of hyperons and heavy mesons. A 15-inch-long liquid hydrogen bubble chamber has been operative since March, and is being used to study strange particles and antiprotons. A 72-inch liquid hydrogen chamber is nearing completion.

Electronic counters were used to study the decay of heavy K-mesons. Results of this experiment demonstrated nonconservation of certain symmetries previously attributed to physical interactions, occurring in the same way and to the same extent with strange particles as with ordinary particles. Calculations have been completed relating

to low-temperature fusion of protons and deutrons catalyzed by *mu*-mesons.

Other Physics Research

The mass of fission fragments of uranium 233 and 235, as it relates to the energy of the incident neutrons causing the fission, was analyzed in one of the series of studies that are reported in these pages. The mechanics of disruption of molecules by radiation, a technique and results of tests for confirming the theoretical spin of positrons—positive beta particles—as predicted by new theory, and progress in design of new high-speed digital computers, also are described.

Fission mass distribution measurements. If a neutron enters a target nucleus with an energy just right to bring the compound nucleus formed thereby into an excited energy level, the cross section for the reaction will be particularly high (a resonance phenomenon). In an unresolved beam of incident neutrons, there will be a distribution of energies such that the energy of a compound nucleus will be brought into any one of several available levels.

One theoretical prediction by J. A. Wheeler based on the collective model of the nucleus proposed by Aage Bohr and Ben Mottelson is that the mass distribution of the fission fragments may vary from resonance to resonance, that is, with energy levels. This prediction has been tested experimentally at several laboratories. At Los Alamos Scientific Laboratory, radiochemical studies were carried out on the mass distribution of fragments from the fission of uranium 235. The uranium 235 was bombarded with thermal neutrons (representing primarily fission at two resonances) and with epicadmium neutrons representing fission from the remaining resonances). The results showed that symmetric fission, that is, division into roughly equal fragments is somewhat more probable at thermal than at higher energies.

At the Materials Testing Reactor, radiochemical studies have been carried out on fragments from the fission of uranium 233. Multilevel resonance analysis of the fission cross section of uranium 233 indicates that fission at thermal energies should have different properties from fission at the strong resonance at the 1.8 ev level. Mass distribution studies made by radiochemical means on uranium 233 samples irradiated by a 1.8 ev neutron beam from a high intensity crystal spectrometer showed that the probability of symmetric fission at the resonance was some 15 percent less than at thermal energies, averaging some 0.025 ev. These radiochemical studies are being continued for additional resonances in uranium 233.

At the Argonne National Laboratory, the following experiment was performed. Two fission fragments, produced by the fission of a nucleus of either uranium 233 or uranium 235 in a thin film, gave ionization pulses measured in two ionization chambers. Electronic equipment directly indicated the sizes of these two pulses in terms of the corresponsing masses of the fragments and recorded the distribution in a 1,024 channel analyzer. A sufficiently intense beam of neutrons of selected energy was obtained from the CP–5 reactor by filtering out unwanted energies.

This investigation also indicates that mass distribution varies from resonance to resonance, but the magnitude of the effects differ from those obtained by the high mass resolution radiochemical experiments. This investigation indicated that symmetric fission was somewhat less common at thermal energy than at the average resonance at higher energies. The mass distribution from the 1.8 ev. fission resonance in uranium 233 was not appreciably different from the one at thermal energy, but symmetric fission was distinctly more probable at the 8.9 ev. resonance in uranium 235 than for the thermal neutrons.

Analysis of resonances. The probability that a neutron or other particle will react with a nucleus can change several orders of magnitude for small changes in the energy of the particle. These high narrow peaks (resonances) in the cross section curves (curves which show the interaction probabilities as a function of energy) provide interesting information for nuclear physicists in their attempts to understand atomic nuclei. The sizes, and distribution of sizes and spacings of these peaks, give indications of the nuclear forces for that particular nucleus. The Breit-Wigner resonance formula has been very successful in describing the shapes of these resonances until the past few years. Cross-section studies of the heavy elements in which fission occurs for low energy neutrons and in which the resonances are so close together that there is extensive overlapping have demonstrated that new methods of analysis are needed.

At the Materials Testing Reactor, accurate measurements on the fission and total cross sections of uranium 233 have provided a basis for extensive theoretical studies on applying the Wigner-Eisenbud multilevel formalism to an experimentally determined cross section curve. This formalism makes provision for the destructive and constructive interferences between the tails of the closely spaced resonances, several of which may influence the cross section at a given energy. Major progress at the Materials Testing Reactor has made it possible to fit the experimentally determined data over about 12 electron volts of neutron energy or over 10 resonances. It is this work

which led to the MTR fission mass distribution studies described earlier. The types of interferences found in the fitting process indicated which resonances belonged to which of the 2 possible spin states.

Much work in the Commission Laboratories during the past year in the cross section field has been directed to the determination of the spin state responsible for a given resonance. The problem is to determine whether the spin of the incoming neutron or particle is parallel or antiparallel to that of the target nucleus in a given resonance. The resonances must be segregated into those having a given spin state for further study directed toward a better understanding of the nuclear forces.

Studies with the MTR and at Brookhaven National Laboratory with significantly different approaches have determined the spin state assignments for four resonances in tungsten.

Reversibility in nuclear reactions. The failure of some time-honored symmetry theorems—displaced by such new concepts as the nonconservation of parity as suggested by Lee and Yang—reemphasizes the need for careful experimental evaluation of the validity of all such theorems. The theorem of "time reversal invariance" has been of particular interest, not only for weak interactions such as radioactive beta decay and certain reactions with mesons but also for strong interactions: for example, neutron capture by a nucleus followed by emission of a charged particle.

One method of determining the validity of "time reversal invariance" for the case of strong interaction is the measurement of a nuclear reaction and its inverse. That is, if particle A bombards nucleus B, producing particle C and nucleus D, the measured behavior of this reaction (if time reversal is indeed invariant) can be used to compute the behavior of the "inverse" reaction—where particle C bombards nucleus D, producing particle A and nucleus B.

At the Oak Ridge National Laboratory, the development of a flat response neutron flux integrator made possible the investigation of total neutron yields from charged particle reactions. The results on five different reactions compared with inverse reactions, are, within experimental errors, entirely consistent with the assumption of time reversal invariance in strong interactions.

Disruption of molecule by radioactive decay. The energy from the decay of a radioactive atom is more than adequate to ionize and disrupt the molecule of which that atom is a part, but most of the emitted energy is carried off by nuclear radiations. However, even after this energy loss, the molecule is left in an unstable configuration,

with more than enough energy to cause it to break up in various ways. Such disruption processes have been studied at Argonne National Laboratory by using a mass spectrograph to determine the masses of the various charged fragments of the molecules.

In the case of beta decay of tritium (hydrogen 3) or bromine 82 in simple organic molecules, the nuclear charge changes very abruptly when tritium or bromine emits a beta particle (nuclear electron), so that the radioactive atom is left in an excited state. In some 80 percent of the disintegrations, the effect is that the excited atom which has decayed breaks off from the molecule. In the remaining cases, the excitation energy is great enough to shake two or more atoms free from the rest of the molecule. Theoretical predictions, based on the sharing of energy between different modes of vibration in the molecule, are in reasonable agreement with the experimental results. In all cases of this kind, the ionization resulted only from the negative charge of the emitted beta particle itself; no orbital electrons of the atoms were lost.

The results are very different in the case of the radioactive nucleus (such as bromine 80) that emits no particle but gives up its excess energy to one of the electrons in orbits surrounding its nucleus by the process called "internal conversion." In such a case a gamma ray normally produced by this form of decay may undergo a kind of photoelectric effect and cause the ejection of one of the orbital electrons of the atom. Previous studies of isolated atoms have shown that bromine 80 can lose from 1 to more than 10 electrons in this way. Since the negatively charged orbital electrons normally balance the positive charge on the nucleus, loss of electrons leaves the atom with a net positive charge. As soon as any of the resulting positive charge on the bromine nucleus is shared with the rest of the molecule, the bromine is broken off by electrostatic repulsion. In the meantime some energy of excitation of the bromine atom may also be shared with the rest of the molecule and produce disruption similar to that observed after decay by beta particle emission.

Computer research. Digital computing machines play an important role in modern physics. Problems of current interest may require large numbers of arithmetic calculations, for example, in obtaining good statistics, or for the large number of steps required for the approximate solution of partial differential equations in several dimensions. The size of a problem which can be solved in a given time is determined by the speed of the computing machine.

The University of Illinois, under a contract with the Commission and the Office of Naval Research, has carried out research in several aspects of mathematics and logic which are important to the design

of high-speed computers. Research and development on electronic circuits for computing machine use has been carried out in conjunction with the mathematical work.

A theoretical study of asynchronous circuits has resulted in design methods which can be used in large arrays of computing circuits of the asynchronous type. Faster methods for doing multiplication and division have been devised. Although a high-speed memory is proposed, technological advances in circuit design and machine logic make possible relatively faster arithmetic units. The problems posed by this imbalance in relative speeds have been studied and have resulted in a design with five intermediate high-speed registers and other changes in logical design.

A computer now under development, aside from the input-output, will contain 13,000 transistors, 38,000 diodes and 42,000 resistors. A set of computer circuits has been developed from these transistors which have operation times of from 5 to 40 millimicroseconds. The circuits use recently developed graded-base transistors manufactured by the base diffusion process and have alpha cutoff frequencies in excess of 500 megacycles per second.

Using these elemental logic circuits, an arithmetic unit has been designed which uses a separate carry-register and carry-completion sensing to achieve an addition time of 0.32 microsecond for 52-bit numbers without access to memory channels. Multiplication, using the schemes mentioned, requires 3.8 microseconds without memory access. A memory of 8,192 words with an access time of 1.7 microseconds is proposed to work with the arithmetic unit.[40]

Germanium fission counters. Fission, among other nuclear reactions, depends strongly on the spin of the uranium nucleus. The study of this dependence is facilitated by forcing the spin axes of nuclei in a sample to orient in a direction common to all. Nuclear orientation techniques have been generally developed and, in particular, extended to fission studies at Oak Ridge National Laboratory.[41] These investigations must be performed at temperatures near absolute zero at which point the fission fragment detectors which are useful at room temperatures, become unsatisfactory or inoperative. For this reason, a compact and efficient germanium solid state counter has been developed, which detects alpha particles and fission fragments over the temperature range of interest. This device has an exceptionally fast response time and may be used to measure fragment energies up to 100 Mev or more.

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[40] A detailed report on this work is available from the University of Illinois Report No. 80 under the title "*On the Design of a Very High-Speed Computer*" (October 1957)

[41] See p. 244, Twenty-third Semiannual Report to Congress (July–December 1957).

Polarization and annihilation of positrons. One manifestation of nonconservation of parity in weak interactions is the longitudinal polarization of an electron or positron emitted in the beta decay of a nucleus, i. e., its spin about its axis is parallel to its direction of flight. A method has been developed at the Argonne National Laboratory to detect and study the polarization of positrons (positive beta particles) by observing the gamma rays created by their annihilation with electrons (negative beta particles) in a magnetized material.

This method is based on the fact that a positron and an electron very rarely annihilate each other unless they are moving at nearly the same velocity and with their spins in opposite directions. If both are at rest, the annihilation results in two gamma rays emitted in exactly opposite directions; if they are moving, the angle between the two gamma rays deviates from 180° by an amount depending on their velocities. "Magnetic" electrons, those responsible for the magnetic properties of the material, have different velocities than the other electrons whose spins do not respond to an applied magnetic field; thus the angles between the two gamma rays are different when positrons annihilate with magnetic electrons than in the case when annihilation occurs with other electrons. By observing at properly selected angles, the annihilations that involve the magnetic electrons can be recognized. If the positrons are polarized, the probability that the annihilation will involve the magnetic electrons will be different in these two conditions: (*a*) when a magnetic field aligns the magnetic electrons so that their spins are opposite to that expected for the positrons, and (*b*) when the field is reversed so that electrons spin in the same direction expected for the positrons.

In this way the expected spin of the positron was confirmed. Viewed as the positron approaches, the spin is counterclockwise. Moreover, it was shown that the initial direction of spin was not entirely lost in the collisions suffered as the positrons slowed down, and that the loss of alignment was greater (as might be expected) if the initial energy of the positrons was higher so that slowing involved more collisions. The fact that reversing the magnetic field has no noticeable effect in ferromagnetic nickel and gadolinium indicated that the positrons were effectively prevented from penetrating into the regions which magnetic electrons occupy in these atoms.

Chemistry

Analysis of the man-made element, americium, was accomplished during this reporting period with the aid of a 30-foot spectrograph accurate to better than one one-thousandth of an inch. Other basic chemical research described in this report, include: spectrographic

work on curium useful in studies of transplutonic elements; development of a high sensitivity spectrometer for studies of gases produced by high energy protons; attempts to define the rest mass of the neutrino; work on the energy spectrum of plutonium 241 fission neutrons; examination of the energy levels of plutonium 239 by means of a new technique with results useful in confirming theories of nuclear structure, and work with the heavy-ion accelerator.

Atomic spectra. Steady progress has been made in interpretation of the characteristic wavelengths of light emitted by vapors of the actinide elements under the action of an electrical discharge. The first analysis of the spectrum of an element heavier than uranium now has been accomplished at Argonne National Laboratory. This is for americium, atomic number 95. The analysis shows that an inner shell (5f) of electrons surrounding the nucleus—the shell that is filled in progressively with electrons as transuranic elements increase in atomic number—has in americium become half filled. In the actinide series, the various energy levels for electrons in different shells are closer together than in the corresponding rare earth elements in the periodic table; this accounts for the fact that the chemical properties of the actinides show more variation among themselves than do those of the rare earths, since electron placement and the number in various shells determines chemical properties.

The spectra being studied were produced in discharge tubes excited by a diathermy machine and spread out in a spectrograph 30 feet in diameter and accurate to better than one thousandth of an inch. The spectra were measured with the aid of an oscilloscope-equipped comparator which records the data on punched cards ready for machine computation. With these improvements it now is possible to make much better measurements in much less time than with previous spectroscopic equipment.

Analysis of radiation generation of nitric acid. Interest of radiation chemists since the beginning of the atomic energy project has been focused on the reactions of liquids. Only one gaseous system has been of practical interest, that of air. Early work showed that radiation-fixation of nitrogen to form nitric acid in the moist air over a water-moderated reactor was responsible for the increasing acidity of the water. More recently, it has been suggested that this reaction might have practical use in the manufacture of nitric acid. However, little definite knowledge existed about the mechanism of the reaction because of the large number of intermediate products for which satisfactory analytical methods were not available.

Experiments at Oak Ridge National Laboratory have demonstrated

that the use of infrared spectroscopy permits a detailed analysis of intermediate compounds of nitrogen and oxygen. By combining this method with conventional measurements of pressure change, both carried out on the irradiation cell itself, it has proved possible to unravel most of the details of this process. In particular, the role of water has been clarified, and it will be possible to choose rationally the best conditions for nitric acid synthesis, and to evaluate with greater certainty the ultimate economic prospects of radiation synthesis of nitric acid.

Absorption spectra of transplutonium elements. Early studies of the solution absorption spectrum of curium were carried out using the intensely alpha-active isotope, curium 242, which caused a solvent decomposition that made it extremely difficulty to discern the curium structure. The availability of a longer lived curium isotope, curium 244, produced in the Materials Testing Reactor in the course of Argonne National Laboratory's heavy element production program, has made it possible to reexamine the spectrum of curium with the result that three principal and several minor peaks were discovered.

These results have important consequences in understanding the atomic structure of the heaviest elements and the validity of the so-called "actinide" hypothesis, and they have been shown to be in agreement with theoretical predictions. The spectrum will be particularly useful for analytical purposes as further longer-lived curium isotopes become available.

The existence of the unique curium structure also makes possible a spectroscopic study of the chemical complexing of curium with important ramifications in its separation chemistry. As larger quantities of berkelium and californium become available it will be possible to investigate their basic chemistry and, in the course of this work, their solution absorption spectra. Since with these elements, the second half of the 5f electron shell begins to be filled, their structures, as evidenced by the formation of chemical compounds and absorption spectra, are of particular interest.

High sensitivity mass spectrometry. A high sensitivity mass spectrometer has been constructed at Brookhaven National Laboratory to study the noble (nonreactive) gases that result from nuclear reactions of high energy protons. The instrument can measure samples which contain as little as a billion atoms of a given nuclide. The reaction cross sections for helium 3 and helium 4 have been measured with 0.16, 0.43 and 3.0 Bev protons in iron targets. The helium 3 cross sections are higher at all energies than the reported tritium (hydrogen 3) cross sections (by a factor of 2.4 at 3 Bev). This is contrary to the effect

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of the coulomb (electrostatic) barrier expected from simple considerations.

Using the same technique, the rare gases which are produced by high energy cosmic ray protons in iron meteorites were studied and a comparison of the proton cross sections with the rare gas contents of iron meteorites leads to the belief that (*a*) present helium 3-tritium ages of meteorites should be lowered by a factor of about 3, (*b*) a study of the argon 39 and chlorine 36 content of meteorites should yield information as to how long meteorites have been in space, and (*c*) from a study of helium 3-helium 4 ratios and especially neon-helium 3 ratios it should be possible to estimate the relation of the content of rare gases to their penetration energy and draw conclusions about the size of the meteorites before entering the atmosphere.

Rest mass of the neutrino. Comparison of atomic mass differences obtained by measuring energy given off in nuclear decay, with those directly determined by mass spectrometry, is of fundamental importance in physical theory. An important question in processes of decay by electron emission (beta decay) is whether the mass differences as measured by the two independent techniques are exactly the same. Any discrepancy giving a larger value to differences measured by the mass spectrometer could be interpreted at evidence for a neutrino of finite mass, whereas theory predicts the neutrino has a rest mass of zero.

The tritium-helium 3 system is one of the best for this type of study. A novel radiofrequency mass spectrometer has been used at Brookhaven National Laboratory to determine this mass difference with a precision of about 1 part in 15 million. This represents the first precise mass spectrometer determination of the tritium and helium 3 masses. A slight positive discrepancy in mass was found to exist in these helium 3-tritium measurements as compared with a weighted average of data gathered by other workers on the maximum energy given off in tritium decay. However, the spread in collected data from experiment to experiment is about seven times as much as the possible error of the mass spectrometer data. This large spread in data makes a reliable estimate of the upper limit of neutrino mass very difficult. Calculations now place an upper limit of approximately one five-hundredth of an electron mass for the mass of the neutrino.

Fission neutron energies. The energy spectrum of fission neutrons from plutonium 241 has been measured at the Argonne National Laboratory as ranging from 1.1 to 8.0 Mev. Quantitatively, the distribution of neutron energies agrees with the expected fission spectrum, but qualitatively energies proved somewhat higher than the fission

spectrum of uranium 235. Comparison of these results with the measured spectra of other fission processes indicates that the average fission neutron energy and fragment temperature increase slowly with the mass of the fissionable nuclei.

Delayed neutrons of californium. Experimental determination of the delayed neutron yield for the spontaneous fission of californium 252 has been completed. The delayed neutrons are primarily associated with the heavy fragment precursors; the light precursor groups found in the fission of uranium 235 such as bromine 87, are markedly absent. Three groups of neutrons have been identified, emitted by precursors with half-lives of 20, 2, and 0.5 seconds. These presumably are emitted by the same precursors that yield like groups of delayed neutron emitters in the fission of the isotopes of uranium and plutonium.[42]

Unexpectedly, the total fragment energy from the spontaneous fission of fermium 254 has turned out to be remarkably low, being of the order of 175 Mev. The most probable ratio of the masses of the heavy and light fragments appears to be about 1 to 1.36, which does not agree with the trend toward symmetrical division expected with increasing mass of fissionable nuclei.

Spectrographic determination of gases in metals. Continuing studies in the Ames Laboratory on spectrographic determination of gases in metals have resulted in developing techniques for determining oxygen content of zirconium, titanium, niobium, and yttrium metals. Oxygen in yttrium was detected to less than 100 parts in 1 million. Experimental conditions for the spectrographic determination of nitrogen in steels, and hydrogen in titanium, also have been established. The presence of hydrogen in titanium was detected down to 10 parts in 1 million. These methods should find extensive use in the routine control of gas contents of various metals.

A precise and accurate wet chemistry method involving an isotope dilution technique also was developed for determining nitrogen in metals. The method has been applied to a number of metals and alloys ranging from steels, special nonferrous alloys, thorium and the rare earth, with nitrogen contents varying from 2 parts per million to 5.69 percent nitrogen. Analyses were made with a precision of 0.5 to 5 percent depending upon the material being analyzed and the size of available samples.

Radiation effects on crystals at low temperatures. The alkali halides offer a simple system for studying fundamental processes involved in

[42] See p. 91, Twenty-second Semiannual Report to Congress (January-June 1957).

the damage caused to solids by all types of ionizing radiation. A combination of optical (light) absorption and paramagnetic resonance (microwave spectroscopy) techniques has been applied to the study of the effect of radiation on single crystals at low temperatures. Recent work at Argonne National Laboratory has shown that potassium chloride crystals containing any of the impurities, lead chloride, silver chloride, or thallous chloride, when exposed to X-rays at the temperature of liquid nitrogen contain negative chlorine molecule-ions. It was found possible to bleach an irradiated crystal with polarized light and produce changes, not only in optical absorption, but also in the paramagnetic resonance spectrum.

The optical and resonance spectra of the chlorine molecule-ion are identical in both pure potassium chloride and potassium chloride containing the listed impurities, indicating that negative chlorine molecule-ions are characteristic of the pure crystal and not influenced by the added impurity. The impurity, however, acts as a very efficient electron trap and thus increases the rate of formation of the molecule-ions.

At liquid nitrogen temperature, the chlorine molecule-ions can be forced by polarized light to orient in one direction in the crystal. These oriented ions are able to move slightly at a temperature of −100° C. (degrees below zero centigrade) and become equally distributed in all directions. At temperatures around −70° C. the ion is no longer stable in the lattice and disappears.

Molten salt research. Molten salts have potential uses in reactor technology as coolants, fuels, and chemical processing media. As a part of a fundamental program for the study of molten salts at the Oak Ridge National Laboratory, absorption spectrophotometry is being developed as a major tool for the determination of ion interactions, such as complex-ion formation in salt melts. Recent studies have shown that electronic transitions in nitrate and chromate ions are substantially modified both by changes in temperature and by changes in alkali-metal cation (positive ion) neighbors. Other studies have shown the formation of several different chloro-complexes of nickel in salt melts containing both nickel and chloride ions.

Nuclear chemistry. Within the past 6 months, a very interesting and perplexing problem in nuclear spectroscopy, a subject of speculation for several years, was solved at the University of California Radiation Laboratory. Plutonium 239, the isotope of plutonium used in nuclear weapons and in nuclear reactors, also has been of central importance in recent developments of nuclear theory because the details of its energy-level structure have provided some of the best evidence for

the applicability of the Bohr-Mottelson, or collective, theory of nuclear structure.

The energy levels of plutonium 239 have been the subject of intensive study using alpha-, beta-, and gamma-ray spectroscopy. An outgrowth of those studies was an unequivocal prediction of the spin, or angular momentum, of neptunium 239, the parent nuclide of plutonium 239. The predicted value was 5/2 in units of angular momentum. On the other hand, a direct measurement of the spin value several years ago by the methods of optical spectroscopy (by which spins of radioactive nuclei can be measured only with difficulty) gave a spin of 1/2, a value in direct contradiction both to the theory and to the interpretation of a large amount of experimental data. The promise of a new research program instituted at the Radiation Laboratory, that of the direct measurement of spins of radioactive nuclei by means of atomic beams, was emphatically demonstrated when the spin of neptunium 239 was recently determined with great certainty as 5/2. Also, within the past year, spins of more than a dozen other radioactive isotopes have been measured by the atomic-beam method. Many more determinations, considered extremely difficult prior to the development of the present technique, will be made in the near future.

Heavy-ion accelerator research. During the past few months, operation of the new Heavy-Ion Linear Accelerator at University of California Radiation Laboratory has begun on a scheduled basis. The unique feature of this kind of machine is that it accelerates to very high velocities highly ionized atoms of carbon, nitrogen, oxygen, and even heavier elements. Conventional "atom smashers" are designed to accelerate only the light atoms, those of hydrogen and helium. Experiments with this machine have demonstrated distinctive new features of the mechanisms of nuclear reactions with carbon and nitrogen nuclei.

Very recently, definitive evidence has been obtained at the Radiation Laboratory for the production of element 102 by bombarding curium 246 with high speed ions of carbon 12. The result of this bombardment was the production of the nuclide 102^{254} and 4 neutrons. The half-life of this alpha-emitting isotope of the new element is 3 seconds. The experiment culminated on April 18 with the chemical identification of the daughter product as an isotope of fermium (Fm^{250}). The method used was essentially a continuous milking experiment wherein the atoms of the daughter element 100 were separated from the parent element 102 by taking advantage of the recoil due to the decay emission of an alpha particle by element 102.

Another research program utilizing the Heavy-Ion Linear Accelera-

tor involves *coulomb excitation with heavy ions.* Coulomb excitation is a process whereby fast-moving nuclear projectiles, passing near target nuclei but not reacting directly with them, are able under certain conditions to transfer discrete amounts of energy to these nuclei. A great amount of information has been learned about nuclear structure from coulomb excitation processes with light projectiles, information which concerns nuclear shapes, lifetimes of nuclear states, energy-level regularities, nuclear rotational motion, etc. It is hoped that the heavy-ion coulomb-excitation research will add further knowledge of this kind, especially with regard to vibrational motions expected in heavy nuclei.

Radiation Laboratory studies of the mechanisms of nuclear reactions at low and high energies continued during the report period. Recently, the measurement of *angular distributions of recoil nuclei* has shown that neutrons from the reaction bismuth 209 (alpha, 3 neutrons) astatine 210 [43] are emitted isotropically; that is, with equal probabilities in every direction, with an energy spectrum which corresponds to a nuclear "temperature" of 1.5 Mev. The results from the reactions bismuth 209 (alpha, 2 neutrons) astatine 211 and curium 244 (alpha, 2 neutrons) californium 264 are, however, very different. They indicate that the same theoretical model which describes the behavior of the alpha, 3-neutron reaction cannot be used to explain these other two reactions. The results of the alpha, 2-neutron reactions also are different from each other, and this difference may shed light upon the effect of fission competition on reaction mechanisms.

Studies of technetium 97. A study of the two isomeric states of technetium 97 and their ruthenium 97 parent has recently been completed at the Brookhaven National Laboratory. The results help to explain why natural technetium has not been found in the earth's crust although it has been observed in certain stars. The half-life of the technetium 97 ground state is 2.6 million years—longer than the half-life of any other technetium isotope but still at least 100 times too short to allow for survival on earth of primordial technetium. In some stars, it is probable that nuclear reactions are taking place now (or in the recent past) which produce isotopes of technetium. Some astrophysicists have postulated a neutron-capture mechanism in the interior of stars during a certain stage of evolution, while others have postulated processes involving proton acceleration by variable magnetic fields in the stellar atmospheres.

Experiments with 2.88-day ruthenium 97 showed that it decays 99.96 percent to the 2.6 million year ground state of technetium 97

[43] The reaction symbols describe bombardment of bismuth 209 with alpha particles to produce astatine 210 and 3 neutrons. Other nuclear reactions are to be read similarly.

and 0.041 percent to the 90-day isomeric state of technetium 97. This result suggested a modified decay scheme for ruthenium 97.

The cross section for producing ruthenium 97 by thermal neutron activation of stable ruthenium 96 was found to be 0.21 barns.

Spectrophotometry of aqueous reactor solutions. In considering the possibility of operating an aqueous homogeneous reactor at 250° C., researchers had to determine experimentally the limits of stability of the proposed fuel, uranyl sulfate in water. If operated for reasonable times at useful power levels, such a reactor will accumulate sizable quantities of transmutation products of uranium. An important product is neptunium, and its chemical behavior in water at high temperatures is under study at Oak Ridge National Laboratory. Since neptunium may occur in several valence states, affecting its combining power in molecules, a prerequisite is an analytical method separately for each valence state at the temperature of interest. Spectrophotometry early suggested itself as such a method, but no instrument existed for making the studies safely. Dilute aqueous solutions at 250° C. exert pressures of around 30 atmospheres, and neptunium 237, the long-lived isotope of the element, is a hazard in experimental studies because of its radioactivity.

A suitable light absorption cell and associated equipment has been designed and built for operation under these conditions, using a commercial spectrophotometer for the light measurement. With it, a solution of a neptunium salt has been studied from room temperature to 250° C. This is the first time that the studies have been possible, and the results demonstrate that spectrophotometry can be used to follow concentrations of various valence states of neptunium.

Metallurgy

Research on metallurgy and materials, described in this report, deals, among other studies, with work in support of a proposed liquid metal-fueled reactor; studies on the effects of mechanical and thermal treatment of metals on the orientation of metal grains and the stability of the metals under reactor conditions; basic studies of alloys, and fundamental studies on preparation of fuel elements by powder metallurgical techniques.

Materials studies for liquid-metal fuel. Study of the effect of adding tellurium to a slurry of thorium bismuthide ($ThBi_2$) in bismuth has continued at Brookhaven National Laboratory [44] as part of the support research for design of a liquid metal-fuel reactor. As little as 0.1

[44] See p. 269, Twenty-third Semiannual Report to Congress (July–December 1957).

weight percent of tellurium has a marked effect on particle growth and prevents thorium bismuthide from forming a deposit in the cold portion of a tube in which one end is heated, the other cooled. This amount of tellurium slows down the deposition rate even in a loop with a small temperature differential (16° C.).

Two electromagnetically pumped loops constructed of 2¼ percent chromium, 1 percent molybdenum steel and of 1¼ percent chromium, 1 percent molybdenum steel with bulk temperature differentials of 75° C., varying from 520° to 445° C., have been circulating a uranium-bismuth system for 7,500 hours and 4,000 hours, respectively. Some corrosion has been noted in welds which are made with a higher chromium content—5 percent chromium in the 2¼ percent chromium, 1 percent molybdenum steel loop. In thermal convection loop tests, no pitting type of corrosion has yet been noted in carbon steels, or in 1¼ percent chromium, ½ percent molybdenum steel and 1 percent chromium, ½ percent molybdenum steel.

The investigation of the fundamentals of corrosion inhibition in uranium-bismuth alloys containing zirconium and magnesium has led to a more detailed study of the zirconium carbide and nitride films. These now can be stripped from steel surfaces by treatment with a solution of bromine in methanol. The films are being microchemically analyzed in the expectation that their composition can be related to the composition of the steel and the method of formation of the film.

Oxidation of metals. A study at the Oak Ridge National Laboratory, aimed at determining why oxide films on metal surfaces sometimes protect metals from further corrosion and sometimes do not,[45] should help increase the usefulness of such important reactor metals as niobium (columbium), tantalum and zirconium. In recent work the formation of submicroscopic cracks in the oxide films on niobium and tantalum was discovered, and was correlated with the rate of corrosion by oxidation of these metals. Some insight was gained into the mechanism by which these cracks formed and the role which they play in the corrosion process.

Preferred orientation in metals. The directionality in physical and mechanical properties frequently exhibited by metals after mechanical and thermal treatment is a direct consequence of the preferred orientation of the grains composing the metal. Consequently, a study is being made at the Oak Ridge National Laboratory on the effect of fabricating methods on the type and degree of preferred orientation or "texture," as determined by new and more powerful X-ray techniques.

[45] See pp. 266-268, Twenty-third Semiannual Report to Congress (July–December 1957).

Not only will such a study assist basic understanding of the mechanisms of plastic flow and recrystallization, but also may advance knowledge of fabricating procedures required to give desirable properties. For instance, a rolling procedure has been found for zirconium alloy plate which gives essentially no preferred orientation and therefore gives uniform properties in all directions, a condition desired in metals for some reactor vessels. On the other hand, it has been found possible by control of extrusion conditions to produce a texture which gives a desirable 70 percent increase in the longitudinal strength of aluminum and thorium rods.

Basic irradiation studies of alloys. Neutron irradiation affects the properties of alloys in two ways.

First, collisions between impinging neutrons and the atoms of the alloy produce defects such as vacancies and interstitials in the metal crystal lattice which reduce the crystallinity of the solid. This effect is expected to take place in pure metals as well as alloys and to be largely independent of the temperature of irradiation.

The second effect of neutron irradiation is to enhance certain diffusion-controlled solid state reactions. These reactions are of particular importance for alloys, since many of their special properties, such as hardness, electrical resistivity, or magnetic permeability, depend upon the extent to which these reactions—that is the diffusion of one metal into the other—are permitted to progress during the preparation of the material. Examples of such diffusion-controlled reactions are the ordering and precipitation of the material from solid solution.

The effect of neutron irradiation on a diffusion-controlled reaction of this type is being studied in copper-aluminum alloys at Oak Ridge National Laboratory. It has been found that the electrical resistivity of copper-aluminum alloys decreases sharply in the early stages of neutron irradiation at 40° C. This effect decreases with reduction of the aluminum content and is absent in pure copper. Thus, the effect is established as one having to do with the alloy and not with the pure metal. Furthermore, the decrease in resistance is not observed when the irradiation is carried out at −120° C. instead of 40° C. The reaction therefore is diffusion-controlled, because at the lower temperature atomic mobilities are severely reduced. The irradiation effect can remain latent in the material, for if the alloy is allowed to warm after having been irradiated at −120° C., the decrease in resistance will set in.

The rate at which decrease in resistance takes place as a function of annealing temperature was studied and the activation energy for the process was found to be about one electron-volt. A similar de-

crease in resistance will take place after rapidly cooling (quenching) the alloy from a high temperature. This process also had an activation energy of about one electron-volt.

However, the decrease in resistance after quenching took place at temperatures about 65° C. higher than the temperatures for the decrease in resistance after cold irradiation. The inference is that essentially the same process was being observed in the quenching and irradiation experiments but that the neutron irradiation endows the material with the ability to carry out the process at lower temperatures than are possible in the absence of radiation. As yet, the detailed mechanism of the process has not been determined.

Two possibilities might be suggested as an explanation for the observation that diffusion-controlled processes are enhanced by neutron irradiation. First, diffusion in solids is thought to occur chiefly by a process of migration of atoms into vacancies. Thus, the vacancies produced by neutron bombardment might significantly increase diffusion rates. Secondly, many solid state reactions are known to require nucleation of crystals at special sites; the damaged regions produced by the irradiation may serve as crystalline nucleation centers at which the process is initiated.

The experimental evidence available at this time does not allow a choice to be made between these ideas. However, some statements may be made concerning the general significance of this work. Alloys are frequently prepared to have optimum properties by allowing diffusion-controlled reactions such as ordering or precipitation to occur to a critical point. Then the solid is returned to room temperature and diffusion is relied upon to be sufficiently slow at service temperatures so that the properties of the solid remain stable. However, the experiments reported here indicate that reaction temperatures may be significantly lowered by neutron irradiation and, as a consequence, the important properties of irradiated alloys may deteriorate at temperatures at which they are normally thought to be stable.

Preparation of high purity yttrium. The oxygen content of yttrium metal was lowered considerably at the Ames Laboratory by reducing yttrium fluoride with calcium. Previously the lowest oxygen content achieved was about 1,500 parts per million. By careful treatment of the fluoride and the calcium, yttrium containing less than 500 parts per million of oxygen has been prepared.

Thermal conductivity of crystals and lattice defects. The thermal conductivity of single crystals is very sensitive to the presence of lattice defects. Point defects, such as interstitial atoms, vacancies, or impu-

rity atoms, result in reducing the thermal conductivity in an otherwise perfect crystal. Dislocations, introduced by bending a crystal, result in a decrease in thermal conductivity at low temperatures. However, there is a qualitative difference in the thermal resistivity introduced by point defects on the one hand, and dislocations on the other. Furthermore, it is possible by measurements of the thermal conductivity to ascertain whether the lattice defects are clustered together, thereby acting as a scattering region that is large compared to isolated point defects.

The low temperature thermal conductivity has, consequently, been a useful property in studying the nature of lattice defects, whether present in the original crystal or purposely introduced by irradiation with cobalt 60 gamma rays, fast neutrons, or thermal neutrons.

In research at Oak Ridge National Laboratory, the difference in the type and distribution of defects produced by gamma ray bombardment and bombardment by fast neutrons is being studied by examining the resulting thermal conductivity changes in high purity single crystals of potassium chloride, calcium fluoride, magnesium oxide and silicon dioxide. Using lithium fluoride single crystals, the effects of successive thermal neutron bombardments on resulting decrease of thermal conductivity at low temperatures are being studied to obtain information with regard to reported structural changes in lithium fluoride. The difference between thermal neutron damage of lithium fluoride and cobalt 60 gamma ray damage of the same material will be ascertained. The structures of quartz crystal and fused silica are altered by fast neutron bombardment. Both, upon bombardment, approach a limiting density intermediate between that of the two forms, suggesting an intermediate state of order. The low temperature thermal conductivity, which is sensitive to crystalline order, was measured on fused silica before and after successive exposures to a maximum dosage of 7×10^{19} fast neutrons per square centimeter. The resulting increase in thermal conductivity and density indicates that the short-range order in silica improves with fast neutron bombardment.

Self-diffusion of niobium. Niobium is an attractive possibility for core and cladding material in high temperature nuclear fuel elements. Its chief drawback is lack of resistance to oxidation at elevated temperatures.[46] In order to obtain fundamental information useful in the development of oxidation-resistant niobium-base alloys, an effort is under way at Sylvania Electric Products, Inc., under Commission contract, to measure the self-diffusion coefficient of metallic niobium. This is being done by plating the radioactive isotope, niobium 95,

[46] See pp. 109–110, Twenty-second Semiannual Report to Congress (January–June 1957)

from an atmosphere of niobium pentachloride vapor onto the surface of diffusion specimens of bulk metal. Subsequently, the penetration of the isotope into the samples is determined by radiochemical techniques. Preliminary values of the self-diffusion coefficient indicate that this is quite low, as anticipated from the high melting point of niobium.

Fundamental studies of sintering. The preparation of fuel elements by powder metallurgical techniques has become an important fabrication procedure in fuel element technology; however, the fundamental understanding of the mechanism of sintering—solidifying materials by applying heat below melting temperatures—has been hampered by the geometrical complexities of the usual powder compacts. Investigations have been conducted at the Sylvania Electric Products, Inc., under Commission contract, using artificial compacts of fine wire wound in a close-packed array. The effect of wire or particle size upon the sintering rate has been found to obey theoretical predictions, indicating that the fundamental mechanism of densification is one of volume self-diffusion. Although previous investigations had indicated that structural imperfections, such as grain boundaries, had an important effect on the rate of densification, most recent data do not seem to bear this out. Particularly, it appears that densification takes place at an appreciable rate, even in the absence of grain boundaries.

An important consideration appears to be the path of diffusion, and data obtained indicate that a distinction exists between rate of bonding of particles and rate of densification, which is primarily dependent upon the diffusion path.

Elastic modulus and internal friction studies. An understanding of the fundamentals of dislocation motion in metals is essential to any further understanding of the more practical manifestations of dislocations such as the creep, yield strength, and brittle fracture of structural materials. To this end a series of fundamental measurements upon the internal friction and Young's modulus of copper single crystals has been performed at Oak Ridge National Laboratory from very low temperatures to room temperatures. Both properties are very sensitive to the dislocation content of a metal crystal, and it is within this temperature range in copper that much of the dislocation activation takes place. Neutron irradiation provides a unique tool for the study of dislocation motion, for the dislocation component in both of these quantities can be quenched with very small irradiations that do not otherwise destroy the properties of the copper lattice. Studies of the modulus and internal friction before and after irradiation as a function of temperature thus yield information

on the thermal activation of the dislocations themselves in a unique way.

It is felt that considerable progress toward an understanding of the thermal activation of dislocations has been made as a consequence of these studies. It has been possible to formulate a theory which, at least in part, is in quantitative agreement with the results.

Biology and Medicine

The first nuclear reactor designed and built exclusively for treatment of patients and for biological and medical research was nearing completion at Brookhaven National Laboratory as the January–June reporting period ended. The broad research programs in the life sciences which the Commission conducts to assess radiation hazards, to determine the injuries that may result from them, to treat those injuries, to study and treat cancer, and to apply the tools of atomic science to basic research on animal and plant systems, continued to make vital contributions to understanding in these fields.

A study of natural background radiation existing in various parts of the United States was made and may provide data for geneticists attempting to correlate mutations in human populations with geographical variations in natural background radiation. In other research to assemble fundamental data on human genetics, information was collected in this country and in Japan on inheritance of harmful physical traits in families that included marriages between cousins. Inheritance of sensitivity or resistance to radiation injury was investigated in mice.

Special radiation detection instruments—whole body radiation counters—have found new uses in research on fallout, and in medical diagnosis in cases of exposure to internal radiation hazards.

In continuing studies on treatments against radiation injury, experiments with mice showed that the alleviation of long-term effects such as life-shortening paralleled the short-term benefits. Diversified research on effects of both internal and external radiation, as demonstrated in laboratory animals, through viruses, bacteria, and other biological material, including findings that, for certain types of tumors in mice, a dosage level apparently existed below which strontium 90 caused no obvious injury.

In Commission laboratories and hospitals high energy radiation-producing machines, radioisotopes, and radiation, continued to be used in clinical treatment of certain types of cancers, techniques were improved, and fundamental studies of differences in vital processes of cancerous growths and normal tissues were conducted. Among other

work described in this report, radioactive antibodies were developed that concentrated radioactivity with considerable selectivity in certain cancers in rats; the possibility that a leukemia of mice was caused by a virus was investigated.

In radiation safety and health protection, a number of studies on specific hazards was published during the reporting period. First results of stratospheric surveys on radioactivity from weapons tests are described in this report and a summary of the status of findings on fallout is given, as presented in an address by Commissioner Willard F. Libby.

Brookhaven Medical Research Reactor

The Brookhaven Medical Research Reactor (MRR), 85 percent complete by June 30, is scheduled to go critical this summer and become available for patient use by 1959.

The MRR is a forced-circulation water-cooled tank reactor, fueled by 17 elements of a type developed for the Materials Testing Reactor. Each element is composed of 18 plates of highly enriched uranium-aluminum alloy. The core will be 2 feet in diameter and surrounded by a 7-foot cube of air-cooled graphite. The graphite reflector is pierced by 478 $^{11}/_{16}$-inch cooling holes. Cooling air will pass also over the front face composed of some 6 tons of bismuth metal blocks which act as gamma ray filters for radiation beams to be used in treatment of patients and in laboratory animal tests.

Thermal neutrons can be beamed from the west shield into a patient treatment room which has heavy concrete walls 2 feet thick. A 20-ton shutter to control the beam through the main shield will be raised or lowered by a hydraulic jack in 10 seconds, thus insuring accurate timing of neutron exposures. An animal exposure beam port, shutter, and room, identical to the patient facility, will be located on the opposite side of the reactor.

The north reactor shield has three 4-inch experimental holes, all penetrating through the graphite reflector to the core. The south face has a 5-foot cubical irradiation cell, exposed to the bare surface of the graphite reflector for various whole body radiation studies. This cell will be shielded by a 3-foot rolling door of concrete.

The reactor and its treatment and test facilities will be enclosed in a gastight insulated steel cylinder 60 feet in diameter which can be entered only through air locks. Additional safety features include a combination system of instrument channels which will permit periodic and frequent testing and checking, or even removal of individual instrument systems (channels) without affecting the overall safety. In the Medical Center complex—hospital, laboratories and offices—

interior finishing is under way with installation of lighting, flooring, and laboratory equipment. Occupancy of quarters is scheduled to start in July.

Although development of a detailed research program must await testing, one expected principal use is further experiments on tumor therapy by neutron capture. When the MRR beam of 10^{10} thermal neutrons per square centimeter per second becomes available, it will no longer be necessary to treat patients at the big Brookhaven reactor. Work there is handicapped by the location of the big reactor, inconvenience in handling patients, the necessity of shutting down other experiments during treatments, and the lower neutron flux available.

Background Radiation Measurements

Interest in the amount of radiation received by man from naturally radioactive sources has been stimulated by the presently held concept of many geneticists that each increase in radiation dose received means a corresponding increase in genetic mutations. This linear relationship has not been demonstrated at the low levels of radiation prevailing in nature. However, useful data might be derived by determining the correlation, if any, between geographical variations in the frequency of spontaneous mutations and geographical differences in the natural radiation doses of gamma radiation received by populations.

The Commission's Health and Safety Laboratory has made a series of measurements in the United States to establish the approximate geographical distribution and range of population exposures to the cosmic ray and terrestrial gamma radiation which together comprise natural background radiation. An effort was made to obtain data which would be representative of the unperturbed natural background, affected as little as possible by the occasional variations caused by fallout, or local conditions caused by such factors as ore bodies, granite buildings, or brick paving.

Using a specially designed ionization chamber, survey teams took more than 100 readings in the Great Plains the Rocky Mountains, New England, and the Atlantic seaboard.

In order to assess the contribution of cosmic rays to total background readings at high altitude locations in the West, measurements were made on flights at similar altitudes along the east coast.

In general, the contribution from the earth itself was found to be about 60 to 90 mrad (millirads [47]) per year, and the cosmic ray contribution ranged from about 30 mrad at sea level to about 70 mrad at elevations of 5,000 feet.

[47] Dose in soft tissue deemed equivalent to the effect of one one-thousandth of a roentgen of gamma radiation, or 0.1 ergs of energy per gram.

Table I summarizes the information gathered by the survey during August 1957.

TABLE I.—NATURAL BACKGROUND RADIATION IN UNITED STATES AUGUST 1957 [1]

LOCATION (Altitude in feet)[2]	RANGE OF RADIATION LEVELS[3]	MEAN ANNUAL DOSE[3]	AVERAGE BAROMETRIC PRESSURE	ATYPICAL RADIATION LEVELS[4]
	(microroentgens/hr)	*(millirads/yr)*	*(inches of mercury)*	*(microroentgens/hr)*
Harrisburg, Pa. (365)	9.6–11.9 (2) [5]	88	29.8	
Pittsburgh, Pa. (745)	9.8–13.9 (3)	96	29.2	
Cleveland, Ohio (660)	10.5–11.8 (2)	91	29.4	
Toledo, Ohio (585)	8.7–10.0 (2)	76	29.5	14.9 (over granite paving stone).
Chicago, Ill. (595)	10.3–11.6 (4)	88	29.4	17.0 (adjacent to U. S. Post Office Bldg. of granite construction).
Madison, Wis. (860)	10.1–10.4 (3)	84	29.1	
Minneapolis-St. Paul, Minn. (815)	9.1–12.5 (4)	92	29.3	
Sioux Falls, S. Dak. (1395)	11.5–11.8 (2)	95	28.8	
Cheyenne, Wyo. (6100)	17.2–17.6 (2)	142	24.4	
Denver, Colo. (5280)	16.6–19.4 (10)	147	25.0	22.4 (between U. S. Mint and city and county buildings).
Colorado Springs, Colo. (5980).	19.3–22.3 (4)	168	24.2	
Grand Junction, Colo. (4573)	15.7–18.4 (3)	138	25.5	
Albuquerque, N. Mex. (4945)	13.8–14.5 (4)	116	25.2	
Amarillo, Tex. (3685)	12.9–13.6 (4)	108	26.4	
Oklahoma City, Okla. (1195)	9.9–10.5 (4)	84	28.7	
Tulsa, Okla. (804)	10.8–11.6 (4)	92	29.3	
Little Rock, Ark. (800)	12.8–13.3 (2)	106	29.7	
Memphis, Tenn. (275)	9.4–11.0 (2)	83	29.8	13.3 (near brick apartment house).
Chattanooga, Tenn. (675)	11.1–12.3 (2)	95	29.6	14.8 (near brick-faced motel units); 16.1 (on narrow business street between Broad and Market).

[1] From HASL–25, "External Environmental Radiation Measurements in the United States," Solon et al., Mar. 11, 1958.

[2] Commercial atlas figures in altitude.

[3] Dose in soft tissue, assuming constant dose rate. 1 rad = 100 ergs/gm, 1 microroentgen/hr = 8.152 mrad/yr.

[4] Elevated radiation levels produced by localized sources are shown in the last column.

[5] The number of observations for each range is shown in parentheses.

INSTRUMENTATION AND RADIATION DOSIMETRY

Development of whole body counters and improved types of instrumentation for use in atomic energy plants, is described in the following section.

Monitoring Instruments

At the Hanford Works, efforts continued toward the development of a hand and shoe counter which combines alpha and beta-gamma

counting for use in protecting atomic energy workers. The new counter uses a scintillation instrument.

Other developments at Hanford included transistorized scintillation counters, a table model for alpha-counting of hands, and a portable gamma-energy analyzer. Instrumentation was improved for the pulse method of reading pocket ionization chambers, with first emphasis on obtaining the best sensitivity from the chamber. Sensitivity of a small fraction of a millirad has been obtained; one millirad can be measured to 20 percent accuracy.

At Oak Ridge National Laboratory, a beta-ray dosimeter of the general size and shape of a wrist watch has been developed to measure radiation exposure to the hands. The device is a thick, perforated, plastic cover surrounding a thin-walled container for the active air volume of the dosimeter. The cover shields the dosimeter to the extent that the dosimeter records about one-half the beta radiation exposure recorded by a pocket chamber minometer. The cover does not attenuate X- and gamma radiation and the dosimeter has a uniform response to these radiations. Thus, in a mixed radiation field, the dosimeter tends to allow for the higher radiation levels for skin exposure permitted under the National Bureau of Standards Handbook 59 adopted by the Commission as a guide in atomic energy operations.

Instrumentation for Medical Research and Clinical Use

In case of an accident involving inhalation and ingestion of unknown amounts of potentially dangerous radioisotopes, medical treatment may depend on an accurate estimate of the amount of radioactivity retained in the lung, skeleton, or other critical organ. Excretion tests currently in use are not sufficiently accurate and require time.

Whole body counters developed for experimental purposes permit very accurate measurement of retained radioactivity and identification of the radioisotopes involved.

Two types of whole body counters developed in the United States have been used for basic research involving fallout as well as for studies of retention and excretion of various radioisotopes in humans. Counters now in the planning stage for medical centers may also be used in medical diagnostic and research procedures.

The first type of counter, designed at Argonne National Laboratory, requires that natural background radiation be reduced to a minimum and, accordingly, the patient is placed inside heavy shielding. The thickness of the shielding is a compromise between its ability to absorb extraneous radiation and the amount of radiation emitted by the shield itself because it unavoidably contains traces of naturally

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occurring radioactive impurities. The counter at Argonne is a cubical room 6½ feet on a side with 8-inch steel walls. The patient is placed at a precise distance from a single, large, thallium-activated sodium iodide crystal which converts emitted radiation into a light pulse. The light pulse then is transformed into an electrical pulse by a photomultiplier tube. The steel room design permits identification of a radioisotope in the patient's body in the presence of radiation from other radioisotopes.

A second type of whole body counting apparatus, developed chiefly at Los Alamos Scientific Laboratory, relies on electronic coincidence circuits—circuits that interrupt recording when radiation from exterior sources impinges—to separate random background radiation from that emitted by the patient. It also is shielded to reduce background radiation to a relatively low level. The apparatus includes multiple photomultiplier tubes and the patient is placed horizontally at their focus.

The Los Alamos Scientific Laboratory instrument can also be used to measure the slight additional gamma activity in standard foodstuffs resulting from presence of the fission product, cesium 137. Strontium 90, being a beta emitter, cannot be measured directly in these instruments, but the cesium measurements have produced considerable information about fallout from weapon tests.

Dried milk was selected as one standard foodstuff to be studied. It has the advantage of coming from known locations at known times. Fifty pound samples of dried milk are sent in weekly from 21 producers; monthly samples are collected from 12 additional points. Two samples of dried milk collected during the preatomic era are used as standard controls. One was stored away at the University of Arkansas, the other was dug up from under many feet of snow in the Antarctic where it had been left by Adm. Richard E. Byrd's 1939 expedition. These samples were completely free of contamination with cesium 137.

During the past 2 years, the radiation from some 40,000 pounds of dried milk, together with 3,000 gallons of fresh milk, has been counted. Many other foodstuffs, including meats, fruits, and vegetables, have been and will continue to be measured for radioactivity, but the dried milk program seems to be a most sensitive indicator. The radioactivity from cesium which tests have found in milk and in humans is approximately 20 times less than the radiation emitted by radioactive potassium 40 which is a naturally occurring material.

Body radiation of more than 2,000 people visiting Los Alamos from all parts of the country has been measured in the counter and groups of local Cub Scouts come each week for measurements.

The instruments already in use and new ones under development make feasible in a short time many scientific procedures which previously could be carried out only with weeks or months of work, and permits other procedures that previously were impossible. Most important, perhaps, they permit studies of living beings. Similar but smaller counters are used for laboratory animals.

Research in Treatment of Radiation Damage

Continued research apparently showed that methods of treating mice to reduce the prompt effects of heavy dosages of radiation also accomplished protection against delayed effects. Various methods of administering protective drugs were studied, and experiments were carried out to analyze the system of immune mechanism which has an important bearing on the successful preventive use of bone marrow transplants.

Survival of Irradiated Mice

Female mice that have been protected against a single lethal exposure to X-rays by dosage before irradiation with chemicals or after irradiation with bone marrow transplants are being observed throughout life at Oak Ridge National Laboratory. The objective is to determine the amount of protection which the treatments afford against delayed effects of irradiation. The substances used—the chemical compound AET (S,2-aminoethylisothiuronium·Br·HBr), isologous bone marrow (IBM, or marrow taken from the same strain of mouse) or AET and IBM together—are known to increase the number of survivors of a given lethal dose of radiation. Groups of mice so treated were exposed to X-rays that normally would kill half a group of untreated mice within 30 days (LD_{50}/30 days).

Results indicated that the degree of protection afforded against the life-shortening effect of a given dose of radiation apparently showed a reasonably close correspondence with that afforded against acute effects which cause death within 30 days. Induction of thymic lymphoma was inhibited by administration of either AET or bone marrow. Kidney damage (nephrosclerosis) was much more prevalent in the mice exposed to doses above 1000 roentgens (*r*) than in those exposed to 700 to 800*r*, indicating that AET did not protect the kidney to the same extent that it protected intestines and hemopoietic (blood forming) tissues. Tumors of the ovary and lung appeared less commonly in pretreated mice than in those not treated against irradiation.

Structure and Activity of Protective Compounds

Oral administration of mercaptoethylguanidine (MEG) and mercaptopropylguanidine (MPG) has been shown at Oak Ridge National Laboratory to reduce radiation damage in mice. Both compounds must be prepared by neutralization from their respective thiuronium salts—AET and APT (S,2-aminopropylisothiuronium·H·HBr)—and are susceptible to oxidation into the less-active disulfides. Thus, it would be advantageous to administer the more stable thiuronium salts, AET and APT, either as solids or in solution. The acidity-alkalinity balance of the animal is such that both AET and APT would be expected to convert into MEG and MPG upon absorption into the body fluids.

Tests showed protection was found to be just as effective when provided in this manner, and was effective over a longer period of time; probably because the effective agent was absorbed more slowly.

The LD_{50} radiation dosage of the test animals was determined at different drug doses. It was found that as the dosage of drug increased, higher radiation exposure could be tolerated. APT was relatively more effective at lower dosages than was AET. The compound, APMT (3-aminopropyl N′-methylisothiuronium·Br·HBr) that had been found to provide very effective protection at 900 *r* exposures did not show increased protection with larger therapeutic dosage. APMT was found to saturate very rapidly whatever sites it was protecting. Even increasing the drug dose 16 times did not bring about any further improvement in the LD_{50}.

These results illustrate how dependent the protective activity is on the actual structure of the compound. The compound with the simplest molecular structure, AET, apparently is widely distributed in the body, and small changes in its structure are sufficient to increase the selectivity and narrow the distribution of the compounds markedly.

The period for which a single, maximum, oral dose of AET or APT remained effective in rodents was found by determination of the radiation LD_{50}/30 days. The protective activity remained at its maximum for an hour, then fell off until at 5 hours the LD_{50}/30 days was 900 *r*—about the same as for unprotected mice. An estimate of the rate of excretion of the compounds indicates that at 5 hours about 20 percent of the AET still was retained, whereas APT was more rapidly excreted with only about 10 percent retained at 5 hours.

Studies of Immune Mechanisms

The success of bone marrow transplants in rodents depends on complete suppression by radiation of the host animal's *immune mech-*

anism. If the mechanism functioned normally, it would produce antibodies and prevent the transplanted donor cells from "taking." [48] A number of studies are under way to elucidate these mechanisms. Other studies are directed toward understanding the method by which the antibody-forming capacity may recover after irradiation, since this is important to resistance against disease.

At the Argonne Cancer Research Hospital, the antibody-forming capacity of lethally irradiated rats, kept alive with injections of either rabbit bone marrow cells (heterologous transplants), or rat bone marrow cells (homologous transplants), was tested at various intervals by injecting them with *bovine serum albumin* (BSA) and *Salmonella typhi vaccine.* Since rats do not form a precipitating antibody to BSA, whereas rabbits give a strong response, it was hoped the survival of rabbit cells in rats could be detected by this method. Even a low degree positive anti-BSA titer (enough antibodies to cause a reaction) would be evidence of the survival of at least some transplanted rabbit cells capable of antibody formation.

Rats that received rabbit cells did show a positive anti-BSA titer, which suggests that the rabbit cells had colonized and maintained their original antibody-forming capacity. This observation may help to explain the mechanism of early mortality observed in animals that have received a "protecting" injection of bone marrow cells after irradiation; the colonized cell grafts may produce antibodies against the tissues of the injected animal and thereby contribute to the death of the host.

The *mechanism of antibody formation* by cells has been investigated in a series of experiments utilizing numerous techniques including: particulate antigens labeled with radioiodine; total-body irradiation; spleen shielding; and, more recently, fluorescein-labeled antibodies. The studies show that neither the white blood cell (macrophages and lymphocytes), nor the blood plasma cell, is the exclusive producer of the antibody.

In another study, this one at Argonne National Laboratory, experimenters attempted to restore the effectiveness of the immune mechanism after massive radiation dosages, since this mechanism is important in bolstering the resistance to infection which is lowered in heavily irradiated animals. A noninfectious agent, red blood cells of sheep, was injected into rabbits to test the functioning of the mechanism, together with a variety of substances that might help reactivate the mechanism: yeast extract, HeLa cells (cells of human epithelioid cancer of the uterine cervix), rabbit spleen, and mouse spleen.

Investigations directed toward isolation and identification of the

[48] See pp. 120–122, Twenty-second Semiannual Report (January–June 1957).

active principle in the various preparations listed found it was associated with breakdown products of large complex nucleic acid molecules that control protein synthesis. Possibly the preparations are effective in irradiated animals because they supply a substance that is essential to an early stage of the body's synthesis of protein antibodies. If confirmed, this information may in time suggest methods of treatment.

Genetic Studies

Studies in human genetics, described in this report, are directed toward determining the average numbers of harmful recessive genetic factors present in populations. The animal genetic studies reported have been directed toward determining the extent to which some strains of mice inherit a degree of resistance or sensitivity to radiation injury.

Human Genetics

The overall study of the mutation-generating effects of ionizing radiation in man has been hindered by lack of many important facts concerning human genetics. Knowledge is needed about the load of existing mutations carried by mankind, mutation rates, the structure of human populations, the rate of elimination or dissemination of mutant genes in human populations, and about those factors, including radiation, which affect human genetics.

Most of the genes that are known to cause abnormal effects in man are those that are dominant to the normal form of the gene; that is, the effect of dominant genes can usually be observed since they are transmitted from one affected parent to affected offspring through two or more generations. Recessive genes are less well known, though they may be far more common than dominant genes. Recessive genes produce observable effects only when received from both parents (both of whom, however, may appear normal). Rare recessive genes frequently are first identified as such when they are observed among the children of closely related persons, since close relatives have a greater chance than do unrelated individuals of both bearing the same recessive genes.

Studies of consanguineous marriages in Japan were initiated in 1957 and will continue during the next 4 years in conjunction with the work of the Atomic Bomb Casualty Commission. A number of smaller studies will be initiated to study the effect of consanguineous marriages in different segments of the population.

In studies by Argonne National Laboratory, children of first-cousin marriages are being compared with those of control families, in an attempt to add to knowledge of the genetic constitution of man.

The most frequent type of marriage between close relatives is between first cousins. The Roman Catholic Church requires that first cousins who wish to marry receive a formal dispensation to do so. With the cooperation of the Roman Catholic Archdiocese of Chicago, a study is being carried out concerning children of first-cousin marriages. These children of consanguineous marriages are being compared with the children of relatives of the parents who did not enter consanguineous marriages and thus form an adequate control group.

The consanguineous families have been found to be very similar to the control families as to fertility and the proportion of children lost through miscarriage or stillbirth. However, the frequency with which consanguineous children are affected by serious sickness or death appears to be several times the rate found among controls. Mathematical analysis of the increase in sickness and death, and of the very slight increase that has been observed in the frequency of miscarriage and stillbirth, allows a calculation of the probable number of defective genes that must have been present in both parents. Further calculation permits estimation of the frequency of occurrence of abnormal recessive genes present in the common ancestor of these first cousins. This is the best way of estimating the rate of the occurrence of recessive genes in modern man, since the rate probably has not changed in the past few generations. It appears from these studies that people, on an average, carry the equivalent of 4.5 harmful recessive genes.

Animal Genetics

Genetic variation in radiation sensitivity. At Argonne National Laboratory, radiation toxicity studies are being carried out using a group of highly inbred strains of mice, in order to measure genetic variation in radiation sensitivity. Since all members of a given strain are genetically homogeneous and equally different from the members of all other strains, differences in radiation response can be attributed in part to genetic factors. Then, by appropriate cross-breeding between strains, the mode of inheritance of resistance or sensitivity can be studied. Information obtained in this way may be applicable to the variation in radiation response among human populations.

Both a single dose and long continued daily doses of radiation have been used to test the genetic variables.

The single-dose method tests variation in sensitivity to acute radiation lethality, by determining the differences between strains in the

LD_{50}/30 days dosages. Survivors of these experiments are observed for differences in long-term effects such as changes in life expectancy, induction of various tumors, and degenerative diseases.

The daily exposure method similarly provides information covering differences between strains for both acute and chronic effects. Thus it supplements data on single-dose effects and permits relating the chronic effects following single-dose exposure to the chronic effects following long continued daily exposures.

For young adult mice subjected to *single doses of whole-body X-irradiation* the LD_{50}/30 days dosage varies from 500 *r* for the most sensitive strain to nearly 700 *r* for the most resistant strain. There was greater individual variation in response among the sensitive strains than among resistant strains, despite the fact that both strains have equal levels of genetic homogeneity. When these strains were cross-bred, the LD_{50} was similar to that of the more resistant parent. In other words, radioresistance tends to be genetically dominant. It is estimated that in a genetically heterogeneous population of mice, 55 percent to 60 percent of the observed variability in radiosensitivity may be due to genetic factors.

Among both inbred strains and their hybrids, higher LD_{50} values are associated with longer normal life expectancies, suggesting that the level of sensitivity to acute radiation exposure may reflect the general vitality of the individual. For example, strains of mice with a low LD_{50} have poor normal survival, generally associated with a high incidence of mortality from infectious diseases.

In mice that survive acute lethal exposures, the reduction in life expectancy varies with sex as well as with strain: in males the percent reduction varies with strain from 16 to 29 percent as compared to 20 to 37 percent for females. These variations appear at present to be unrelated to the observed strain differences in either the LD_{50} or the normal life expectancy.

In mice under *daily exposure*, genetic variation in mean survival time also is directly related to innate variation in normal life expectancy, although this positive relation becomes less distinct at low daily doses.

Genetic variation in *acute and chronic radiation response*, as shown in the tests, conforms to a sufficiently definite pattern to permit certain generalizations:

If a population group has, for either genetic or environmental reasons, a poor life expectancy, it will probably have a comparatively high sensitivity to acute radiation exposure. Its survival under continuous exposure will also be proportionally short, except at very low dose levels where little change from normal may be observed.

Premature deaths among rats surviving the prompt effects of heavy doses of radiation were found, in research reported in this section, to occur sometimes from cancer and sometimes from other causes not directly related to radiation effects. Other studies were directed toward distinguishing between natural and radiation-induced aging in mice. In investigations of the effects of strontium 90 upon mice, it appeared that a dosage level existed below which obvious injury causing certain types of tumor was not observed.

Other research described here deals with studies of external and internal radiation effects upon a variety of biological materials, including dogs, rabbits, and goldfish, as well as with work on microorganisms and molecular material: viruses, bacteria, nucleic acids, and various of the body's building blocks including the fatty acids and proteins.

Studies of Effects of External Radiation

Animals receiving a large dose of radiation may survive the acute effects of the radiation but will eventually die prematurely. While some develop cancer, others seem to age and die prematurely from much the same causes as do unirradiated animals. It thus appears that radiation may accelerate the natural aging process.

Late effects of total body irradiation. Longevity of rats is known to be reduced among the survivors of large doses of total body X-radiation (600 roentgens is the LD_{50} dosage for normal female rats). Comparable radiation doses to only a portion of the body also reduces longevity but to lesser and varying degrees. Partial body radiation may prove a useful experimental tool in locating and studying the nature of physiologic changes that influence the aging process.

Systolic blood pressure levels were studied at the University of California at Los Angeles–Atomic Energy Project in 63 female Wistar rats as controls, and in 59 rats of the same stock and age surviving a sublethal 1,000 *r* hypoxic total body irradiation (irradiation in a low-oxygen atmosphere to afford a degree of protection against damage. Under these conditions the LD_{50} for these rats is 1,200 to 1,400 *r*). Mean systolic blood pressure of the irradiated rats at monthly intervals from 13 to 23 months postirradiation averaged 39 millimeters (mm.) of mercury greater than the controls of the same age. Forty-six percent of the irradiated rats also developed bilateral nephrosclerosis (a disturbance in structure and function of both kidneys). The mean value of maximal blood pressure determinations

from individual rats was 193 mm. of mercury in the irradiated group compared to 139 mm. in the controls. Mean blood pressure maximal in the irradiated rats without evident renal disease was almost as high (185 mm.) as in those with nephrosclerosis (202 mm.). No correlation between duration hypertension as evidenced by higher blood pressure and eventual development of nephrosclerosis could be made, but no rat with nephrosclerosis had normal blood pressure.

Direct renal irradiation may be necessary to initiate the hypertensive phase of the total body radiation "late effects" syndrome, but inclusion of the kidneys within such a radiation field did not consistently produce nephrosclerosis. There are unreported observations that this postirradiation nephrosclerosis of total body exposure does not differ in histologic appearance from the renal lesion observed in nonirradiated rats made hypertensive by removing a kidney and having them drink a one percent salt solution.

Eighty-three female Wistar rats surviving a single exposure to 1,000 *r* hypoxic total body irradiation at 4 months of age, and 84 controls of the same stock were observed throughout their life span.

The irradiated animals were all dead 24 months after irradiation, with a mean survival of 15 months, compared to the 24.5-month mean survival of the controls. This represents a 39 percent shortening of life span after irradiation. This reduction of life span following hypoxic radiation is comparable to that reported in rodents following total body radiation in air, if the dose is expressed in each case as a percent of the LD_{50} dose.

These further observations were made:

Irradiated rats were retarded in growth, weighing approximately 18 percent less than the controls 20 months after irradiation.

All irradiated rats surviving at least 9.5 months developed cataracts with a mean appearance time of 10.5 months. Aged control rats also acquired cataracts, but they appeared first at 26.5 months.

Eighteen irradiated rats developed severe bilateral nephrosclerosis, a disease not observed in the control group.

Large pituitary adenomal tumors were common in the controls, but absent in the irradiated group. Other major pathologic findings in the irradiated rats were closely similar to those found in control rats of advanced age.

Tumors, as a rule, appeared sooner in the irradiated rats, but did not appear in greater final numbers. The incidence of tumors in both irradiated and control rats generally followed the pattern characteristic of the animal strain; that is, tumors of the reproductive and endocrine systems predominated. Ovarian tumors appeared to be increased specifically by irradiation exposure.

Lymphomal tumors were not increased or accelerated by radiation under these conditions in this strain.

In general, the earlier onset of tumor-formation in the irradiated rat seems best explained as one aspect of an accelerated aging process. Other diseases prevalent in aged rats, such as cataracts, acute inflammations, epilation, and skin ulcerations were accelerated similarly.

In *longevity studies with dogs,* at the University of Rochester, animals which survived acute LD_{50-80} dosages of X-ray or cobalt 60 gamma ray exposure for up to 40 months showed only distinct graying of hair and a definite reduction in circulating white cells compared to pre-exposure levels and to unirradiated control animals. Only one animal out of 100 has developed a tumor of unknown type thus far. Experiments in carcinogenesis due to di-benzanthracene painted on skin and mucous membrane have shown no essential differences in controls, survivors of acute radiation, or long-term surviving groups of animals.

A recent observation shows that the acutely irradiated dog exhibits an increased sensitivity to pentobarbital anesthesia such as to require reduced dosage for all levels. In addition recovery from anesthesia is markedly delayed. No essential change has been noted in dogs surviving acute irradiation for 60 days or longer and the long-term survivor has shown no increased sensitivity.

In contrast to previously published information on the dog, the survival time after lethal irradiation in dogs is not related to dosage in the range where irradiation will be fatal to 50 to 90 percent. In an analysis of data obtained on more than 350 animals, survival time was consistently around 15 days for all doses in this range.

Brookhaven National Laboratory designed experiments to determine the similarity between *natural and radiation-induced aging,* and to investigate the cause of decreased life-span in the irradiated animals.

The first experiments tested the assumption that any *nonspecific stress* will produce the same age-accelerating effect as radiation. Several different severe stresses such as typhoid vaccine, tetanus toxin and toxoid, and nitrogen mustard were applied to groups of mice. The longevity of these mice was compared with that of unstressed controls and with that of mice receiving comparable radiation stresses. All stresses were given both as massive single doses and also as smaller doses repeated at weekly intervals for half the normal life-span of the of the mice. The irradiated mice alone showed lasting effects from the stresses; the other mice subjected to stresses lived as long, and were as healthy, as the controls. During the acute phase of the stress, the irradiated animals lost weight which they never fully regained;

they did not live as long as the controls. Thus, radiation seems to be unique as an age-accelerating stress.

Mice receiving a large dose of radiation when they are young were found to be less able to withstand a stress when old, as compared with normal mice of the same age. Thus, it is suggested that radiation has accelerated the aging process independently of its ability to induce neoplasia (tumor formation).

One prevalent theory of the cause of aging, especially radiation-induced aging, is that radiation causes *mutations in somatic tissue cells*, which accumulate to the point of weakening the tissues and leading to degeneration or neoplasia. To test this hypothesis, the mutation-causing agent nitrogen mustard was given to mice, either as a massive single dose or as small doses over a period of many months. These mice lived as long as the controls, thus providing a strong argument against the somatic cell mutation theory of aging.

Earlier experiments have indicated that neutrons shorten the life span more than do X-rays or gamma rays. In recent research, it was found that the *relative biological effectiveness (RBE) of radiation*—fast neutrons compared to X-rays—was the same (1.7) for the shortening of the life span as for 30-day mortality. This indicates that the RBE varies considerably, depending upon the schedule of irradiation dosages given and the peculiarities of the strain of animal under study.

In another study at Brookhaven National Laboratory, it was shown that the *survival time of goldfish* after X-irradiations was increased if a preliminary exposure of the order of 200 roentgens was given approximately one month previous to the lethal exposure (the LD_{50} for goldfish is about 600 *r*). Experiments are now under way to determine if the LD_{50} of other test animals, as well as the survival time after irradiation, is increased by a preliminary dosage.

Effect on the lens of eye. At Northwestern University, irradiation of the eye lenses of 10- to 12-week-old rabbits of both sexes with 4,000 *r* of X-irradiation caused progressive changes in the protein composition of the lens. A 260 kilovolt X-ray machine delivering 180 roentgens per minute was used. Distribution of the protein components, as revealed by electrophoresis, remained unchanged in an irradiated lens until after a cataract appeared. A significant decrease in soluble protein then occurred, but apparently there was no increase in insoluble protein. In cataracts that were slow in developing—195 days after irradiation—only 2 soluble protein components remained and 6 components present in the normal lens had disappeared.

Effects on lymphocytes. Based on volume measurements *in vivo*, a quantitative study has been undertaken at the University of Chicago

regarding the destructive and regenerative processes caused by various dosages of X-rays in the lymphatic tissue of the rabbit appendix.

On the basis of the minimum number of changes found after irradiation with eight different dosages, the relation between the dose and irradiation effect was studied. The data indicate that the radiosensitivity of the lymphocyte population is a result of two quantitatively different events, one of higher efficacy than the other. This may be explained by assuming the presence of two lymphocyte populations of different radiosensitivity or by abscopal (secondary) mechanisms affecting the radiosensitivity of the lymphocytes differently at different dose levels. Another possible explanation is that the doses received by lymphocytes in different areas or tissues are not identical.

The possibility of an abscopal effect has been studied at the University of Chicago. In one group of animals, the appendix was irradiated while the rest of the animal was enclosed in a thick lead shield. In a second group of animals the appendix was similarly exposed but the rest of the animal was covered by a plastic shield. In a third group of animals—a sham-irradiated control group—the appendix was exposed, while the rest of the animal was shielded with plastic but without any irradiation.

The results showed definitely that the radiosensitivity of appendix lymphocytes is in part dependent on the abscopal effect. In addition, experiments with total body irradiation, as well as those in which only the appendix was irradiated, showed that a similar two-component effect is present. It appears then that the two-component effect in itself is not dependent on an abscopal mechanism.

Bacteriological aspects of radiation injury. Studies on the bacteriological aspects of radiation injury have been in progress for a number of years at the University of Chicago. Early results demonstrated that infection plays a significant role in the death of mice exposed to mid-lethal doses of X-rays or fast neutrons. Irradiated mice developed generalized infections involving bacteria normally present in their intestinal tracts. Treatment with appropriate antibiotics reduced the mortality whenever the radiation was not excessively intense.

Recent studies have measured the increase with time in susceptibility to infection after X-irradiation. By subjecting mice to inoculation with known numbers of bacteria at different times after 500 *r* irradiation (the LD_{50} is about 550 *r*), investigations found that susceptibility to infections increased rapidly during the first three days, persisted for about two weeks, and returned to normal about 20 days after irradiation. After exposure to 400 *r*, increased susceptibility was less marked, but persisted for about 20 days. Exposure to 300

r produced no detectable change in susceptibility to experimental infection.

Experiments are in progress at Argonne Cancer Research Hospital to assay the resistance to infection of mice continuously exposed to low dosages of gamma radiation.

The influence of ion density in radiobiological effects. The Donner Laboratory of the University of California has anticipated interest in the effects of radiation as they may apply to space medicine. The group there has been making use of the heavy ion linear accelerator (HILAC) at the University of California Radiation Laboratory to study the effects of heavy particles resembling cosmic rays on biological materials. These studies were started recently and will proceed very slowly because of the complexity of the equipment and the subtleties of effects involved.

A conference at Donner Laboratory January 21–22 reviewed present knowledge about the nature of cosmic radiation, acknowledged the dearth of information on biological effects, discussed the kinds of data needed, and suggested some areas of research which might prove valuable.

Studies of Effects of Internal Radiation

Research has compared the cancer-causing effects of alpha-emitting radioisotopes and beta-emitting isotopes lodged in the body, has found evidence that in mice obvious injury causing certain types of tumors does not occur below certain dose levels of strontium 90, and has explored other aspects of the effects of internal radiation.

Induction of tumors by internal radiation. When plutonium and the radioactive fission products first became available for biological investigation, they were administered to laboratory animals in a variety of ways to evaluate the potential hazards to man. The expectation that these materials would cause cancer was quickly verified; tumors arose in tissues where radioactive material lodged. The tissue where the material lodges depends upon the particular element being used, its chemical state, and the manner in which it is administered. For example, injection of solutions of yttrium 91 resulted in malignant bone tumors because most of the material became fixed in the skeleton. Inhalation of insoluble yttrium 91 compounds led to cancer of the lung: ingestion to cancer of the colon; and intramuscular or subcutaneous administration to local tumors.

At Argonne National Laboratory, continuing studies of such radiocarcinogenesis are designed to relate specific tumor-inducing potency

to the physical and biochemical characteristics of different isotopes. The experiments are providing information essential to understanding the neoplastic or tumor-generating processes.

In terms of the injected dose per unit body weight of female mice of the CF_1 strain, it has been found that bone-seeking radioactive elements that emit alpha particles are more potent agents of bone cancer than are bone-seeking elements that emit the lighter and less-damaging beta particles. However, at higher dose levels, beta emitters seem to be equally or more effective than alpha emitters. This is probably because alpha emissions are so lethal to cells that this effect masks the carcinogenic effect which would show only in cells that survived. Apparently the level of greatest carcinogenic effect is the amount of radiation that induces the greatest degree of neoplastic change while at the same time killing the smallest number of potentially neoplastic cells.

It has also been demonstrated that potency of a material as a carcinogenic substance varies directly with beta ray energy—that is, potency rises as beta energy rises—and that physical half-life of the radioactive element and the duration of its retention in the body influence induction of neoplasms. In addition, those isotopes that decay quickly into another short-lived isotope are more potent than isotopes, otherwise comparable, that decay into stable elements or long-lived radioisotopes. All these characteristics influence the dose rate of radiation from the isotopes and the total integrated dosage at the potential tumor site.

Extrapolations of tumor data from the experimental animal to man require an understanding of the factors associated with the latent period. For example, in rats and mice the shortest time between radioisotope administration and death with bone tumor is approximately 150 days, or from 10 to 20 percent of the normal life span of these species. It is of considerable importance to know whether the latent period in man also is 150 days, or whether it is somewhere between 7 and 14 years; that is, 10 to 20 percent of the life span as in the case of mice. Recent information on cats and dogs—species with intermediate life spans—supports the view that absolute time (150 days in the case of mice) rather than relative time (the percentage of life span) is the factor in latency. There is also evidence that when a tumor is formed, the latent period is independent of size of dose, independent of the isotope administered, and independent of the animal's age at the time of administration.

Estimating the potential hazard to human populations contaminated with very small quantities of radiosotopes requires information concerning the minimum dosage at which detectible response occurs, and the shape of the curves indicating relation of response to different

dosages. The dosages of all bone-seeking radioisotopes tested in CF_1 female mice have included levels so low that the treated populations receiving radioisotopes showed no more response than did undosed control populations.

Other data concerning tumors of connective tissues in mice after administration of strontium 90 similarly indicate that there exists a dosage below which strontium 90 does not have any obvious effect. The animal data do not seem to support the hypothesis that the carcinogenic effect increases in direct linear relation to increasing dosage. On the contrary, the findings emphasize the dangers of wide extrapolation from information based on a small range of dosages.

Long-term effects of internal radiation. To assure adequate protection of health in nuclear energy activities, knowledge is needed on the effects of various radioactive elements which might be ingested by man. Five radioactive elements were chosen for study: plutonium, radium, mesothorium (radium 228), radiothorium (thorium 228), and strontium 90.

At the University of Utah, the effects of these radioisotopes are being studied on a colony of about 375 beagle dogs. The location and amount of the elements internally deposited in the animal are determined, and the influence of the deposits on metabolism is being evaluated. Pathological changes have been observed in the 5 years this study has been under way. In addition to the effects of the radioactive materials mentioned, investigators are conducting a general study of the phenomena of aging.

Studies on the metabolism in human beings of strontium 85—shorter lived than strontium 90—are continuing at Argonne Cancer Research Hospital in close cooperation with the Argonne National Laboratory. Facilities at the laboratory for counting very low levels of radioactivity make it possible to keep an accurate record of body radioactivity for more than 1 year after an individual has received a 25 microcurie dose of strontium 85-chloride.

Cellular and Molecular Level Studies

Studies on transport across the cell wall. The damage produced in individual cells by ionizing radiation may take various forms depending on the type of cell, the amount and type of radiation, the exact locus struck by radiation and many other factors. When such damage is considered, all aspects of the cell which may be altered by irradiation are examined and each factor is assessed in its relationship to the changes taking place in the cell. The prime suspect as a locus of damage leading to death of the cell is a template type of molecule,

since destruction of such a unique molecule would deprive the cell of the entire chain of reactions stemming from the molecule's normal action. Other potential sites of damage are considered even though they may not appear to be direct links between irradiation and cell death.

Such a potential site is the cell wall, damage to which might result in loss of essential substances, or entry of unwanted substances, or general changes in permeability of the cell wall. A study has been carried out at the University of California at Los Angeles-Atomic Energy Project to test this possibility, and also to gain further insight into the mechanism of the transport into cells of the fatty acids, lipids or lipoproteins.

Recent information suggests that the most probable form in which fatty acids reach the cell is as the albumin complex. Accordingly, this simple lipoprotein was examined first and the Ehrlich mouse ascites tumor was used because of the ease of making *in vitro* preparations of these cells, and the fact that metabolic studies can be carried out with some confidence that essentially normal reactions are being observed.

It was found that the lipid, palmitic acid, by itself was oxidized by the cells, but oxidation was irregular and incomplete. When the acid was combined with albumin, oxidation continued regularly for as long as 2 hours. When the complex contained radioactive albumin, no radioactivity appeared in the cells or in respiratory carbon dioxide. The albumin apparently served as a solubilizing and transporting agent only and did not enter the cell. It is postulated that the fatty acid is removed from the albumin to the cell wall by a passive distribution process and is then drawn within the cell and metabolized by an active process.

Irradiation of the tumor cells with 2,000 *r* of X-rays did not decrease oxidation of palmitic acid or increase absorption or oxidation of albumin. It seems likely that the enzyme systems for oxidation of palmitate are not affected by these doses and that the permeability of the cell wall to lipids or protein is not altered drastically.

These suppositions are being investigated with other types of lipoproteins.

The irradiation chemistry of cyclohexanone. Information on the chemical changes that result when naturally occurring compounds are irradiated is important in the search for the substances in living animals and tissues that are initially damaged by irradiation. Certain steroids which exist normally in the skin of animals have long been suspected of forming cancer-causing substances when subjected to radiation. Typical of the steroids is provitamin D, of which the plant sterol,

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ergosterol, is typical. Irradiation of ergosterol at the University of California at Los Angeles-Atomic Energy Project resulted in a complex mixture from which no identifiable compounds could readily be isolated. Separate portions of ergosterol were isolated for separate study in an effort to understand reactions occurring in the whole molecule.

The first portion studied was the cyclohexanol molecule. When irradiated in aqueous solution by cobalt 60 gamma rays, it produced several compounds that apparently are products of oxidative reactions.

Products isolated from the reaction mixture were the 1:2- and 1:3-cyclohexanediones, adipic acid and epsilon-hydroxycaproic acid. The first two compounds are considered as formed by oxidation of the intact cyclohexane ring; the latter two are products of ring scission. Rate studies indicated that the first type of oxidation is dependent on the amount of radiation and oxygen tension, is increased by acidity, but is independent of radiation rate and initial concentration, and is decreased by alkalinity.

With this knowledge, a somewhat unique reaction mechanism has been postulated involving participation of the hydroperoxy radical in the production of hydroperoxides which then decompose to the products observed.

Predictions now can be made concerning the effect of radiation on this type of grouping in many different compounds of biochemical interest.

Virus RNA. It is now known that only the ribonucleic acid (RNA) portion of the tobacco mosaic virus (TMV) is necessary for infection of a plant. This means that all the genetic "information" necessary for the virus to reduplicate resides in the nucleic acid, including the synthesis of both nucleic acid and protein, and the organization of these components into a complete virus. Workers at the UCLA-Atomic Energy Project have determined the radiosensitive molecular weight of the infectious molecule corresponds to the total nucleic acid content of the virus. These results indicate that a single X-ray photoelectron hitting anywhere on the nucleic acid mass may lead to loss in virus activity. This confirms the finding that the nucleic acid portion of the virus of itself can accomplish self-replication and infection.

From these studies, it has been concluded that one break in any, or in certain ones, of the 7,000 phosphodiester bonds can destroy the capacity of the virus for infection. These data, together with those known for desoxyribonucleic acid (DNA), lead to the proposal that TMV–RNA is a single-stranded molecule in contrast to DNA, which is double-stranded. Since both RNA and DNA are bearers of infor-

mation, any explanation of the genetic mechanism based on double-stranded DNA must take into account the possible single-stranded structure of TMV–RNA.

Cancer Program

In the broad-ranging use of radioactive substances and radiation in cancer studies and cancer treatment, the Commission's research institutions employed tracers in efforts to determine differences in vital processes of cancerous and normal tissue, or to localize radiation in cancerous growths. The treatment of cancer and other conditions by the use of special radiation sources and byproduct materials from atomic energy operations was continued, and new techniques were tested.

Studies of a hormone that controls red blood cell formation were continued, special metabolic work was done using a continuous monitor associated with a digital computer, and a theory of virus-caused leukemia in mice was investigated. For the first time, radioactive antibody preparations were developed that concentrated radioactivity in certain cancers in rats. Data were collected on radium-poisoned individuals and on therapeutic X-ray as a possible cause of cancer in specific cases.

A technique was developed for destroying the pituitary gland in certain cancer patients where this might prove helpful by surgically implanting radioactive pellets; treatment with high energy machines continued, including one using a needle beam. This section describes this, and other work under way in these fields at major Commission laboratories.

Argonne Cancer Research Hospital

Studies at the Argonne Cancer Research Hospital on erythropoietin,[49] a hormone that controls red blood cell formation, have been devoted to attempts to apply measurement of uptake of iron 59 by blood cells to test red cell production; to find more sensitive preparations for the assay of erythropoietin; to elucidate the role of this hormone in maintaining the dynamic equilibrium of the erythron (the red cell tissue); to determine fundamental conditions that control the levels of erythropoietin in the blood and thus the rate of erythropoiesis (red cell generation); to learn the effect of the cobalt ion on the production of erythropoietin; to locate the site of formation of the hormone; and to apply the knowledge gained to clinical problems,

[49] Earlier studies described pp. 122-123, Twenty-second Semiannual Report to Congress (January-June 1957).

e. g., the anemia of cancer, leukemia, and other disorders of the blood-forming tissues.

Rabbit and sheep plasma are being purified, and partially pure fractions containing erythropoietin in high concentration are being studied to learn more about the chemical nature of the hormone. Purification by a factor of more than 1,000 has been accomplished.

It has been demonstrated that fractionated plasma from anemic human beings can be assayed for erythropoietin content in starved or hypophysectomized rats (pituitary gland removed). The hormone has been found to be present in high concentration in the plasma of patients with various types of anemia, including the anemia associated with cancer.

The status of erythropoietic-stimulation factors in the unusual cogenital hypoplastic anemia of children has been undergoing investigation. A striking erythropoiesis-stimulating effect was produced by a heat-denatured extract obtained from two children with this disorder. When these children were given plasma (300 milliliters daily for 8 days) from adult donors with acute blood loss anemia, the count of reticulocytes (young red blood cells) was elevated from a baseline of less than 0.5 percent to 3.4 and 4.0 percent. This finding led to attempts to determine the nature of the substance in the plasma from anemic donors capable of stimulating erythropoiesis in patients with congenital hypoplastic anemia.

Erythropoietin-containing plasma has been found to stimulate the proliferation of bone marrow cells in tissue culture. These studies will be continued and directed toward efforts to stimulate the maturation of the erythrocytic elements in tissue culture, and to discover which stages in the development of these cells are most affected by erythropoietin.

Pituitary treatment of cancer patients. Patients with cancers that are susceptible to hormonal alteration, e. g., metastatic (migrative) breast and prostate carcinoma, have been treated by hypophysectomy, the pituitary being destroyed by surgical implantation of one millicurie yttrium 90 pellets in the gland. The use of local anesthesia and the short duration of the operative procedure make the method particularly suitable in the treatment of patients in advanced stages of the disease. A simultaneous biplane fluoroscopic image intensifier is used as a control while the pellets are being introduced.

Isotopes for interstitial radiation therapy. The use of conventional interstitial radiation therapy entails exposure to the surgeon at operation. New radioisotopes have properties that help to circumvent this problem. Palladium 103, which decays with a 17-day

half-life and which emits principally 20-kilovolt X-radiation, is one of these, since its lower energy radiation is less penetrating and more easily shielded. Results obtained in experiments in which palladium 103 has been used to treat tumors offer much hope. Plans are under way to use this isotope in treating advanced cancer of the uterine cervix.

The development of methods for using isotopes in solution in sealed applicators for internal irradiation has made possible a much wider choice of materials for radiation sources. One such substance, cesium 131 (half-life 9.6 days), appears to be an excellent material for interstitial implantation. Water and air dose measurements have been carried out surrounding point sources of radiocesium and experimental implants in animals have demonstrated the clinical feasibility of using this isotope.

The frequent use of colloidal gold 198, yttrium 90 and radiochromic phosphate for the treatment of ascites tumor and destruction of tumor cells seeded at operation has led to an investigation of the distribution of these substances in the peritoneal cavity where ascites fluids accumulate. Radioactivity, determined by means of radioautographs, was found to appear first in the mesenteric lymph nodes and omentum and later in the liver and spleen. Factors influencing the distribution were found to be local peritonitis, protein conjugation, carrier and gravitational effects.

Treatment with high energy machines. The 2-Mev Van de Graaff X-radiation generator and a high intensity cobalt 60 source, both applicable for vertical or horizontal rotation, are being used to treat cancer patients at the Argonne Cancer Research Hospital.

An analysis of the relative biologic effectiveness of the three high energy machines in use in the hospital is essential to provide a better understanding of their biologic effects, and to learn how to utilize them most effectively for cancer therapy. Toward these ends, the recovery of biochemical processes and of the immune response in animals that have been given lethal amounts of X-radiation and then saved from death by injections of hematopoietic cells from donors of the same strain is being compared with recovery of lethally-irradiated animals injected with cells from widely divergent species.

High energy electrons will be used soon to treat deep-seated cancers in people. A single small beam having a diameter that equals that of the lesion is directed toward the patient, using either single or multiportal techniques. This means of therapy has been made possible by construction of a device that directs a high energy electron beam of small diameter to scan over any arbitrary field size. The device is capable of accepting electrons from 5 to 50 Mev with a beam size of 1

centimeter diameter or smaller. The advantages the scanning device offers are that the depth of penetration within a single field can be varied by altering the energy of the electrons; the size and shape of the field, including circles and rectangles as well as irregular shapes, can be selected rapidly; either a multiport or revolving radiation source can be employed; and the patient may remain in a recumbent position. The device may be used with any accelerator that provides a free electron beam with sufficient output.

The device at the Argonne Cancer Research Hospital is being added to the linear accelerator.

Radium cases. Clinical studies of radium-poisoned individuals have continued. Bone samples obtained from several patients are being studied to learn more of the mechanism of necrosis in bone and of the induction of cancer. The relationship between lesions in bone and the appearance of cancer with the total-body burden of radioactivity has been determined for several new patients.

Metabolic studies. The continuous radiocarbon-dioxide monitor has been developed into an automatic instrument, the output of which can be transcribed into digital data for rapid machine computation. Theoretical formulations have been completed that permit the measurement of the extent and rate at which metabolites are utilized in normal and diseased human beings as well as in experimental animals.

The intermediary metabolism of the purines is being studied to learn whether this system may be used as a model and indicator of aberrations in the metabolism of cancerous tissue. For the first time, the pathways of the degradation of uric acid in the human digestive tract have been demonstrated, and much has been learned of the synthesis of uric acid in humans.

University of Michigan

Teletherapy. A large number of patients at the University of Michigan School of Medicine have received treatment with the 1,900-curie radiocobalt source and the 2,000-curie radiocesium source, as well as treatment with conventional X-ray procedure. This is a long-range program with radiocobalt therapy begun early in mid-1955 and will require another 2 years for evaluation.

Though the radiocesium unit has been in operation only since September of 1957, it is recognized that its usefulness in therapy has definite limitations. It has a much longer half-life than cobalt, but

the bulkiness of the source and the lesser penetration of its gamma-rays limit its application largely to shallow therapy.

Brookhaven National Laboratory

Neutron capture therapy. Continuing studies have improved the technique developed at the Brookhaven National Laboratory of using neutrons from the research reactor in treating patients with malignant brain tumors. Basically, the treatment calls for injecting boron that, concentrating in the tumor, becomes radioactive by neutron capture and emits alpha particles that destroy tumor cells.

In the application of neutron capture therapy to glioblastoma multiforme, a malignant brain tumor, the interarterial route of administration of the boron in the form of sodium pentaborate, was employed without complications on two patients. The surgical procedures associated with this therapy have been standardized. No delay in wound healing has been observed.

One aspect of further studies will be the development of procedural maneuvers to take advantage of opportunities presented by the new Brookhaven medical reactor.

University of California School of Medicine

70 Mev synchroton. Patients have been treated on a regular schedule with X-rays from the 70 Mev synchroton. During this reporting period, over 50 cancer patients with rather advanced cases of the disease have been treated.

At first, patients were selected whose disease involved the head or neck so that tissue reactions could be examined easily and followed closely. Tumors now being treated are primarily in the lung, uterus or bladder. At this early time it is not possible to draw any final conclusions on success of treatments but normal tissue reactions and satisfactory tumor regression have been observed.

Radiation doses delivered from the synchroton are standardized daily with a ferrous sulfate-benzoic acid dosimeter developed in the University of California Radiological Laboratory. This solution maintains high sensitivity and stability.

University of California Radiation Laboratory

Experimental irradiation of the pituitary with 184-inch cyclotron. Work on experimental irradiation of the pituitary with the 184-inch cyclotron at the University of California Radiation Laboratory, Berkeley,

was resumed in October 1957 following a shutdown of the cyclotron for nearly 20 months. During this reporting period, an additional group of 30 patients has received pituitary irradiation. Earlier work using high energy particles from the 184-inch cyclotron has been described in previous reports.[50] This work was designed to investigate the effectiveness of high energy beams in accomplishing destruction of the pituitary gland with the basic objective of determining the control exerted by the pituitary on other endocrine organs whose hormones are believed to regulate the growth and spread of breast cancer.

It is planned to irradiate a series of 100 patients, in order to make an adequate statistical evaluation of the procedure as palliative treatment for advanced metastatic breast cancer.

University of Chicago

X-ray as cause of cancer. X-ray irradiation of the stomach has been used at the University of Chicago for treatment of peptic ulcer since 1937. This therapy reduces the secretion of gastric acids and thus facilitates the healing of the ulcer.

Studies are under way to determine whether, in patients who undergo this treatment, any organs within the radiation field are damaged by the radiation or undergo subsequent malignant change with a frequency greater than normal. Overall mortality experience to date indicates an increased frequency of deaths from cancer among patients receiving this treatment when compared with mortality experience of the United States population at large, or with the experience from 10 urban areas. The validity of the conclusion is not yet established completely. Increase in lung cancer in these cases is greater than that for any other cancer.

The need for a satisfactory control group has become increasingly clear and steps are being taken to find and analyze such a group.

University of California at Los Angeles—Atomic Energy Project

Leukemia virus studies. Leukemia in the mouse, a disease similar in many ways to a certain type of leukemia in man, is being studied in the Medical Division, University of California at Los Angeles—Atomic Energy Project. There have been reports in recent years that mouse leukemia may be caused by a virus. Attempts have been made in this study to transmit the disease from strains of mice that have a higher incidence of leukemia by injecting cell-free extracts of leukemia tissues that may contain virus into newborn mice of a

[50] See p. 38, Twenty-third Semiannual Report to Congress (July–December 1957) and p. 129, Twenty-second Semiannual Report to Congress (January–June 1957).

strain resistant to leukemia. The incidence of leukemia in adult life of the resistant strain has been increased from less than 1 percent to 19 percent.

Nucleic acids prepared from leukemic and normal tissues also are being studied in this manner, and evidence is being accumulated to determine whether or not the nucleic acids, known to be associated with hereditary factors, may have leukemogenic properties in mice.

Determining if a leukemogenic virus exists, or if leukemogenic properties reside in nucleic acids, are essential steps in increasing understanding of the disease, and the effect of radiation in the production of leukemia.

University of Rochester

Cancer antibodies. Since 1952, University of Rochester research has attempted to produce and purify antibodies to cancer tissue that would concentrate in cancer tissues and remain localized there for periods of several days. If antibodies with a high specificity for localizing in human cancer can be developed, at least two possibilities exist for therapeutic use: (*a*) Labeled with a radioisotope, the antibodies might carry a sufficient amount of radioactivity to destroy cancer tissue too widely disseminated to be treated successfully by surgery or by presently available radiation therapy techniques; (*b*) Antibodies able to react only with cancer tissue might exert, through an immunological mechanism, a specific destructive effect on cancer cells.

During this reporting period, radioactive antibody preparations were developed that, after intravenous administration, led for the first time to concentrations of radioactivity in animal cancer lesions many times higher than occurred in normal organs.

First, methods were developed for isolating labeled antibody preparations from the tumors of animals injected with relatively crude iodine 131. On subsequent intravenous injection into tumor-bearing animals, the labeled antibodies showed a high specificity for localizing in cancer tissue. In addition, completely *in vitro* techniques were developed for isolating the tumor-localizing antibodies from immune serum. As an example, average iodine 131 concentration in the tumors of two rats the day following injection of an iodine 131 labeled antitumor preparation isolated from immune serum was 27.5 percent of the total injected radioactive dose per gram of tumor tissue. The highest average iodine 131 concentrations in other tissues as a percent of injected dose per gram tissue were blood, 3.35; adrenals, 1.90; lung, 1.61. Antitumor preparations have been made that, when

injected intravenously immediately after iodine 131 labeling and without further purification, show significant tumor localization.

Most recent work has been with the transplantable Murphy-Sturm rat lymphosarcoma. However, work with other animal tumors indicates that specific antibodies for some other types of transplantable cancer can be produced.

Tracer Studies

Some of the more important research findings of recent months, made with the tracer use of radioisotopes in labeling biological substances, concern metabolism of fatty acids and the synthesis and metabolism of sex hormones, and in plants, studies of nucleic acids, photosynthesis, and growth substances. Selected projects are described in this section of the report.

Human and Animal Studies

Tracer studies in lipid metabolism. The University of California at Los Angeles—Atomic Energy Project is using tracers to study the metabolism, function and chemistry of the essential fatty acids. These vitamine-like unsaturated acids have an important, although imperfectly understood, role in growth processes and repair mechanisms of higher animals, and also readily autoxidize (oxidize by direct combination) through a reaction initiated by ionizing radiation which leads to toxic hydroperoxide derivatives. The autoxidation is of particular interest because a single event caused by radiation can cause alteration of many molecules.

Using unsaturated fatty acids labeled with carbon 14, it has been demonstrated in rats that linoleic acid—the essential nutritional factor which higher animals cannot synthesize and must therefore acquire in food—is converted to arachidonic acid by acquiring a 2-carbon unit with introduction of 2 additional carbon-carbon double bonds between portions of the molecule. The sequence of these events has been established to the extent that it is now known that one double bond is created first. Proof of the likelihood that the 2-carbon unit is added next, followed by creation of the other double bond, awaits completion of preparation of another C 14-labeled acid, homo-γ-linolenic.

In an attempt to gain insight into the vital function of the essential fatty acids, experimenters are studying changes in serum lipids (including cholesterol esters in which these acids occur in high concentration) which result from various types of physiological damage, especially that produced by whole-body ionizing radiation.

Studies of female sex hormones. Synthesis and metabolism of two important female sex hormones, progesterone and estrone, have been studied at the Argonne Cancer Research Hospital, using compounds labeled with radiocarbon and tritium (radiohydrogen). Cholersterol was found to be a precursor for both hormones. In human pregnancy, the pathway of the principal route of synthesis and metabolism of progesterone is from acetate to cholesterol to progesterone, to pregnanolione, to pregnanediol. However, there is conclusive evidence that the hormone can be converted into other steroid hormones which contain only 19 carbon atoms in their molecules as does progesterone.

In the pregnant woman, carbon 14-4-testosterone can be converted to some extent into carbon 14-estrone. The site of conversion is thought to be the placenta. Progesterone has been found to be a precursor of estrogens in patients with chorio-carcinoma.

Plant Studies

Gibberellic acid in plant physiology. Gibberellic acid is one of a group of closely related plant growth substances known collectively as the *gibberellins* that occur naturally in certain fungi. The substances were discovered in Japan and have been studied there for 20 years, but, because of war and the language barriers, did not arouse much interest in this country until 1950. Although they have been demonstrated to influence plant growth, it is not yet certain that they occur naturally except in fungi.

In order to facilitate studies of the mode of action, movement, and metabolism of the gibberellins in plants, uniformly labeled carbon 14-gibberellic acid has been prepared at Argonne National Laboratory by biosynthesis in the fungus *Gibberella fujikuroi.* The labeled substance was applied in solution to stems, leaves or terminal buds of pinto-bean seedlings, and its movements in the plant were traced. It was absorbed rather rapidly and it or its metabolic products moved both upward and downward, but chiefly downward in the plant.

Nucleic acid synthesis in dividing cells. Nucleic acids appear to play a dominant role in the major functions of cells. Desoxyribonucleic acid (DNA) is found in the cell nucleus and appears to be the chemical basis for heredity. Another type called ribonucleic acid (RNA) is found in the cytoplasm of cells as well as in the nucleus in a small body called the nucleolus and appears to be related to protein synthesis. In actively growing tissues in which the cells are undergoing rapid division, the nucleic acids are undergoing rapid synthesis.

To study this synthesis, specialized autoradiograph tracer techniques have been developed. Living material is grown on a nutrient

solution containing various isotopically labeled precursors of nucleic acids; after incorporation of the labeled compound into the nucleic acids the tissues are fixed and processed. The sections then are covered with a photographic emulsion and stored in the dark. When the emulsion is developed, the autoradiograph of the tissue shows as concentrations of silver grains in clear gelatin and the tissue itself can be studied microscopically.

Recently these techniques have been used at Brookhaven National Laboratory in studying the synthesis of RNA and DNA in dividing root-tip cells in seedlings of the broad bean *Vicia faba*. Because of the short range of its beta particle tritium was used to label cytidine. The autoradiographs showed that incorporation of the labeled precursor took place first in the nucleolus and later in the cytoplasm.

An attempt was made to determine whether the tritium-labeled cytidine was incorporated in both the nucleolus and cytoplasm, either with or without turnover, or whether it was incorporated largely in the nucleolus and later transferred as a large molecule to the cytoplasm. Other seedlings were treated with tritium-labeled cytidine long enough so that only the nucleoli were labeled, and then were removed and grown on a nonlabeled solution containing an excess of cytidine and uridine. Autoradiographs showed that, with increased posttreatment time, a decline occurred in radioactivity in nucleoli and a rise took place in the cytoplasm.

These observations indicate (*a*) that the nucleolus is the only site of RNA synthesis in the cell, or that it is concerned with accumulating RNA that has been synthesized elsewhere, but that the synthesis time is very short; (*b*) that RNA is then transferred as a large molecule to the cytoplasm, and (*c*) that DNA and RNA syntheses are independent processes.

Studies of photosynthesis. The study of photosynthesis may be described as the problem of determining how green plants convert electromagnetic energy, in the form of sunlight, into chemical energy, in the form of reduced carbon compounds and molecular oxygen. Upon this process all life on earth today depends.

Until after the war, little was known about the way in which photosynthesis reduced carbon from carbon dioxide to the energy-rich compounds of plant material. Since then the use of tracer carbon 14 has made possible the mapping of very nearly the entire detailed route from carbon dioxide to many plant compounds. It has been possible to reproduce the major steps of this route, using catalysts isolated from a variety of living organisms and supplying the energy in the form of two specific energy-containing materials. The major unsolved problem remaining in the study of photosynthesis is the determination of

the way in which these two specific energy-rich compounds can be produced by the light absorbed by chlorophyll.

Understanding of the process depends on the fundamental observation that when light shines on chlorophyll-containing material unpaired electron spins appear which can be detected by their electron-spin resonance spectra. The characteristics of these spin-resonance spectra for different types of chlorophyll-containing materials are being investigated and compared with other physical and chemical properties such as luminescence and enzymatic activity.

One investigation at the University of California Radiation Laboratory, Berkeley, has resulted in the evolution of concepts of the electronic behavior of macromolecules that could lead, on the one hand, to the creation of organic solar-converters, and on the other, to new thoughts on the relation between macromolecular structure and visible microstructure and function in living organisms.

Light energy transformation in photosynthesis. Light energy storage in green plants and in a suspension of chloroplasts was discovered several years ago at Oak Ridge National Laboratory and it was demonstrated that plants emit light for some time after they have been illuminated. It was demonstrated that chloroplasts dried to thin films on metal plates emit light on being heated, provided the heating follows a period of illumination. Such films of chloroplasts also give a strong signal in the paramagnetic resonance apparatus at the correct frequency and magnetic field for unpaired electrons. The signal is reduced to zero by heating the sample to 140° C. It has been shown that this temperature in the absence of light will free essentially all the stored light. The finding that heating to 140° C. frees the stored light and eliminates the paramagnetic signal, suggests that the stored energy may be in the form of a free radical, an excited triplet, or a trapped electron.

Effect of high irradiation on photosynthesis. The photosynthetic process in green plants has been found to be relatively insensitive to ionizing and ultraviolet irradiation. Formation of the photosynthetic process (greening) in etiolated (dark-blanched) plants upon exposure to light is also radiation insensitive. Experiments at Oak Ridge National Laboratory showed that dosages of 150,000 *r* of gamma radiation were necessary to produce a temporary inhibition of photosynthesis. After 24 hours green plants returned to a normal rate of photosynthesis and etiolated plants had greened normally. Analyses were made of the irradiated plants for the subsequent period during which they survived.

Etiolated wheat plants were exposed to an acute dose of 150,000 *r* gamma radiation and then kept in pots of soil in a constant-environment plant-growth chamber. For 2 to 3 weeks the plants appeared normal, but there was no new growth except for some general enlargement of the plant, probably from cell elongation. By the fourth week the plants were chlorotic (yellowed) and fungal growth appeared on the dying leaves. At intervals, the respiration was measured, photosynthesis was examined by fixation of radiocarbon dioxide and the products of the photosynthesis experiments were examined. The respiration rate increased at the end of the second week; part of the respiration may have been due to bacterial contamination. Even after the second day, the trend was away from normal pattern sucrose synthesis to incorporation of carbon 14 into glycine and serine. This same trend previously had been noted in green plants immediately after radiation. During the last 2 weeks of survival several substances, such as glutamic acid, were not labeled during one hour of exposure of radiocarbon dioxide in the light.

Though the wheat plants had received a lethal acute dose of radiation, there was inhibition neither of respiration nor of photosynthesis, but growth was prevented. During the first 2 weeks after radiation, there appeared on the epidermis of the leaves numerous droplets of a gummy concentrate, which dried as beads and was collected and analyzed. Had the plants been watered by rain or spray this phenomenon would not have been detected, since the the exudate would have been washed off. The droplets contained much glucose as well as substantial amounts of fructose, glutamine, serine, and many other amino acids. The exudation ceased between the second and third week when the photosynthetic rate dropped. During the first 2 weeks after irradiation, the leaves probably accumulated excessive amounts of the products of photosynthesis since this process was not inhibited while growth, which otherwise would have utilized these products, ceased. This accumulation of photosynthesis products may also have been partially responsible for the drop in rate of photosynthesis and change in the distribution products of photosynthesis.

Between the second and fourth weeks, the plants showed a slow decline. No definite period of death occurred; rather, fungal growth slowly took over the leaves. This pattern of death in plants is in marked contrast to that found with animals exposed to massive dosages of acute radiation.

Carbon dioxide fixation. At the University of Chicago, the following observations of importance in the field of photochemical and enzymatic carbon dioxide metabolism of plants and bacteria have been made. In certain green algae a fixation of carbon dioxide and trans-

formation into organic substances may proceed not only by photosynthesis (when an amount of oxygen equivalent to carbon dioxide is evolved), but also with a corresponding absorption of hydrogen gas (photoreduction). Without light, the process is promoted, instead, by an enzymatic reaction between hydrogen and oxygen-yielding water. There are conditions under which these three ways of fixing carbon dioxide may proceed simultaneously. While the two light reactions were found to be very closely related, the dark fixation shows kinship to respiration rather than to photosynthesis.

Effect of fluoride. A report printed in the technical literature of equivalence between chlorophyll content and a carbon dioxide-holding compound was checked by this research group and found to be erroneous. Treatment of green cells with fluoride releases a variable amount of carbon dioxide—the quantity being either larger or smaller than the chlorophyll content of the cell. This bound carbon dioxide—the carboxyl group of an organic acid—is light stable and therefore is not at all identical with the carbon dioxide the plants assimilate during photosynthesis.

Effect of mercury. The mercury-dropping electrode (polarograph) is often used for measuring oxygen potentials and for analyzing traces of metals in living systems. Thus some metallic mercury comes in contact with the biological material investigated. The metabolism of certain lower plants was studied with such a polarograph. Unexpectedly, it was found that traces of mercury metal may produce profound metabolic disturbances. Mercury vapor dissolved in aquatic media may stimulate the rate of respiration in algae 300 percent while the capacity for photosynthesis declines. The oxidation of the uncharged mercury atoms to toxic mercuric compounds occurs within the cell.

Effect of commercial herbicide. A commercial herbicide DCMU, a substituted urethane, is one of the most powerful poisons of photosynthesis known. It was found that one molecule of this poison interferes with the action of several hundred chlorophyll molecules. The site of the inhibitory action could be located in the mechanism which enables the plant to release free gaseous oxygen. Thus, DCMU does not interfere with the enzymes engaged in carbon dioxide fixation.

Effect of radiation on pigment components. Work also continued on the effects of ionizing radiation on the pigment components and subreaction of the photosynthetic process in higher plants and green

algae. Pigment sensitivity to gamma radiation is dependent on state of aggregation, solvent composition, water content of the solvent, and oxygen partial pressure. Some subreactions of photosynthesis show a differential radiation sensitivity. Carbon dioxide fixation, for example, appears to be less sensitive to gamma radiation than does the Hill (water-splitting) reaction.

Radiation Safety and Health Protection

The Commission's program in radiation safety and health protection was described in some detail on pages 109–260 of the Twenty-first Semiannual Report to Congress (July–December 1956). This report describes some continuing activities in this area.

Environmental Hazards in Milling Ore

To evolve a sound engineering base for protecting the health of workers in uranium ore mills; and to assist Commission procurement and inspection organizations in evaluating expenditures for engineering controls, a survey of 12 domestic ore mills in operation as of July 1957 was conducted by teams of the Commission's Health and Safety Laboratory.

Detailed analyses were made of daily average exposures to the chief materials processed, particle sizes of plant atmospheric dusts were determined, and radiation was measured inside and outside the plants, and in plant effluents and ground water.

The report on the survey [51] made recommendations for simplifying the interpretation of maximum permissible concentrations in ore handling areas, and for modifying some plant practices, and suggested ventilation requirements in specific process areas.

The Commission's Winchester (Mass.) Laboratory will assist in further studies in this field.

Industrial Hygiene of Beryllium Plants

With increase in the use of beryllium outside the atomic energy industry, the Health and Safety Laboratory prepared a monograph on Commission experience in health protection in beryllium processing.[52] It sets forth medical experience with beryllium, explains the

[51] HASL-40, "Environmental Hazards Associated With the Milling of Uranium Ore—A Summary Report," Harris, et al., June 4, 1958.

[52] HASL-36, "Health Protection in Beryllium Facilities—Summary of 10-Years of Experience," Breslin and Harris, May 1, 1958.

maximum permissible concentrations of beryllium in air and in environment established for Commission operations, and describes operational methods providing satisfactory health control.

Particle Accelerator Radiation Safety

Occurrence of eye-lens cataracts in physicists working with cyclotrons led to neutron dosimetry studies and stray radiation surveys, begun in early 1953 by the Health and Safety Laboratory. These have been supplemented by radiation protection advisory work and reviews of hazards and protection for proposed accelerators, or modifications of existing machines.

The work performed in 1953 and 1954 has been summarized in NYO–4699, "Stray Radiation Measurements at Particle Accelerator Sites," June 1, 1956.[53]

The 1955 and 1956 work is described in NYO–4699, Supplement 1, "Stray Radiation Measurements at Particle Accelerator Sites," issued February 7, 1958.[54]

The Commission sponsored a high-energy radiation shielding conference held in New York City in 1957, and the papers given there were included in TID–7545, "Conference on Shielding of High-energy Accelerators," published December 6, 1957.[55]

Studies of Bi-lobe Cells

Some time ago blood studies of laboratory personnel of the University of Rochester exposed to very low levels of radiation revealed the presence of lymphocytes (white blood cells) with nuclei abnormally shaped in the form of an hourglass.

A series of studies of the incidence of bi-lobe cells among uranium miners of the Colorado Plateau was initiated by the University of Rochester in cooperation with the United States Public Health Service. Control populations in the Rochester area have been checked. A preliminary examination of the data seemed to indicate an increased incidence of bi-lobe cells for the Colorado area as contrasted to controls from outside the test area. Whether differences exist between the uranium miners and other Colorado plateau residents has not yet been determined.

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[53] Available from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., 40 cents.

[54] Available from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $2.25.

[55] Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $5.50.

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Collateral studies on bi-lobe cells. The University of California Radiation Laboratory at Berkeley has confirmed an increased incidence of bi-lobe cells in the blood of workers chronically exposed to levels of radiation averaging 200 millirems per week. Efforts are being made to relate the response to dosage, and to define the time pattern of response after single and multiple exposures.

An experiment was carried out on 9 persons who, during laboratory work, were exposed to single acute doses of radiation ranging from 700 to 2,600 milliroentgens of gamma radiation. Preliminary results show a statistically significant higher incidence of bi-lobe cells in the cases of the two highest exposures (2,300 and 2,600 mr.) at certain times after the exposure, compared with their pre-exposure levels.

A similar experiment is planned to include about 15 subjects who have had a single exposure in the 1,000 to 2,500 mr. range.

Studies of Heavy Water

Investigations have been carried out to define any hazards that might exist if heavy water, used as a moderator in some reactors, were ingested or inhaled. It was determined that heavy water (D_2O), which contains the heavy hydrogen nucleus, deuterium, would be harmful only if taken in quantities so large that the possibility of a dangerous accidental exposure is extremely remote. Research at the Argonne Cancer Research Hospital in collaboration with Argonne National Laboratory determined that mice tolerate up to 40 percent D_2O in drinking water for at least 4 months during which time contained body water reached a stable value of about 30 percent heavy water. If ingestion continued for longer periods, deuterium was incorporated into various tissues and organs, and heavy water reached a value of from 40 to 50 percent of all body fluids.

Mice have been maintained at an internal concentration of 25 atom percent D_2O for as long as 12 months without any obvious effect, except that fertility may have been reduced.

At concentrations above 30 atom percent, mice and rats showed weakness, neuromuscular hyperexcitability, bradycardia, and eventually, stupor and death. Deuteration of mice also resulted in reduced growth rates of injected Krebs-2 ascites tumors and of inoculated leukemia cells. The basis of the biological action of deuteration is that chemical bonds of deuterium react less readily than do those of light hydrogen; consequently, reaction rates are decreased.

Growth of algae in heavy water. Studies at Argonne National Laboratory showed that heavy water slowed the growth of algae. In concentrations of nearly 100 percent heavy water, growth was delayed for

about 200 hours, after which growth resumed but at rates considerably below those of controls in ordinary water.

When algae adapted to growth in heavy water were transferred back to ordinary water, they exhibited a similar but shorter delay in growth indicating that adaptation was again necessary.

Attempts were made to locate roughly the biochemical site of the disturbance by exposing the deuterated algae to carbon 14, and examining the labeled products of photosynthesis. The results suggested that the conversion of the early photosynthetic products into large complex molecules is markedly affected.

Radiation Exposure Information for Employees

The Commission issued, effective May 13, policy and procedures for informing Commission and Commission contractor employees concerning occupational radiation exposure recorded as having been received by them during the period of their employment.

Background Radiation Survey of Installations

Arrangements have been concluded for the United States Geological Survey to conduct airborne background radiation surveys of all major Commission production sites, licensee reactor sites, and the Nevada Test Site. The purpose is to obtain information useful to an understanding of the long-term effects of low-level radiation in the environment. The data should provide a basis for appraisal of changes in environmental levels of radiation brought about by the testing program, reactor operation, Commission plants, and radiation accidents.

Commission Teams to Assist in Radiation Incidents

Atomic Energy Commission offices throughout the United States are acquainting State and local governmental officials with services the Commission and the Department of Defense have available should an incident involving radiation occur.

While highly unlikely, it is possible that an accident involving a nuclear reactor or radioactive materials, either in use or in shipment, could result in release of radioactivity hazardous to the public: for example, in a traffic accident involving a truck carrying radioactive materials. Containers for radioactive materials in shipment are designed to withstand most accidents, but a rupture could result in radioactive material escaping to the surrounding environment.

For some time the Commission has had in readiness at its various installations radiological personnel to help protect the public in the

event of such incidents. They are trained and equipped to monitor radioactive materials and advise local officials and physicians on the extent of radiation hazards and the steps that should be taken for the further protection of public health and safety. These groups now have been integrated into a network covering all areas of the continental United States. In addition, key United States military commands have teams especially trained and equipped to assist in protecting public health and safety in case of a radiation incident (see section on Military Applications).

If a radiation incident occurs, local officials may seek advice and assistance from the nearest Commission office or the nearest military installation.

Civil Effects Program

A Civil Effects Exercise, designated No. 58–1, was conducted at the Nevada Test Site in May with participants from the Commission, the Federal Civil Defense Administration, Tracer Lab, Inc., University of California "Project Civil," and Oak Ridge National Laboratory.

Under the technical leadership of Oak Ridge National Laboratory, the exercise sought to determine the shielding characteristics of typical residences remaining at the Nevada Test Site, and the value of simple modifications and methods of improving the shielding. Data were developed which may be useful in preparing standards for fallout protection, and in determining means for improvement and improvisation of shelters.

The research group also collected data on which to base recommended specifications for a vehicle equipped with radiation sources and instruments for evaluating the shelter characteristics of homes.

Return of instruments to France. At the request of the French Government, arrangements were concluded for return to France of certain instruments used for measurements in connection with the effects on French shelters of the Smoky detonation during Operation *Plumbbob*.

Studies of Fallout

Monitoring and sampling programs to study the distribution of radioactive fallout were continued during the past 6 months as was research on the biological hazards of fallout. The results of analyzing some samples are reported in this section.

Commissioner Willard F. Libby, in an address at Lausanne, Switzerland, before the Swiss Academy of Medical Sciences Sym-

posium on Radioactive Fallout, presented a review and analysis of available data on fallout and radiation effects. In his address, data presented in earlier publications were brought up to date to show the most recent results for rainfall collections, for the strontium 90 content of milk, for animal bone, and for human bone. The data continue to show the principal features noted previously, and indicate that little that is new in principle has appeared. The text of this address appears as appendix 12 to the report.[56]

Stratospheric Monitoring

The preliminary results of analysis for strontium 90 of stratospheric samples collected during the period November 1956 through January 1958 are summarized in table I. Progress was made in tests of filter efficiency but it still was not possible to interpret these data in terms of strontium 90 concentrations in the stratosphere. Moreover, there were considerable variations in the data from one sample to another, which have not yet been accounted for on meteorological grounds.

TABLE I. AVERAGE CONCENTRATIONS OF STRONTIUM 90 IN SAMPLES NOVEMBER 1956–JANUARY 1958 [1]

Altitude (feet)	Minneapolis, Minn.		San Angelo, Tex.		Panama Canal Zone France Air Force Base		Sao Paulo, Brazil	
	Average Strontium 90 Content	Number of Samples	Average Strontium 90 Content	Number of Samples	Average Strontium 90 Content	Number of Samples	Average Strontium 90 Content	Number of Samples
	(μμc/1,000 cu. ft.) [2]		(μμc/1,000 cu. ft.)		(μμc/1,000 ft.)		(μμc/1,000 cu. ft.)	
90,000	[3] 7±10	10	5±5	14	7±5	2	9±9	11
80,000	10±7	8	15±10	11	14±11	5	12±8	14
65,000	24±15	17	29±12	10	29±26	6	17±13	11
50,000	9±5	19	2±2	10	----------	0	1±1	[4] 5

[1] Based on data available through June 26, 1958. Analyses have not been completed on all samples collected during this period. The program calls for one sample a month from each altitude at each location. In some instances the sample was not recovered.

[2] Strontium 90 content expressed in micromicrocuries per 1,000 cubic feet of air, reduced to standard conditions.

[3] Range shows one standard deviation above and below average. Standard deviations shown include both errors of measurement and variation in strontium 90 content from month to month.

[4] These samples were collected in the vicinity of the tropopause and probably do not represent stratospheric concentrations. The 50,000 foot sampling level is usually below the stratosphere at this location.

[56] The document includes tabulations of recent data and bibliographic references to recent contributions to the subject.

Foreign Food Collection

The results of analysis for strontium and calcium of food samples collected in the Philippine Islands, Turkey, and Libya by teams of the Interdepartmental Commission on Nutrition for National Defense are given in table II. Values for foods in the United States also are given for comparison.

TABLE II. SUMMARY OF FOREIGN FOOD ANALYSES

[United States food values included for comparison]

LOCATION, DATE AND TYPES OF FOODS COLLECTED	STRONTIUM UNITS [1]	LOCATION, DATE AND TYPES OF FOODS COLLECTED	STRONTIUM UNITS [1]
	(μμ curies per gram of calcium)		*(μμ curies per gram of calcium)*
Ankara, Turkey, April-June, 1957 (wheat, wheat products, beans, milk products).	1 to 5.	United States, coast to coast 1957,[3] (vegetables, cereals, liquid and powdered milk).	1 to 29. 4 to 23. 3 to 10.
Philippine Islands, February-March, 1957 (legumes, cereals, vegetables, fruit, meat, fish, eggs, coconut, rice, evaporated milk).	4 to 12.	Perry, N. Y.,[4] January-August 1957 (powdered milk).	3 to 4.7.
		New York City, January-August 1957 (liquid milk).	3 to 6.5.
Libya, June-July 1957 (meat, fish, bread, vegetables, cereal, evaporated milk).	[2].	Mandan, N. Dak., January-July 1957 (powdered buttermilk).	4 to 17.
		Ithaca, N. Y., July 1957 (cabbage, beans).	23. 6.

[1] Strontium units correspond to the former terminology, "Sunshine Units."

[2] Data inadequate to convert to strontium units. The *minium* range of values would be 5-29 strontium units (calcium content assumed to 0.10, the maximum value given); if the calcium content is lower, the range would be higher.

[3] Taken from the manuscript, "Current Strontium 90 Level in United States Diet," J. L. Kulp.

[4] Values for Perry, N. Y., Ithaca, N. Y., and Mandan, N. Dak., are determinations by the Health and Safety Laboratory, New York.

Some Research Programs on Strontium 90

In addition to its sampling and monitoring program, the Commission describes in this report some of the research it supports into the effects of strontium 90 on man and his environment, on the distribution, uptake, accumulation and eventual deposition in bone of strontium 90, and on methods of removing it from biological materials and from the soil. The earlier section dealing with the Effects of Internal Radiation reports on other related research projects.

Toxicity of strontium 90 in rats and monkeys. Investigators at the University of Rochester, conducting a systematic study of the effects of strontium 90 upon life span and incidence of bone cancers, give rats of varying ages radiostrontium in their drinking water. The concentrations are many times greater than those expected from fallout

either from nuclear tests or from nuclear warfare. Experiments are incomplete, but findings thus far suggest that adult rats may carry a body burden of 1 microcurie of radiostrontium for as long as 21 months without marked shortening of life, or significant increase in occurrence of bone cancer.

The 1 microcurie body burden of strontium 90 delivered approximately 1,200 *rads* [57] to the skeleton of the rat. A body burden of 1 microcurie of strontium 90 in the human being, the so-called Maximum Permissible Concentration, would deliver approximately 150 *rads* to the human skeleton in 50 years.

Other experiments have shown that a body burden of 15 microcuries or more of strontium 90 in the rat is necessary to produce a significant incidence of bone cancers among the test animals in about 1 year. The radiation dose to the skeleton in these cases is on the order of 5,000 to 7,000 *rads*.

Similar studies also are in progress with monkeys.

Ecological Studies

White Oak Lake bed. Ecological studies have been conducted at Oak Ridge National Laboratory in the contaminated White Oak Lake bed, for 12 years an area for impoundment of radiactive waste. Because of this history, it is a unique tract of land and contains more of the fission products strontium 90 and cesium 137 than any land now known. Average concentrations of radiostrontium are about 400 millicuries an acre; radiocesium ranges up to 20 curies an acre. In addition, there are significant concentrations of cobalt 60, ruthenium 106, cerium 144 and rare earths with a total average radiation level above 0.5 roentgen a day. Distribution and uptake of these fission products by both natural and cultivated vegetation can be studied in this environment, as can the long-term effects of low-level radiation on plant and animal populations.

During the past year, the complex soil system has been further analyzed, the natural flora and fauna developing on the lake bed have been characterized and the concentrations determined for strontium 90 and cesium 137 in the soil, in the natural vegetation, and in corn.

First results of the corn analyses indicated that concentrations of cesium 137 may differ between the various plant organs. The ratios of cesium 137 to potassium, an element employed similarly by the plant, indicated a considerable discrimination by the plant against taking up cesium 137. Preliminary analyses of strontium 90 and calcium concentrations indicated the plants discriminated less against

[57] *Rad.* One hundred ergs of absorbed energy per gram of absorbing material.

strontium than against cesium. The evidence also indicated the highest concentrations were found in the leaves.

Several species of mammals have been trapped on the lake bed. Since they undergo external exposure to radiation and also ingest contaminated food materials, the animals offer an opportunity to obtain information on long-term effects.

Hanford. For ecological studies in the Hanford environs, a simulated natural pond was constructed as an initial experiment of a new research group. Cesium 137 was added to the pond, and its dissipation was studied. From work of this type it may be possible to determine types of organisms which will take up the greatest amounts of various isotopes and thus serve as indicators of contamination levels and as guides in evaluating potential hazards.

Studies of Fallout Patterns

The Atomic Energy Project at the University of California at Los Angeles conducted studies during Operation *Plumbbob* at the Nevada Test Site to (*a*) delineate fallout patterns of devices greater than 10 kilotons in yield with respect to radiation intensities and particle sizes, (*b*) characterize fallout material with respect to beta and gamma radiation characteristics and physical, chemical, and radiochemical properties, (*c*) determine the environmental persistence of fallout in selected areas, and the accumulation of radioisotopes by native animals collected from these selected contaminated areas, (*d*) measure the radioactivity level of Nevada and Utah agricultural areas and their produce by sampling before and after the Plumbbob series, and (*e*) train participating personnel in assessing environmental contamination.

The groups who participated, totaling approximately 190, included university student employees, veterinarians from the United States Air Force and the United States Department of Agriculture, and technically trained staff of the United States Food and Drug Administration, the Federal Civil Defense Administration, the United States Geological Survey, and Atomic Energy Commission contractors.

Gamma radiation levels of fallout patterns were determined by aircraft using techniques of the United States Geological Survey and the Commission's raw materials exploration group, and by mobile ground teams. Cross checking of the aerial values corrected for height above the surface, and the ground monitor's readings, showed an agreement generally within plus or minus 15 percent.

The fallout patterns of 7 tower-supported and 3-balloon-supported detonations were delineated to distances ranging from 100 to 600 miles from ground zero and, at the greater distances, fallout was timed for 12 hours after detonation. Up to 12 hours, balloon-supported shots appeared to produce at these distances less than 10 percent as much fallout as did tower-supported shots of equivalent yield and detonation height. It was estimated that 10 to 30 percent of the total radioactivity produced by tower-supported shots was accounted for by these measurements.

Particle size analysis indicated that tower-supported shots produced much greater amounts of fallout than did balloon-supported shots in size ranges greater than 44 microns in diameter. In many locations most of the radioactive particles from balloon-supported shots were less than 5 microns in diameter.

Biological availability of fallout was tested by solubility of fallout material in dilute hydrochloric acid and in water. Fallout material from tower-supported shots was soluble on the order of 7 percent in hydrochloric acid and 1 percent in water. The solubilities of fallout material from balloon-supported shots were of the order of 70 percent in hydrochloric acid and 15 percent in water.

Gamma measurements based upon both prelocated field monitoring instruments and laboratory analyses showed some deviations from the predicted rates of decay. In cases where variations occurred, the radiological decay occurred somewhat more rapidly for fallout that occurred at early times after a detonation, and more slowly for later fallout. Beta decay measurements more closely approximated the predicted rates.

The accumulation of fission products by native rodents trapped in various locations within fallout patterns was documented for five detonations during Plumbbob to define the factors influencing biological accumulation of radioactive fallout. The data showed a marked similarity in the patterns of biological accumulation related to the time of arrival of fallout. Maximum mixed fission product accumulation in the animal tended to occur at places which fallout reached 2 to 3 hours after detonation, but concentrations in all tissues decreased at sites which fallout reached 3 to 12 hours after detonation. The rate of decrease was rapid for the 2- to 5-hour area. In the case of the several tower-supported detonations studied, fission product concentrations remained more or less uniform between 5- and 14-hour areas. For the single balloon-supported detonation documented by radioactivity in native rodents, the rate of decrease was approximately constant between 2 and 12 hours.

Nuclear Materials Management

Standard Reference Materials

On January 8, the Committee for Uranium Isotopic Standards was reconstituted as the Advisory Committee for Standard Reference Materials and Methods of Measurement to reflect the broadened scope of its activities (see app. 2). The committee reviews, evaluates and recommends means for providing standard reference materials (i. e., certified chemical and isotopic standards for uranium, plutonium, etc.) and approved methods of measurement for materials of special importance to atomic energy activities.

Continuing plans to provide uranium isotopic standards through the joint efforts of the Commission and the National Bureau of Standards, the first nine of a series of 15 provisional uranium isotopic standards were shipped to the Bureau. This series, enriched in uranium 235 in a range from 0.5 weight percent to 93 weight percent will be evaluated by the Bureau before their distribution as provisional standards.

Analytical facilities for handling plutonium were being prepared at the Commission's New Brunswick Laboratory. In addition to development of methods of measurement and general analytical work, the laboratory will study the characteristics of plutonium compounds for use as standard reference materials.

Peaceful Uses of Atomic Energy

Domestic. The annual meeting of Commission and contractor personnel concerned with materials management was held at Commission headquarters the week of May 19. Four panel discussions were held and some 20 papers presented. Approximately 200 attended.

A symposium on "Reactor Fuel Measurements Techniques" was held at Michigan State University, East Lansing, Mich., on June 18–20. The 25 papers presented covered such problems as sampling of fuel alloy melt, nondestructive analysis of fuel elements, and chemical analysis of fuel alloys and homogeneous slurries for major constituents. Both contractor personnel and access permit holders attended the meeting.

Foreign. An information manual outlining the principles of source and special nuclear materials control followed by the Commission and its contractors has been prepared and is available for distribution to foreign nations which have entered into agreements for cooperation with the United States.

Construction and Supply

Construction

Costs incurred by the Commission for new plant and equipment during the 6-month period ended June 30 were estimated to be about $145 million. Total costs for the fiscal year preceding June 30, approximated $285 million, down 10 percent from the levels of the previous year.

Adverse weather during the winter months hampered construction activity at various Commission installations, but no serious delays in schedules resulted.

Reserve Construction Equipment Pools

When major construction programs under the Oak Ridge, Hanford, and Savannah River Operations Offices neared completion in the fall of 1955, some earth-moving equipment and tractors not immediately needed were set aside for future routine or emergency use. This construction equipment had been used on one or more major projects but still was in reasonably good condition and, in the event of a national emergency, would be difficult to duplicate readily. For this reason, and because Commission production facilities and equipment must be promptly available in a national emergency, the Commission established reserve equipment pools for Oak Ridge, Hanford, and Savannah River Operations Offices, and selected for the pools by June 30, 1957, equipment having an acquisition value of approximately $7.6 million.

In addition to providing an emergency reserve, the Commission achieved significant savings. About $4.6 million worth (acquisition value) of equipment of the type pooled was used in other Commission activities, avoiding new procurement.

Identification Marking of Metals

The Commission has instituted a policy requiring marking of metal products under a standard system of identification established by the Department of Defense. The Commission recognized that it needed a standard marking system which would positively identify metal products from point of origin to scrap heap. The Department of Defense, with the help of the metals industry and the support of the Commission, developed a "continuous" marking method by which all identification data are indelibly printed repetitively over the entire length of material. The system is prescribed by a series of bulletins,

Military Standards 182, "Continuous Identification Marking of Nickel and Nickel Base Alloys," 183, "Continuous Identification Marking of Iron and Steel Products," and 184 "Identification Marking of Aluminum, Magnesium, and Titanium."

The Commission expects that its use of the military standards will tend to eliminate (*a*) accumulations of metals insufficiently identified for critical uses, (*b*) expensive projects to establish lost identities of materials, and (*c*) mistakes in materials used.

Small Business

Maximum practicable small business participation in Commission prime contracts and subcontracts continued to receive emphasis at each Commission operations office and by each cost-type contractor purchasing office, consistent with the Congressional statement of public policy "that a fair proportion of the total purchases and contracts for supplies and services for the Government be placed with small business enterprises" (Small Business Act of 1953, amended).

A large part of the Commission's subcontract dollars, as in previous years, were awarded to small business. During the 9 months ended March 31, out of a total of $414 million of subcontracts, $155 million, or 37.5 percent, were awarded to small business. By comparison, the subcontract awards to small business during the fiscal years 1951 to March 31 of this year were $1.574 billion, or 39.5 percent, out of a total of $3.982 billion. Direct contract awards to small business during the same period amounted to $404 million, or 3.7 percent, out of a total of $10.794 billion.

Mobilization Planning

Under authority of the Office of Defense Mobilization (ODM), the Commission formulated policies and procedures to employ the DX Program rating, affording superior priority, to obtain preferential delivery of products and materials required for selected missiles programs. For other programs, the Commission continued to use the original DO rating authority delegated to it in 1951.

The Commission assisted in planning for all phases of Operation Alert 1958 and actively participated in the attack phase held during May. The Commission completed plans for participation in the exercises scheduled for July and September, and continued to cooperate with ODM in various other readiness programs.

Community Activities

Oak Ridge and Richland

As of the end of June, the status of property sales at Oak Ridge, Tenn., and Richland, Wash., was as follows:

Kind of Property	OAK RIDGE				RICHLAND			
	DEC. 31, 1957		JUNE 30, 1957		DEC. 31, 1958		JUNE 30, 1958	
	Units offered	Percent sold	Units offered	Percent sold	Units offered	Percent sold	Units offered	Percent sold
Single and duplex houses	4,360	98	4,360	98	2,220	43	4,806	54
Residential lots	1,422	20	1,577	33	228	19	246	24
Commercial properties	102	68	103	80	---	---	---	---
Nonprofit properties	1	100	31	48	---	---	---	---

The Housing and Home Finance Agency offered thirty 4-family apartment buildings for sale at Oak Ridge in early May, and 84 bids were received for them.

Renegotiation of leases on commercial property, permitted by recent legislation,[58] has been completed at Oak Ridge. Eighty-nine applications for renegotiation are being reviewed at Richland.

Self-government. The *Oak Ridge* Town Council is studying a report prepared by the Public Administration Service which recommended that a referendum be held in the spring of 1959 on the issues of incorporation and transfer of municipal facilities. A decision may be sought by referendum on whether the new 175-bed hospital, being built by the Government at a cost of $2.9 million, should be transferred to the new incorporated municipality or to a private group. The hospital is scheduled to be completed by May 1960.

The Town Council also is studying the recommendations of a report made by Midwest Research Institute on the industrial potential at Oak Ridge.

At *Richland,* the Benton County Commissioners set July 15 as the date for a referendum on incorporation. Fifteen freeholders also will be elected at that time under a mandate to write a city charter within 70 days. Discussions were held with the Richland school district on terms and conditions for transfer of government-built school facilities to the district and for financial assistance. Transfer of the school facilities may take place during the next reporting period.

[58] Public Law 85-162, August 21, 1957, amending sec. 161e of the Atomic Energy Act of 1954 and sec. 35 of Atomic Energy Community Act of 1955.

Los Alamos

Plans have been approved for subdivision of land on Barranca Mesa for sale of residential building-sites to project personnel for private construction of homes. Sales contracts have been executed with a sufficiently large group to assure the economic feasibility of the project; contracts for construction of streets and utilities have been let. It is expected that these land improvements will be completed by December, with some private home construction going on concurrently with these improvements.

The Los Alamos Area Office is modifying existing housing by adding bedrooms and baths to provide more adequate homes for senior project personnel, for which $1 million has been made available for this first program of additions.

New Headquarters

Headquarters of the Atomic Energy Commission was moved to the new building at Germantown, Md., 27 miles northwest of Washington, D.C., on schedule during the second and third weeks of January.

Pending completion of an additional wing [59] to the new building at Germantown, some headquarters offices remained in Washington at 1717 H Street NW. As of June 30, the new wing was 75 percent completed. The offices temporarily in Washington included the Division of Raw Materials, the Division of Security, the Isotopes Branch of the Division of Licensing and Regulation, the Patent Branch of the Office of General Counsel, and the Office of International Conference.

An office and a public document room will be maintained in Washington, D. C., at 1717 H Street NW., for the service of process and papers, and to facilitate Commission business with the public, the Congress, and other Government agencies.

Organization and Personnel

Personnel Changes

During the January–June reporting period, the following major personnel changes took place:

The term of Lewis L. Strauss, Chairman of the Commission, expired on June 30.

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[59] Authorized July 17, 1957, Public Law 85-107. See p. 301, Twenty-third Semiannual Report to Congress; July–December 1957).

John A. McCone, of California, was sworn in as Commissioner and appointed Chairman of the Commission on July 14. His term runs to June 30, 1963. Mr. McCone's nomination was sent to the Senate on June 6, and he was confirmed July 9.

K. E. Fields resigned as General Manager, effective June 30.

Maj. Gen. Alvin R. Luedecke, United States Air Force, was selected as General Manager, the appointment to be effective after the conclusion of the 1958 weapons tests during which he is commander of the Joint Task Force.

Paul F. Foster, Assistant General Manager for International Activities, was designated effective July 1 to serve as General Manager until General Luedecke assumes the office.

R. W. Cook resigned as Deputy General Manager, effective no later than the adjournment of the current session of Congress.

John A. Hall, Director, Division of International Affairs, was designated as Acting Assistant General Manager for International Activities, effective July 1.

Allen J. Vander Weyden, Deputy Director, was designated as Acting Director, Division of International Affairs, effective July 1.

Loren K. Olson was appointed General Counsel, effective March 19.

John H. Williams was appointed Director, Division of Research, effective April 17.

W. Kenneth Davis resigned as Director, Division of Reactor Development, effective July 31.

Lawton D. Geiger, formerly Area Manager, Pittsburgh Area Office, was appointed Manager, Pittsburgh Naval Reactors Operations Office, effective March 15.

Jon Anderson, formerly Manager, Schenectady Operations Office, was confirmed as Manager, Schenectady Naval Reactors Operations Office, effective March 15.

Enzi De Renzis, formerly Assistant Deputy Manager, New York Operations Office, was appointed Area Manager, Princeton Area Office, effective April 1.

Henry A. Nowak, formerly Area Manager, Buffalo Area Office, was appointed Area Manager, Pinellas Area Office, effective March 24.

Harry H. Gorman, formerly Deputy Assistant Director for Administration, Division of Reactor Development, was appointed Manager Lockland Aircraft Reactors Operations Office, effective July.

Organization

Organizational changes. The Pittsburgh Area Office, formerly under the supervision of the Chicago Operations Office, was established as the Pittsburgh Naval Reactors Operations Office, effective

March 15. The Pittsburgh Naval Reactors Operations Office reports to the Chief, Naval Reactors Branch, Division of Reactor Development, to whom supervisory authority has been delegated by the Director, Division of Reactor Development.

The Schenectady Operations Office was redesignated as the Schenectady Naval Reactors Operations Office, effective July 1, and also reports to the Chief, Naval Reactors Branch, Division of Reactor Development.

The Pittsburgh office administers the contract with the Westinghouse Electric Corp., for operation of the Bettis Plant which is working on naval propulsion reactors, and with the Duquesne Light Co., for operation of the Shippingport Atomic Power Station, and related contracts in the naval reactors program. Contracts administered by the Schenectady office include those with General Electric Co., for the operation of Knolls Atomic Power Laboratory and with Combustion Engineering Co., for construction of a small submarine reactor test facility.

All non-Naval Reactors Branch activities at the Pittsburgh and Schenectady offices have been transferred to the New York Operations Office. New York thereby assumed responsibility for administration of access permits and other civilian application activities previously assigned to Pittsburgh and Schenectady.

The Lockland Area Office, previously under the supervision of the Chicago Operations Office, became the Lockland Aircraft Reactors Operations Office, effective July 1 reporting to the Chief, Aircraft Reactors Branch, Division of Reactor Development, to whom supervisory authority has been delegated by the Director, Division of Reactor Development. The Hartford Area Office, formerly under the Chicago Operations Office now reports to the Lockland office. The Lockland office administers contracts with General Electric and Pratt and Whitney Co., for development of aircraft reactors.

An area office was established at Princeton University, Princeton, N. J., effective April 1, under supervision of the New York operations Office, to administer research and development and construction contracts in connection with the controlled thermonuclear and other research programs.

Study of Commission organization. The Commission completed during this reporting period a comprehensive review of its organization. The study was initiated by Chairman Strauss in order to evaluate the effectiveness of existing organization in the light of added and evolving duties of the Commission.

The review was conducted by a small task force in the General Manager's office with the assistance of other Commission headquarters

and field personnel. A large number of individuals was consulted on the basis of their special knowledge of the problems of the Commission, including former Commissioners, scientists, industrialists, military officials, and present and former executive officials of the Commission.

The report on the study, with recommendations, was made to the Commissioners in late April. Action on major recommendations requiring consideration and approval by the Commissioners was deferred at the request of the retiring Chairman until his successor takes office.

History of the Commission. The Commission established an Historical Advisory Committee of outstanding historians, scientists, and public administrators to advise the Commission on preparation of an official history of the Commission. The committee met during June to discuss plans with the Commission.

The Chairman of the new advisory committee is Dr. James P. Baxter III, president of Williams College, Williamstown, Mass. Dr. Baxter, formerly a professor of history at Harvard University, was until 1957 chairman of the Army's advisory committee on the history of the Army ground forces in World War II. His book, *Scientists Against Time*, a history of the wartime Office of Scientific Research and Development, won the Pulitzer Prize in 1947.

Other members appointed to the committee are Dr. Glenn T. Seaborg, professor of chemistry at the University of California, Berkeley; Dr. Arthur H. Compton, distinguished service professor of natural philosophy at Washington University, St. Louis; Rear Admiral Samuel E. Morison, historian of U. S. Naval Operations in World War II; Don K. Price, Jr., vice president of the Ford Foundation, New York; and Dr. James L. Cate, professor of history at the University of Chicago.

The Commission history will be written by a small group of professional historians on the Commission's staff, under the direction of Dr. Richard G. Hewlett.

Commission and Contractor Employment

Contractor employment, totaling 110,359 in December 1957, rose to 113,355 in April of this reporting period: 103,090 in operating activities; 10,265 in construction and design work. Operating contractor employment continued to increase, but the rate of growth is less than it was prior to 1957. Of the approximate 4,000 increase in operating contractor employment since December 1957, the largest gains were in the research and development and weapons programs.

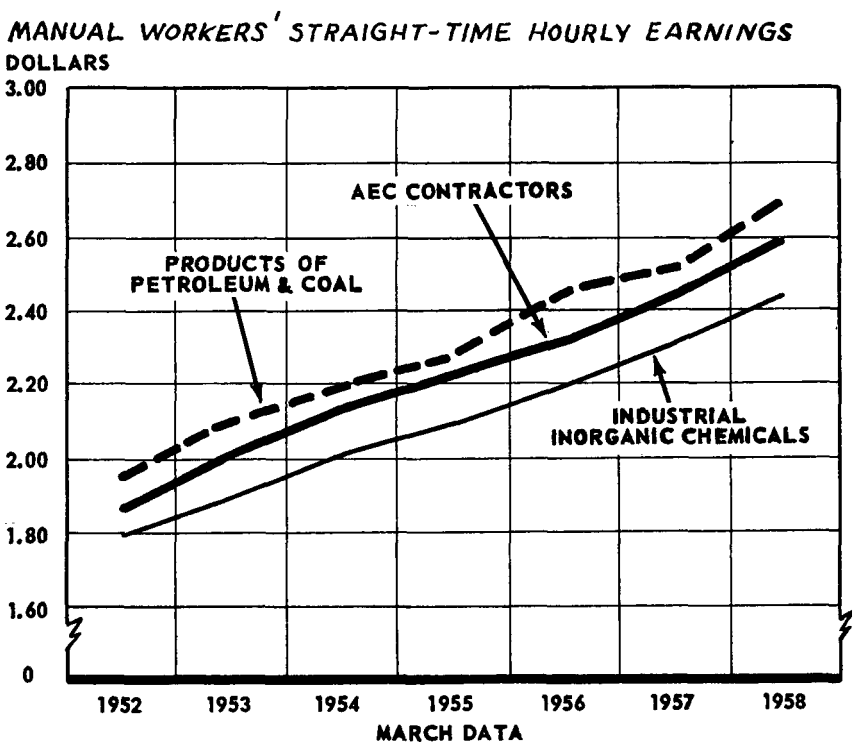
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Construction and design employment declined about 1,000 between December and April continuing the trend of the preceding 12 months, and reflecting decreased construction activity except at weapons test sites.

Commission Federal employment totaled 6,820 on April 30. Except for an increase due to temporary summer employment in 1957, the level has been fairly constant. The ratio of Commission Federal employment to operating contractor employment declined to 1 to 15.1 in April as compared to 1 to 14.5 for 1957, 1 to 8.4 at the time of the 1952 expansion and 1 to 7.8 for 1957.

Operating Contractor Employee Earnings

Manual (hourly) employees comprising nearly one-half of total operating contractor employment received an average of $2.58 in straight time hourly earnings during March. This average falls between similar March averages of $2.42 for industrial inorganic chemical industries and $2.68 for products of petroleum and coal industries. This continues the trend that prevailed since 1952. (See chart—Manual Workers Straight-time Hourly Earnings.)



Labor-Management Relations

A 24-day strike between the Zia Co., and 10 labor unions representing some 550 maintenance and service employees beginning April 8 and ending May 12 occurred when the parties could not reach agreement on new labor contracts. Negotiations were complicated by a general State-wide dispute in the construction industry involving several crafts directly associated with Los Alamos Constructors, Inc., a subsidiary of Zia.

Demands made by the unions included a 2-year contract calling for a substantial wage increase each year.

Settlements were reached with four of the basic crafts on April 21 and with the remaining unions on May 10. By May 19, full work schedules had been resumed. Final settlements included total wage increases for 2-year contracts ranging from 18 cents an hour for laborers and teamsters to 32 cents an hour for electricians, plumbers, and sheetmetal workers.

Operations at the Los Alamos Scientific Laboratory were not seriously affected by the strike as emergency crews continued to maintain essential services throughout the stoppage.

Work stoppages on construction activities caused a loss of 10,897 man-hours during the first 5 months of 1958, which equaled 0.1 percent of scheduled construction hours. This 5-month average is considerably under the 0.7 percent reported for the same period last year. The Commission's annual construction lost time rate of 0.8 percent for 1957 was the lowest since these statistics were first collected in 1952.

In Commission maintenance and service activities, the work stoppages lost-time rate for January through May was 3.7 percent, due entirely to the Zia strike. This compares to a lost-time rate of 0.7 percent for the same period last year.

There were no work stoppages in operating activities during the first 5 months of 1958. The annual lost-time rate for operating activities in 1957 was 0.4 percent.

Safety and Fire Protection

Presidential award. In June, the Atomic Energy Commission received one of the two awards given by the President for excellence in Federal employee accident prevention programs. One large and one small agency receive the citation annually. The U. S. Army was selected to receive the other 1957 award.

Over the past five years the average rate of injury to Commission employees was below that of its contractors. The injury rate for

Commission and contractor employees combined reached an all-time low during 1957, when the rate of lost-time injuries per million manhours for the total program was 25 percent below 1956.

LOST-TIME INJURIES PER MILLION MANHOURS

ACTIVITY	1957	1956	DECREASE
			(*Percent*)
Operation	1.75	2.13	18
Production	1.29	1.80	
Research	1.80	2.34	
Services	5.65	3.86	
Construction	3.92	6.32	38
Architect-engineers	.00	.00	
Cost-plus contractors	3.02	5.75	
Lump-sum contractors	7.45	10.89	
AEC (Government) employees	1.42	1.88	24
All operations	1.96	2.63	25

Industrial accidents. Five fatal occupational accidents occurred during 1957 compared with eight in 1956, a rate of 4.26 fatalities per 100,000 employees compared with the National Safety Council's all-industry average of 23.

DATE (1957)	LOCATION	NO. PERSONS	NATURE OF INCIDENT
Jan. 29	Pike County, Ohio, construction job.	1	Electrocuted while engaged in moving equipment on wet floor.
Mar. 11	Pike County, Ohio, construction job.	1	Electrocuted when boom of crane came in contact with overhead powerline.
June 22	Nevada Test Site	1	Driver turned car over on curve.
Aug. 1	Big Horn County, Mont.	1 AEC 1 Non-AEC	Aircraft accident.
Dec. 4	Savannah River Plant	1	Car crashed into rear of a plant railroad engine.

Lost-time injuries. There were 433 disabling work injuries in all operations during 1957, compared with 527 in 1956. Only one was a radiation injury, which occurred at Rocky Flats, Colo., June 14, 1957, as a result of a chemical explosion.

NATURE OF INJURY	NUMBER	PERCENT	NATURE OF INJURY	NUMBER	PERCENT
Amputation	14	3.4	Foreign body (hand)	2	.4
Asphyxiation	1	.2	Fracture	100	23.0
Bruise; contusion; abrasion	60	13.0	Hernia	3	.6
Burn (except chemical)	26	6.0	Infection	11	3.0
Burn (chemical)	11	3.0	Radiological exposure	1	.2
Cut; laceration	95	22.0	Strain or sprain	83	19.0
Dermatitis	5	1.1			
Electric shock	5	1.1	Total	433	100
Foreign body (in eye)	16	4.0			

Radiation incidents. This tabulation is taken from reports of 12 radiation incidents occurring in Commission installations during 1957. The incidents were known to have involved 26 persons but did not necessarily result in injury.

Date	Location	Number persons involved
Jan. 4, 1957	SANTA SUSANA, CALIF. High level volatile activity was observed in a KEWB reactor building. Personnel exposure was nil.	1
Jan, 31, 1957	ARGONNE NATIONAL LABORATORY. An employee was exposed to radiation during experimental work with strontium 90 on rats.	1
Feb. 12, 1957	LOS ALAMOS SCIENTIFIC LABORATORY. A fissionable material assembly (Godiva) remotely operated, produced a neutron burst greater than intended, resulting in a rupture of the assembly. No one was exposed.	0
Apr. 22, 1957	HANFORD WORKS. A maintenance man was exposed to plutonium nitrate (left thumb and index finger contaminated, 0.15 microcuries) while he was unplugging a tank.	1
May 11, 1957	NATIONAL REACTOR TESTING STATION. Employees were exposed to airborne iodine 131 while installing new equipment in a processing cell. Level of activity in cell was 12×10^{-9} millicuries per millilitre. Urine samples were collected daily from the men. An effective half-life for elimination of the material for the highest exposure was found to be about 5.5 days.	16
May 18, 1957	LOS ALAMOS SCIENTIFIC LABORATORY. Strontium 90 was spilled on a laboratory floor and was tracked to auto and home by employee. 15 milliroentgens at hour levels were found in spots in auto and apartment; 2 milliroentgens per hour levels were found in the home. No health hazard was created and no one was exposed to significant amounts of radioactive material.	1
June 14, 1957	ROCKY FLATS, COLO., PLANT. Two men were injured by an explosion while performing a routine operation inside a sealed dry box. One employee had surgical amputation of 5/16 inch of bone from the right little finger. The other had 0.4 microgram of plutonium deposited in an abrasion wound on the face.	2
June 27, 1957	UNIVERSITY OF CALIFORNIA RADIATION LABORATORY, BERKELEY. An employee received a 1,000 to 2,000 roentgen dose to his hand while working in a glove box with about 85 millicuries of strontium 90 contained in a centrifuge tube.	1
Aug. 5, 1957	ARGONNE NATIONAL LABORATORY. Release of radioactive steam	0
Aug. 16, 1957	UNIVERSITY OF CALIFORNIA, LASL PLANT. An explosion occurred in a room of glove boxes, devices in which personnel work by placing their hands in sealed-in gloves. The employees present were exposed to a plutonium contaminated dust and received less than 1 percent of the maximum permissible body burden.	2
Sept. 11, 1957	ROCKY FLATS, COLO. PLANT. A small amount of metallic plutonium spontaneously ignited and transmitted fire to the plastic structure of the dry box in which it was stored.	0
Oct. 4, 1957	OAK RIDGE NATIONAL LABORATORY. An employee mistakenly entered a room containing radioactive material and was exposed for about one minute to a level of 49 roentgens.	1

Nuclear incident at Oak Ridge. An accidental nuclear excursion occurred in a salvage area at the Y–12 plant at Oak Ridge, Tenn., on June 16.[60] The inadvertent transfer of a solution of highly enriched uranium from a container of "always safe" configuration to one not so designed caused a chain-reacting critical mass to be achieved. The

[60] Text of press releases on the Oak Ridge incident is given in Appendix 16.

resulting radioactivity set off the alarm system and the plant was evacuated. Except for the immediate area in which the accident occurred, the building was reoccupied within four hours. There was no contamination by radioactive fission products, but some radioactivity was induced by neutrons. All areas were returned to operation by June 23.

Eight employees were in the vicinity of the accident and were subjected to radiation of varying degrees. Estimates indicate that 5 were exposed to from approximately 200 rad to 320 rad and showed early definite depressing effects on the white blood cells. Later three of them experienced a further drop in certain other blood elements. This second drop occurred later than expected, and the delay is regarded as a generally favorable sign. The other 3 were exposed to a considerably lesser degree and have shown no symptoms of radiation effect.

All 8 persons were placed under observation at the Oak Ridge Institute of Nuclear Studies Medical Division Hospital at Oak Ridge. The three men who received the lowest exposures were released from the hospital June 26. The other 5 are in the hospital but are not confined to their beds.

Fire, explosion, and property damage. Aggregate property damage losses for the Commission during 1957 amounted to $649,811 or $0.008 for each $100 of Federal property, a loss rate comparing favorably with private industry experience. Almost 70 percent of the loss resulted from fire in a process building at Rocky Flats on September 11, 1957.

The Rocky Flats fire was triggered by spontaneous ignition of plutonium.

The long range study of combustible and explosive properties of metals continued at Argonne National Laboratories and at the Bureau of Mines in Pittsburgh. One hazard of related fire losses is being eliminated. Air used to ventilate areas containing radioactive materials generally is filtered before discharge to the atmosphere. Until recently combustible filters were widely used for this purpose. After serious fires in large filter banks, noncombustible filters were developed and purchase specifications for them have been prepared and distributed.

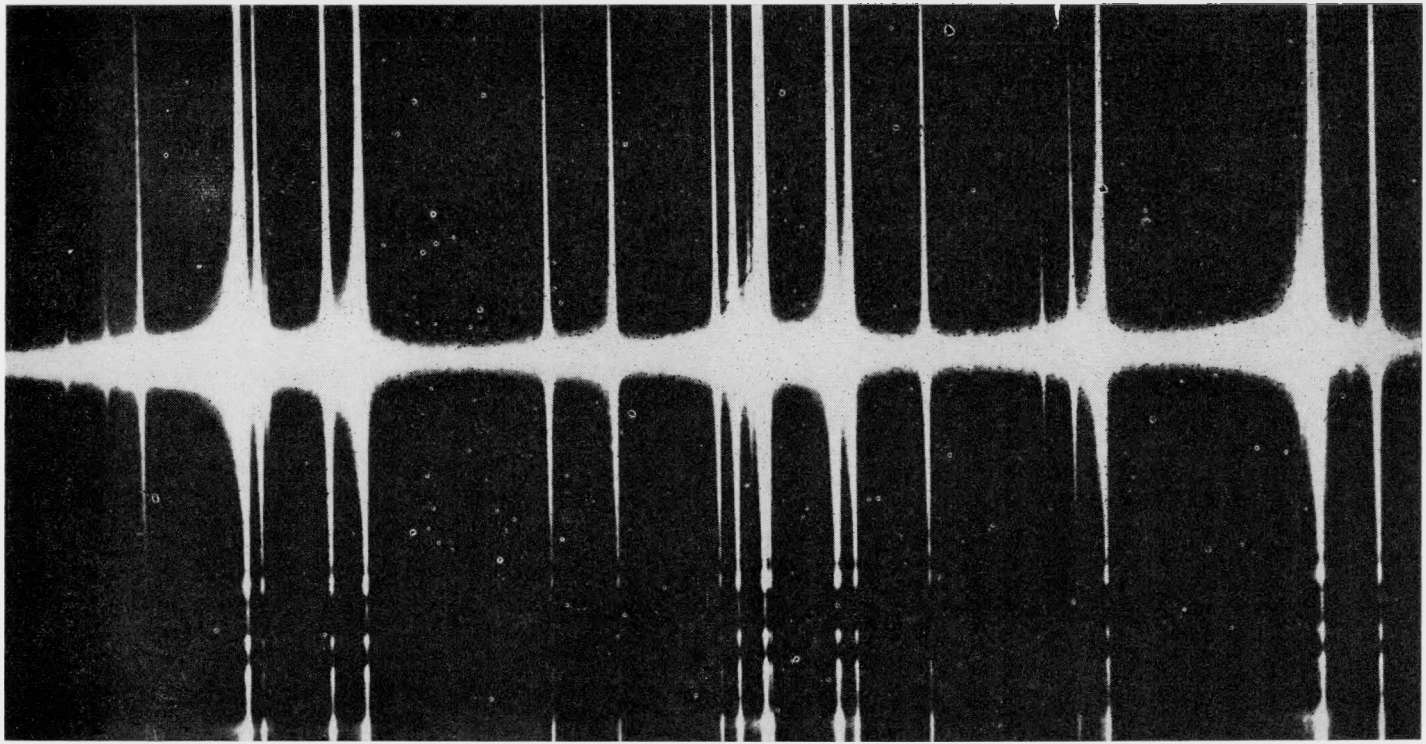
In 1955, nearly 50 percent of property damage losses of a type peculiar to nuclear facilities resulted from spontaneous metal fire incidents. In 1956, 3 of the 8 fatalities suffered in Commission facilities resulted from explosion of metal used principally in the nuclear field.

Safety performance awards. Twenty-eight awards of merit and 13 awards of honor were made to Commission contractors and operations offices during 1957. Among the awards of honor was one presented to General Electric Co. on an Aircraft Nuclear Propulsion Project, Lockland, Ohio, for a new all-time Commission record of 11,175,509 injury-free man-hours from January 1, 1953, to February 1957.

Twenty-two contractors and seven Commission offices will receive the General Manager's Commendation for 200,000 or more injury-free man-hours.

Part Two

Progress Toward Producing Power From Controlled Fusion



A thermonuclear experiment. Spectrograph of a controlled thermonuclear experiment at Los Alamos Scientific Laboratory on what is called the "pinch approach," which through compression of the gas increases temperature and pressure. The increase is shown by the thickening of the central line of the spectrograph study of a xenon gas pinch in a device called a Perhapsatron.

I

THE COMMISSION PROGRAM OF CONTROLLED THERMONUCLEAR RESEARCH

Atomic energy scientists have made steady progress in their efforts to achieve sustained, controlled thermonuclear reactions. The release of energy through fusion of atomic nuclei may ultimately be used to generate useful quantities of economically produced electricity. However, this remains a very long-range prospect.

Results of portions of the Atomic Energy Commission's program in this field, inaugurated in 1951 and accelerating since 1953, were announced during the January–June period covered by this report, described in technical terms in the scientific literature, and reported to the Joint Committee on Atomic Energy, and separately to the Congress.[1] The problems and published results have been explained in press conferences, and in addresses and papers by the Chairman, the Commissioners and other officers of the Commission and of Commission laboratories.

Progress of Research

In connection with publication of a group of papers in this country and in the United Kingdom, Chairman Lewis L. Strauss told a press conference on January 24, "Today's announcements make it clear that fruitful and promising results have been achieved in the laboratories of both countries, but we should not expect early harnessing of fusion for the production of power."

The promise which the scientists, the Commission, and the Congress see in this field is evidenced by the fact that, from quite low levels of effort in 1953, the scientific manpower and the funds committed to this purpose have increased on the order of 1,000 percent.

The progress made cannot yet be measured in terms of the attainment of major goals, but important results have been won:

Scientists believe they have formulated promising methods of attack on the problems of controlled thermonuclear reactions.

[1] See pp. 96–105, Twenty-second Semiannual Report to Congress (January–June 1957).

Research staffs have gained broad understanding of the physical conditions which must be achieved, in order to realize net power from fusion, and have acquired better working knowledge of the physical processes and phenomena involved.

Improvements are continually being made in the laboratory devices, the experimental machines, to increase their capabilities of raising fusion materials to the extremely high temperatures that are necessary and to confine them at those temperatures.

More advanced apparatus is being designed or is under construction.

The prospects of power from nuclear fusion are sufficient to warrant a continuation of the expanding research and development program. A number of extremely difficult problems must be solved in order to reach the ultimate objective. A whole new technology is being created.

In all four major laboratories at work on the program—Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, Princeton University, and the University of California Radiation Laboratory—there has been steady progress. They are exploring a number of different methods of attack, which are described later in this special report, and so far no unsurmountable obstacles have appeared. Significant progress has been made in each of the several lines of effort; each is contributing to knowledge and to the new technology.

There is general optimism about reaching what is called ignition temperature, that is, a self-sustaining controlled thermonuclear reaction. When that point is reached, the effort to produce net fusion power will have attained a stage comparable to that reached in the use of fission on December 2, 1942—the date when Enrico Fermi and his colleagues first demonstrated a self-sustaining fission chain reaction.

Benefits of Fusion Power

Assuming that some day a fusion reactor fueled with heavy hydrogen can be operated successfully, it may be expected to have the following advantages:

(*a*) *The fuel costs would be extremely low.* At present, deuterium (heavy hydrogen) costs about $140 a pound to produce. If its nuclear energy content could be converted completely into electrical energy, a pound of deuterium could yield 40,000,000 kilowatt-hours of electricity. The gross fuel cost would be only 0.0035 mills per kilowatt-hour. This figure does not, of course,

consider the operating efficiencies of the powerplant, or the capital costs of the reactor which may be considerable.

(*b*) *The fuel supply would be virtually unlimited.* Heavy hydrogen exists in all surface waters of the world—the total of this deuterium is estimated at one hundred thousand million, million (10^{17}) pounds. Complete fusion of this quantity of deuterium would produce one thousand million, million, million kilowatt (10^{21}) years of electricity. At present, the United States use is at a rate of 72 million kilowatt years.

(*c*) *A fusion powerplant would be extremely safe.* All calculations indicate that a nuclear explosion could not occur, and the risk of runaway or explosion appears to be about the same as for an ordinary coal-fired powerplant.

(*d*) *Radioactive hazards would be low.* Radioactivity will be induced in the material surrounding the reactor, but the fusion reaction will not create large quantities of long-lived radioactive by-products that must be disposed of.

(*e*) *Plant efficiency may be high.* A part of the energy released in fusion reactions in a powerplant might be convertible directly into electricity without the loss of efficiency that occurs in heating a cooling agent and using the transferred heat to drive a turbo-generator. Heat processes would be needed to put to work the rest of the energy.

Distribution of Information

Classification and Access to Information

The fusion process is the same type of reaction that generates the heat of the sun and stars, and that gives the so-called hydrogen bomb its enormous power. During the early years of the program, the fact that the United States was working on a research program to develop a controlled thermonuclear reaction was classified as restricted data under the Atomic Energy Acts of 1946 and 1954. While there were indications that several countries had programs under way, no official statement was made by any country concerning the scope of its program, the problems involved, or the sites engaged in the work.

The chief reason for this initial secrecy was the recognition that, if the research was successful, the achievement of controlled fusion would provide an intense source of neutrons which could have great military significance from the standpoint of producing fissionable material. Since neutrons for research and production purposes were scarce

throughout the world at the time the research was initiated, this was a serious consideration. However, as the problems involved in obtaining a controlled thermonuclear reaction became known there appeared less likelihood of an early breakthrough, and the need for secrecy diminished. The argument for declassification of information in the field was strengthened by the fact that usable neutrons were becoming more readily available throughout the world as a result of the rapid development of fission reactors.

Shortly before the first International Conference on Atomic Energy (held in Geneva August 8–20, 1955), the Commission determined to announce that it was conducting controlled thermonuclear research.

In his opening statement, the conference president, Dr. Homi Bhabha of India discussed the goals of controlled thermonuclear research and predicted that fusion power would be achieved within the next 20 years. Following this discussion, and in conformity with the earlier decision, Chairman Strauss announced in a press conference that the United States had been supporting a long-range research program in this field since 1951 under the code name of *Project Sherwood*.[2]

From the time of the announcement at Geneva, scientific and public interest in the field increased. A number of statements and articles discussing the general problem were published, both in this country and abroad.

Since the initial announcement of work in the United States, the Commission has moved steadily toward the declassification and wider dissemination of information in this field.

One of the first steps toward this goal was the authorization of the release of classified information to qualified industrial groups in the United States who were holders of permits for access to classified atomic energy information.[3] Access was limited to applicants who demonstrated either that they were qualified to make a significant contribution to research and development in the controlled thermonuclear field, or that they were engaged in a substantial effort to develop, design, build or operate a fission power reactor planned for construction.

As a result of the access permit program, interested industrial groups within the United States were able to review the results of the controlled thermonuclear research. Some industrial groups have established their own study projects, or have started experimental work with private funds, and others have submitted research proposals requesting Commission assistance. Industrial groups also

[2] See p. 9 Nineteenth Semiannual Report to Congress (July–December 1955).

[3] "Access to Restricted Data," Regulaion 10 CFR Part 50, amended, see p. 33 and pp. 284–86, Twenty-first Semiannual Report to Congress (July–December 1956).

have sent representatives to classified conferences. The first of these meetings attended by access-permittees was held in February 1957 at Berkeley, Calif.; the second in February 1958 at Princeton University.

Complete exchange of classified information in this field was mutually authorized in 1956 by the United States and United Kingdom. United Kingdom experimental work on peaceful uses of fusion began in 1951. Since 1956, every major meeting in this field held by the United States and the United Kingdom has included representatives from both countries.

Eleven major conferences have been held since 1951 [4] for the purpose of assuring an adequate interchange of information among groups working in Federal laboratories of attracting additional qualified people into the program, and of stimulating the flow of new ideas.

In 1956 the Commission also authorized discussions with United Kingdom representatives looking toward further declassification of information on research into controlled thermonuclear reactions. A new classification guide, approved by the Commission and United Kingdom authorities in early 1957, permitted the release of certain basic aspects of the controlled fusion program in the two countries. In January 1958, a new Joint Declassification Guide was authorized by the United States and the United Kingdom, making it possible to declassify almost all fundamental scientific work on research, development, and operation of devices in this field (see section in Part One of this report on Classification and Declassification).

Publication and Reports

On January 24, 1958, the Commission and the United Kingdom Atomic Energy Authority simultaneously released technical reports from a number of scientists in the two countries concerning their work with one approach to thermonuclear control, the "pinch process," which is described later.

At that time, Chairman Strauss issued a press statement pointing to the gains in research made by the United States and the United Kingdom, but warned that fusion power still was far ahead. He stated:

"Our research efforts and those of the United Kingdom are at a point, where it occurs, periodically, that first one laboratory and then

[4] The conferences: June 28, 1952, at Denver, Colo.; April 7, 1953, at Berkeley, Calif.; June 24, 1954, at Los Alamos, N. Mex.; October 26–27, 1954, at Princeton, N. J.; February 7–9, 1955, at Livermore, Calif.; June 10–11, 1955, at Los Alamos, N. Mex.; October 17–20, 1955, at Princeton, N. J.; June 4–7, 1956, at Gatlinburg, Tenn.; February 20–23, 1957, at Berkeley, Calif.; October 17–18, 1957, at Princeton, N. J.; February 3–6 1958, Washington, D. C.

another will make a useful and illuminating advance. This has happened in the past, and no doubt will occur in the future as our two countries pursue their studies.

"As I stated on December 18, and as is borne out in the scientific papers released today, both we and the British have succeeded in producing and maintaining quite high temperatures in a plasma of light nuclei, and the containment of such a plasma for brief but nevertheless appreciable lengths of time. But today's reports make it clear that much longer containment must be obtained and much higher temperatures reached.

"Two main conditions are necessary for the attainment of power producing thermonuclear reactions. First, heavy hydrogen must be brought to a temperature of at least 100,000,000° C. Secondly, the atomic nuclei in this hot gas must be held together for an appreciable time.

"When the temperature reaches several million degrees centigrade—a result reached in both United States and British laboratories—neutrons are emitted in quantity. However, at such a temperature, far below the 100,000,000°, it is a delicate and difficult matter to distinguish the neutrons produced by fusion and those arising from other processes which are not of particular interest for controlled thermonuclear reactions * * *

"The progress achieved by scientists and engineers associated with the Commission's Sherwood program is promising and encouraging and today's reports strengthen confidence which I have had for many years that the difficulties in the way of controlled fusion will eventually be overcome * * *

"We are making important progress, but the problems are formidable and it will be a matter of years before we will be able to build and operate commercial reactors utilizing the deuterium of the oceans, thus to produce electrical power and provide a source of energy sufficient for man's expanding needs for ages to come.

"It appears that years of intensive work will probably be required to develop a laboratory thermonuclear device which would yield more energy than it consumes. And after that, it will require more years to develop a full-scale power reactor. Therefore, the controlled thermonuclear program will not interfere with the current development and construction of reactors to produce electricity from nuclear fission."

The problem, and some of the background of research toward control of thermonuclear reactions, was described by the Commission in its Twenty-second Semiannual Report to the Congress, issued January 1958.

During hearings before the Subcommittee on Research and Develop-

ment of the Joint Committee on Atomic Energy in February, the results of the so-called *pinch program* as well as the general problems involved in obtaining a controlled thermonuclear reaction were discussed in further detail by scientists doing the research.

Finally, the principles of three other approaches (designated the *stellarator, magnetic mirror* and *hot-ion injection* concepts) being studied in the United States were made public on May 2 at the spring meeting of the American Physical Society in Washington, D. C. Detailed experimental results obtained through these approaches, in addition to an updating of results obtained in the pinch program, will be presented at the United Nations second International Conference on the Peaceful Uses of Atomic Energy at Geneva, September 1–13 (see section on International Activities in Part One of this report).

Administering The Program

Pattern of Program

Although 1951 is considered the date of inception of Project Sherwood, the problems of controlled thermonuclear reactions actually had been under study at Commission laboratories since before the end of the war. The results of this early work were later applied to the programs developed at the several laboratories.

Research in the controlled thermonuclear field began more or less spontaneously at several different laboratories throughout the country and, as the program increased in size and scope, additional effort was begun at other laboratories having the specialized capabilities required for the Sherwood program.

The Los Alamos Scientific Laboratory research on the *pinch approach* began in 1951 under the direction of James L. Tuck. In the same year Lyman Spitzer, Jr., working independently at Princeton University, conceived the *stellarator* approach to the controlled thermonuclear problem and submitted his proposal to the Commission. After a technical review, the Commission decided to support the project, now called *Project Matterhorn,* at Princeton University.

Shortly after Los Alamos and Princeton began their programs, a third approach—based on *the magnetic mirror concept*—was initiated at the University of California Radiation Laboratory. During the process of organizing the new UCRL Livermore Laboratory, Herbert F. York formed a small experimental group with Richard F. Post as its head. Chester Van Atta now is director of the entire Sherwood effort at University of California Radiation Laboratory.

Controlled thermonuclear research at Oak Ridge National Labora-

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tory began in 1952. Work there is now concentrated on development of a *hot-ion injection system* that could possibly produce a controlled thermonuclear reaction itself or could be used in conjunction with one of the other approaches. E. D. Shipley is directing the Oak Ridge effort.

In addition to these four major laboratories, the Commission is sponsoring work at New York University and the Naval Research Laboratory and is continuing to sponsor smaller research efforts at other university, industrial and government laboratories. At the present the Commission has 17 contracts with organizations of these types.

Administration of the Program

The coordination and administration of the controlled thermonuclear program in the Commission is under the direction of Arthur E. Ruark, Chief of the Controlled Thermonuclear Branch, Division of Research. The Sherwood Steering Committee, advisory to the Commission's Division of Research, meets about four times a year (see Appendix 2).

In the fiscal year ended June 30, 1951, a total 3 man-years and $50,000 in operating costs was expended on the Commission's program. Beginning in 1953, support levels were raised until in the fiscal year ended June 30, 1958, approximately 255 man-years and about $20 million were devoted to the program (see table I and table II). In the next fiscal year, this level of support is budgeted to increase to a level of 306 man-years and $39 million.

TABLE I.—CONTROLLED THERMONUCLEAR PROGRAM OPERATING COSTS BY LABORATORY

Location	Fiscal years 1951–53	Fiscal year 1954	Fiscal year 1955	Fiscal year 1956	Fiscal year 1957	Fiscal year 1958
	(In thousands of dollars)					
Los Alamos	200	290	1,000	1,100	1,756	3,000
Oak Ridge	0	65	368	630	896	3,500
Princeton	500	635	1,030	1,534	2,631	5,750
UCRL (Livermore)	300	751	2,188	3,155	4,459	6,500
Other sites	0	0	132	220	993	1,250
Total operating costs	1,000	1,741	4,718	6,639	10,735	20,000

TABLE II.—MAN-YEARS OF RESEARCH BY FISCAL YEARS

Fiscal year	*Man-years*
1951	3
1952	8
1953	30
1954	51
1955	110
1956	140
1957	201
1958	255
1959	306

Facilities and Construction

The program did not require construction funds in the early years. In the fiscal year ended June 30, 1955, $1.214 million was obligated in construction funds and for the fiscal year ended June 30, 1958, approximately $5,485 million will be obligated for construction requirements. (See table III.)

TABLE III.—CONSTRUCTION OBLIGATIONS

Fiscal year	*Construction obligations*
1955	$1, 214, 000
1956	1, 248, 000
1957	540, 000
1958	5, 485, 000
1959	7, 000, 000

By far the largest construction project currently under way—costing some $8.6 million—is a complex of laboratories and power facilities at Princeton University to serve the Model C stellarator, design and fabrication of which was approved by the Commission in 1957. These facilities will be employed for several years in experiments with Model C and with modifications of the machine.

At the University of California's Livermore Laboratory a project to provide increased power supplies and a high bay building to house controlled thermonuclear devices was authorized during this report period for completion in fiscal year 1959.

A building to house power sources at Los Alamos Scientific Laboratory also will be ready for service in 1959. A construction project to provide additional experimental space at Oak Ridge National Laboratory soon will be needed.

II

THE GOALS AND THE PROBLEMS

Program Objectives

The ultimate objective of the Commission's program of controlled thermonuclear research is to develop means of producing useful power from the energy released in nuclear fusion reactions. In thermonuclear reactions, fusionable material—such as heavy hydrogen, or deuterium—must be heated to extremely high temperatures in order to initiate the fusion of the nuclei, or cores, of its atoms. Such thermonuclear reactions are achieved in the so-called hydrogen bomb with the relatively uncontrolled release of enormous amounts of thermonuclear energy; energy is produced at an exceedingly great rate for a very short time. The production of fusion power for the generation of electricity—the objective of the program—requires a great deal more control over the reaction. Thermonuclear reactions, controlled by natural forces, have for some time been recognized as the source of the energy which the sun and the stars have been radiating for billions of years.

To harness nuclear fusion reactions for the production of power on earth, three goals must be reached successively.

First, a fusionable material must be heated to the ignition temperature—the threshold temperature for a self-sustaining reaction. At this point, fusion energy is being released within the fusion fuel at a rate sufficient to offset the loss of energy from the fuel by radiation. For fusion fuels consisting of heavy hydrogens, this ignition temperature is of the order of 100 million degrees.

Second, after ignition temperatures have been achieved, a machine—a fusion reactor—must be designed that will produce an excess of power; more power than is consumed in operating the machine.

Third, production of power from a fusion reactor must be made economically competitive with electricity produced by other means.

At present, the main effort of the program is directed toward achieving the first goal—ignition temperatures. There is a general belief among scientists in the program that these temperatures will be reached within a year or two.

A device operating at ignition temperatures would not necessarily

be a net producer of power. A net power producer would have to compensate for all energy losses, and also supply power to all the equipment necessary to make the device run. There is no real proof that a thermonuclear reactor yielding net power can be built; however, there is no proof it is impossible either. The achievement of fusion-energy release in a controlled manner is much more difficult than the achievement of explosive release, and requires a markedly different approach.

Experience leads to the belief that several successive generations of machines of increasing complexity and power will have to be built and operated before a successful net power producer can be designed. Thus, the second goal is probably many years away.

As for the economic power producer, no predictions made at this time have much validity. Although fuel costs apparently will be entirely negligible, costs of building and operating large fusion powerplants cannot be calculated on a practical basis at this time. Present indications are that, if such reactors are feasible at all, they will probably be of very large size.

On the basis of all that is known at present, it is reasonable to expect a long-time scale for obtaining an economic fusion power producer, if it can be achieved at all. A fission reactor first produced electricity in 1951. Production of electricity at costs competitive with those of conventional powerplants has yet to be demonstrated.

The Fusion Reaction

In the fission reaction currently used in power reactors to produce electricity, energy is released by splitting the nuclei of certain types of heavy atoms, chiefly uranium 235. The fission fragments are lighter nuclei which have less total mass than the original nucleus, and the difference in mass (m) is converted into energy (E) in accordance with Einstein's formula $E=mc^2$, where c is equivalent to the speed of light.

In the fusion reaction, two light nuclei "fuse" to yield a product nucleus in which the nucleons (the constituents of the nucleus, protons and neutrons) are more tightly bound than they were in the two original nuclei. This tighter binding manifests itself in a slight decrease in mass. The difference in mass is converted into energy and appears as the kinetic energy, or velocity, of the reaction products. The heavy hydrogen isotopes—deuterium and tritium—are materials of choice for thermonuclear experiments.

To cause fusion to occur, the two light nuclei must be brought very close together. Every nucleus carries a positive electrical charge in direct proportion to the number of positively charged protons it

contains. Since similarly charged particles repel each other, the fusion cannot take place unless this mutual repulsion, called the coulomb force, can be overcome;[5] the coulomb forces increase with the number of protons in the nuclei.

Nuclei of the heavy hydrogen isotopes contain only a single proton. The deuterium nucleus (H^2 or, more usually, D) contains a proton and a neutron which latter carries no electrical charge, positive or negative; the tritium nucleus (H^3 or, more usually, T) contains a proton and two neutrons. Deuterium exists in nature—in sea water, for example—in the ratio of one atom of deuterium to 6,000 of ordinary hydrogen. Tritium, which is radioactive with a half-life of some 12 years, must be manufactured. Fusion of deuterium nuclei can be accomplished by bombarding a deuterium target—such as "heavy ice", D_2O—with a beam of high velocity deuterons (deuterium nuclei) from a particle accelerator. The deuterons must have energies in the general range of 10,000 to 100,000 electron volts. The fusion reactions then occur in either of two ways with about equal probability:

(*a*) Two deuterium nuclei may react to form a triton (tritium nucleus) and a proton, with the release of 4 million electron volts of energy as kinetic energy of the triton and the proton ($_1D^2 + {}_1D^2 \rightarrow {}_1T^3 + p + 4.0$ Mev), or

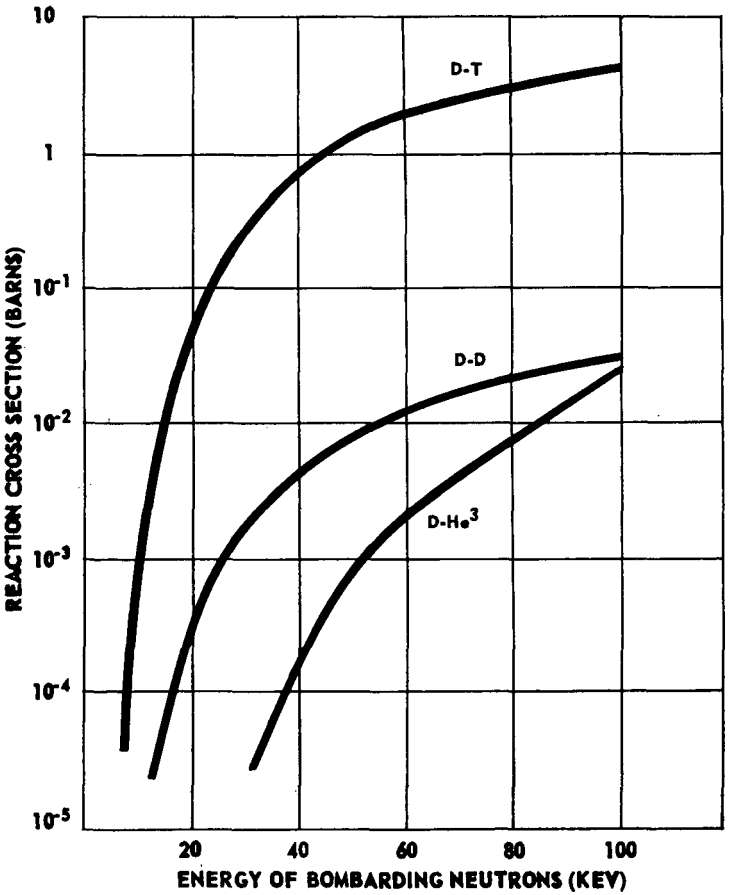
(*b*) They may form a helium 3 nucleus and a neutron, and release 3.25 million electron volts of energy ($_1D^2 + {}_1D^2 \rightarrow {}_2He^3 + n + 3.25$ Mev).

Of the energy released in each reaction, the heavier product particle (the triton, or the helium 3 nucleus), ends up with about one-fourth of the total, and the light product (the proton or neutron) with about three-fourths.

The prospects of using this reaction for the production of energy are clear: although fairly high energies are necessary to make the reaction occur with suitable frequency, the fusion reaction yields a great deal more energy than this—about 3.6 million electron volts (Mev) on an average compared to 0.01 to 0.1 Mev to initiate it. However, bombardment of a solid target by ions from an accelerator will not yield net power in an overall sense. Only a minute fraction of the total number of accelerated deuterons can be made to fuse with the target nuclei; the rest lose energy by scattering interactions (non-fusion collisions) and slow down to the point where they no longer have energy enough to provide high probability of penetrating the coulomb barrier and accomplishing fusion.

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[5] The coulomb force with which two nuclei repel each other is proportional to Z_1Z_2/r^2, where r is the distance between the two nuclei, and Z_1 and Z_2 are the number of protons contained by each. For a more detailed technical exposition of the scientific background of fusion research, see "Controlled Fusion Research—An Application of the Physics of High Temperature Plasmas," Richard F. Post, *Reviews of Modern Physics*, vol. 28, No. 3, pp. 338-362, July 1956.



Cross section (fig. 1). Chart shows the cross section for the fusion reactions vs bombardment energy of incident particle.

Another fusion reaction of interest in producing power is the reaction between a deuteron and a triton (${}_1D^2+{}_1T^3\rightarrow{}_2He^4+n+17.6$ Mev). The bombarding energy needed to provide a given probability of this reaction is lower than for D+D, and the energy yield per reaction is higher. While the tritium for a fusion reactor would have to be manufactured, whereas deuterium occurs in nature, the first D+D fusion reaction given above also produces tritium in about half the D—D fusions. The D–T reaction therefore has to be taken into account in considering practical utilization of the D–D reaction for energy production. There is another secondary reaction that can occur (${}_1D^2+{}_1He^3\rightarrow He^4+p+18.3$ Mev), but the probability of its occurrence is much lower and therefore, it may usually be neglected.

The D–D reaction then may be considered to result in the following:

$$_1D^2 + {}_1D^2 \rightarrow {}_1T^3 + p + 4.0 \text{ Mev.}$$
$$_1D^2 + {}_1D^2 \rightarrow {}_2He^3 + n + 3.25 \text{ Mev.}$$
$$_1D^2 + {}_1T^3 \rightarrow {}_2He^4 + n + 17.6 \text{ Mev.}$$
$$\text{or } 5\ {}_1D^2 \rightarrow {}_2He^3 + {}_2He^4 + p + 2n + 24.85 \text{ Mev.}$$

The energy released thus averages about 5 Mev. for every deuteron which undergoes fusion. In practical terms, this means that the small amount of deuterium contained in one gallon of ordinary water is sufficient to make it the equivalent of about 300 gallons of gasoline as a fuel. The cost of separating deuterium from ordinary water is only 2 or 3 cents per gallon of water processed.

A mixture of deuterium and tritium has obvious advantages as a fusion fuel, chief among which is its relatively high reaction rate and the lower energies necessary to achieve the reaction. One possible method of manufacturing tritium would be to expose lithium 6 to fusion neutrons moderated to thermal energies; upon capturing a neutron, lithium 6 splits into tritium and helium 4. For the D–D reaction, the release of energy at a rate of 1,000 kilowatts would be accompanied by the production of neutrons at a rate of about 2.5×10^{18} per second—that is 2.5 million, million, millions of neutrons per second. The desirability of using fusion neutrons to generate tritium for use as fuel has been public knowledge for a long time.

Key Research Problems

The main difficulties to be overcome in attaining ignition temperatures, the first goal of the effort toward fusion power, may be stated as follows:

(*a*) The temperatures corresponding to the relative energies which the particles need in order to fuse are exceedingly high—capable of vaporizing any material whatsoever.

(*b*) The plasma must be suitably confined, with adequate density, while it is being heated to these extreme temperatures.

The Temperature Problem

The high temperatures sought in controlled thermonuclear research represent the average velocities (or energies) which deuterons must maintain for appreciable periods, with essentially random movements in a confined space, in order for a considerable number of them to fuse.

As described earlier, in order to overcome the coulomb barrier and accomplish fusion, two deuterons must be made to collide with high

relative velocity.[6] However, the most probable result of two deuterons colliding is that instead of fusing, they will bounce apart without reacting. An important consequence of this relatively high probability of scattering is that deuterons must, on an average, be forced to collide many times, in order to assure that considerable numbers will fuse. At each scattering collision, there will be, in general, some exchange of kinetic energy. But if considerable numbers of deuterons in a confined volume are given similar energies, the multiple collisions will not, on an average, change the energies of the deuterons. Thus, after long pre-fusion paths, and many scattering collisions, the deuterons will still have sufficient relative energy for a fusion reaction to occur.

To accomplish these repeated collisions, the energetic deuterons must be allowed to move essentially at random within a confined volume, just as molecules of air in a room have random motion. And to accomplish fusion, the temperature—the relative energies—of the deuterons must be very high.[7]

The heating of matter to very high temperatures results in ionization, that is, atoms become stripped of the electrons which normally surround the nuclei. The resulting mixture of ions (atoms which have lost some or all of their electrons) and electrons is called a *plasma*. Deuterium heated to a temperature sufficient to provide a substantial reaction rate becomes a plasma consisting of deuterons and electrons in equal numbers. The overall charge neutrality provided by equal densities of positive ions and negative electrons is essential for effective containment of the plasma. However, is is not essential for the ions and electrons to be at the same temperature. Through energy-exchanging collisions, the two temperatures will tend to be the same, but it is only the ion temperature which influences the fusion reaction rate, since it is the ions which must maintain sufficient velocities to fuse.

The term "temperature" should be strictly applied only to systems which are in thermal equilibrium, i. e., systems in which average quantities such as the energy and density of a large number of particles

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[6] The probability of fusion occurring at a given relative energy is measured by the cross section σ, which is the effective interaction area per target nucleus. Figure 1 shows experimentally determined cross sections as functions of bombardment energy. Cross sections are usually given in "barns"; 1 barn $= 10^{-24}$ cm^2. These curves were obtained by directing a beam of deuterons at a target containing deuterium, tritium, or helium 3, respectively.

[7] Under equilibrium conditions, the distribution of particle velocities in a gas is such that their average kinetic energy is $\frac{3}{2}$ kT, where k is the Boltzmann constant and T is the temperature of the system. From this, it can be calculated that, if deuterons are to be in random motion at the energies required for fusion the temperature of the deuterons must be several hundred million degrees Kelvin. It is common practice to speak of temperature in terms of the energy kT rather than in terms of degrees; kT is the energy corresponding to the most probable velocity in a Maxwellian velocity distribution, the statistical description which tells what fraction of the particles involve have a given velocity at some given temperature. A kT value of 1 kiloelectron-volt (kev.) corresponds to a T value of about 11.6 million degrees Kelvin, 10 kev. to 116 million degrees, and so on.

do not change appreciably in the time required for the particles to interact with one another through collisions. Fusion reactions can occur in a plasma of fusionable material which is not in thermal equilibrium. Nevertheless, attempts are directed principally toward heating deuterium in systems under conditions such that one can validly refer to the temperature of the system. A very close approach to thermodynamic equilibrium cannot be achieved in man-made fusion systems, but for ease of calculation it is generally assumed that the systems are in equilibrium. Consequently it is assumed that the ions and electrons have the characteristic Maxwellian velocity distributions (see footnote 7); a distribution in which a few particles have extremely high velocities relative to the rest, some have very low velocities, and the bulk are in an intermediate range. Strictly speaking, the term "thermonuclear reactions" should be reserved for those fusion reactions which occur in hypothetical systems where the reacting nuclei are in thermodynamic equilibrium, characterized by a unique temperature, or at least close to such conditions.

The Heating Problem

How to heat a low temperature plasma to the extremely high temperatures required for fusion is a major problem. A number of methods involve applying electric fields to the plasma. The fields accelerate charged particles and impart energy to them.

Passage of a current through a plasma results in ohmic or resistive heating. This is the type of heating that occurs when current flows through the filament of a light bulb. For inductive processes in which the current is not changing too rapidly, energy from the electric field is delivered preferentially to the electrons, which in turn share energy with the ions. However, the resistivity of a plasma decreases as its temperature is increased. At temperatures of the order of a million degrees, it is no longer practical to try to heat ions by using hot electrons. Resistive heating (I^2R) loses its utility because of the decrease in plasma resistance (R) and practical limits to the amount of current (I) that can be used.

The heating techniques employed in various fusion experiments differ from one type of device to another and are described in more detail in succeeding chapters which deal with various approaches to control of thermonuclear reactions.

The Confinement Problem

Containing the hot plasma is fully as difficult as attaining the necessary temperatures.

The plasma exerts an outward pressure proportional to the total number of particles per unit volume and to the temperature.[8] Therefore, it tends to expand. The expansion of the hot plasma must be opposed at least long enough to allow a significant fraction of the fusionable fuel to burn. It is necessary to work at fairly low plasma densities in order to keep the plasma pressure down to manageable levels. Plasma with a density of about one-ten-thousandth of normal atmospheric density will, at the extreme temperatures required, exert a pressure of the order of 100 atmospheres (1,500 pounds per square inch). The temperature required for ignition is independent of plasma density, but low density does result in a very long mean free path for nuclei—the average distance the ions will travel between collisions. Therefore, the mean fusion reaction time also is very long—of the order of seconds—and the average energetic deuteron will travel many thousands of miles before it reacts. Actually, the mean distance that a deuteron must travel before it fuses under these conditions is almost equal to the orbit of an artificial satellite around the earth.

Confinement of a very hot dilute plasma is thus a major problem. Material walls cannot be used for direct confinement because hot particles from the central region would strike the walls, give up a good deal of energy, and return to the central region as cool particles. For any container of reasonable size, this would result in an intolerable drain on the energy of the system. Furthermore, contact between the plasma and the walls results in the introduction of impurities into the reaction zone, and these further increase energy losses.

The plasmas of the stars and sun are confined by gravitational forces, but these forces are far too weak for the smaller systems with which experimenters on earth must work. It is generally agreed that magnetic fields provide the best means of confining a hot plasma. All experimental devices in the United States and, so far as is known, the rest of the world, make use of some form of "magnetic bottle" to confine the plasma and keep it centered in the reaction vessel. Material walls still must be used to separate the low-density plasma from the outside world, but magnetic fields serve to keep plasma away from the walls.

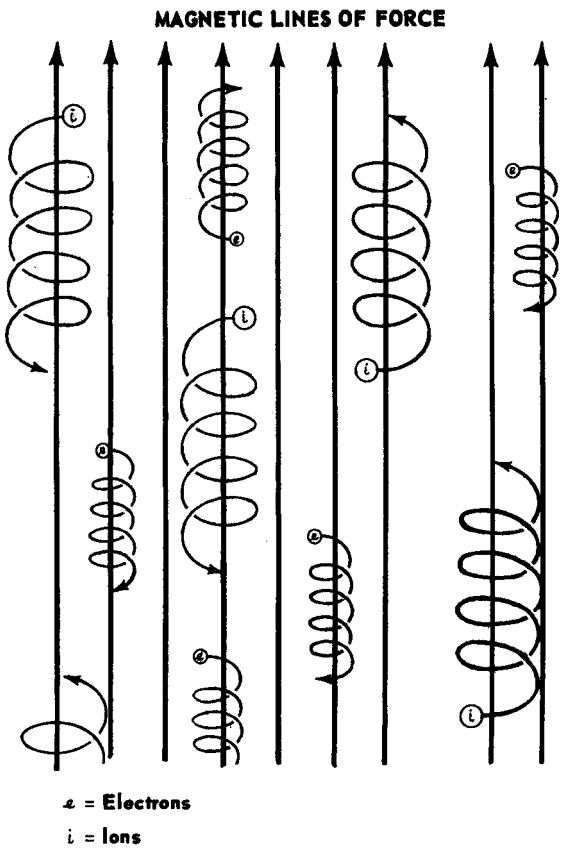
An electrically charged particle moving in a magnetic field experiences a force perpendicular both to the direction of the field and to the direction in which the particle is moving. As a result of this force, an ion or an electron, moving in a plane perpendicular to a uniform magnetic field, will follow a circular path around a magnetic line of force.[9] By means of magnetic fields attainable in a labora-

[8] Although the plasma may not be in equilibrium, it may be said as a rough approximation, that the plasma exerts a pressure equal to NkT, where N is its total number of particles per unit volume.

[9] The radius of the circle described by the particle is proportional to mv/qH, where m, v, and q are the particle's mass, velocity, and electrical charge, respectively, and H is the magnetic field's intensity.

tory—say 50,000 gauss—a deuteron moving fast enough to undergo fusion can readily be made to follow a path whose radius is of the order of inches.

Motion in a direction parallel to the magnetic field's lines of force is unaffected by the field, so that in general a charged particle follows a helical, or spiral, path along a line of force in a strong uniform field. (Figure 2 illustrates the motion of charged particles in a uniform



Lines of force (fig. 2). Diagram shows schematically how ions (i) and electrons (e) move along lines of force in a magnetic field.

magnetic field.) The particle is, in effect, "tied" to the magnetic line of force. Lines of force are fictions which are useful in portraying the "shape" and intensity of a magnetic field configuration.

The particle pressure and density will tend to be low in regions of an equilibrium system where the magnetic field is high, and vice

versa.[10] The confining magnetic fields may be produced by current-carrying coils outside the system or by currents passing through the plasma itself. Under ideal conditions, a magnetic field of 50,000 gauss, existing outside the plasma and thereby containing it, could withstand a particle pressure of about 100 atmospheres.

Additional forces come into play if the magnetic field is not uniform, or if an electric field is applied. In some cases, these forces can be used to good advantage; in others, drifts of particles among otherwise randomly moving particles can lead to a reduction in the degree of confinement.

A number of different magnetic field configurations have been employed in attempts to solve the confinement problems and some are described in succeeding chapters.

Ignition Temperatures

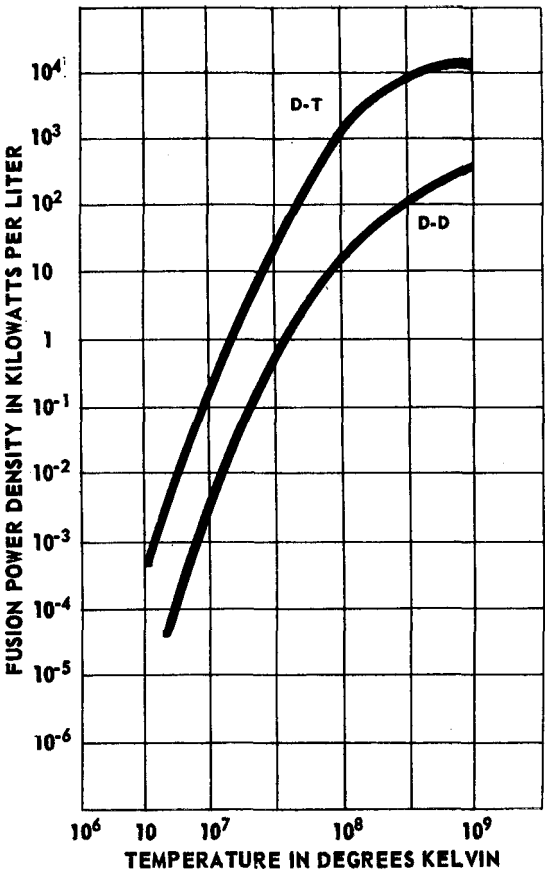
Achievement of a net power balance—the energy level represented by the ignition temperatures—is a problem involving competition between the rate of nuclear energy production by fusion within the reacting plasma, and the rate of energy loss by various means through the outer surface of the plasma column.[11] Radiation is a primary and unavoidable cause of energy loss. Fortunately, the hot plasma in a thermonuclear device does not radiate like a black body (low plasma densities prevent an attainment of radiation equilibrium); if this were the case, the energy loss, and the pressure exerted by the radiation would become impossibly large. The saving circumstance is that the plasma column in fusion reactors will not be dense enough or physically large enough to radiate like a black body, and the radiation will escape immediately from the surface of the plasma column.

Losses of energy may occur through the following means, which are explained later:

(*a*) Radiation, including (1) the so-called "braking radiation" of electrons resulting from coulomb interactions, chiefly electrons

[10] The confining effect of a magnetic field on the charged particles in a plasma is expressed, under equilibrium conditions, by: $p+H^2/8\pi=$a constant, where p is the pressure exerted by the charged particles and the other symbol is the pressure associated with the field.

[11] The fusion reaction rate per unit volume of ions in the plasma is given by $\frac{1}{2}n_i^2\overline{\sigma v}$, where n_i is the density of reacting nuclei, σ is the reaction cross section, and v is the relative velocity of the reacting particles. The bar denotes an averaging, since there is a distribution of velocities, and the cross section is velocity-dependent. At moderate temperatures, only the fastest nuclei will be reacting at any appreciable rate; the slower nuclei do not participate in proportion to their greater numbers. The expression must be modified if more than one type of nucleus is reacting. Multiplying the reaction rate by the energy yield per reaction gives the power density. Figure 3 depicts power density as a function of temperature for a particle density 10^{-4} that of normal atmosphere. The rate of energy production is strongly dependent on temperature.



Power and temperature (fig. 3). Chart shows how fusion power density relates to temperatures.

in collision with ions; and (2) the excitation of partially ionized impurities in the plasma.

(*b*) Particles, including leakage of particles from the magnetic field, either along lines of force which intersect a wall of the reaction chamber, or by migration across lines of force, or through becoming neutralized by charge-exchange processes.

(*c*) Collective movements of particles through instabilities of various kinds.

Radiation. Bremsstrahlung ("braking radiation") is emitted copiously as a result of coulomb interactions in the plasma. The bremsstrahlung loss—essentially soft X-rays—exceeds the nuclear energy production at low temperatures, but it increases with rising temperatures less

rapidly than does the production of fusion energy. At sufficiently high temperatures, the rate of energy release in the form of kinetic energy of the charged reaction products will exceed the bremsstrahlung loss.

The temperatures at which fusion power release equals the radiation loss is the ignition temperature. (Neutrons are not taken into account in calculating ignition temperatures, since the neutrons are not confined by magnetic fields and immediately escape from the system, carrying their energy with them.) The ignition temperature is independent of density since both fusion and radiation processes both depend on two-particle reactions. The fusion flame can be thought of as self-sustaining above this point (excluding burn-up of fuel and other energy losses) without additional external contributions of energy to maintain the temperatures. For deuteron-deuteron fusion, the kT value (see footnote 7) for ignition is 35 kev (about 400,000,000 degrees); for the deuteron-triton reaction, about 4 kev.

At these ignition temperatures and the densities proposed, the thermonuclear flame would be almost invisible. It would produce enormous quantities of soft X-rays but these would not penetrate even a thin window. It would also produce enormous quantities of protons and helium nuclei which would remain in the system, and of neutrons which would escape.

Bremsstrahlung losses are greatly increased by the presence in the plasma of impurities of high atomic number (nuclei possessing many protons).

Another type of radiation loss traceable to impurities is excitation radiation, which can be very troublesome at relatively low temperatures. Partially ionized impurities readily absorb energy from electrons in the plasma and promptly radiate it away in a continuous or cyclic fashion. This effect disappears if the impurities become completely ionized, as they do at higher temperatures.

Particles. Energy is lost from the system when energetic charged particles escape from the magnetic fields that confine them. Charged particles moving freely along lines of force may leak out of the reaction zone if the lines intersect the walls of the reaction chamber. Another loss process is diffusion, or migration of particles across the magnetic field, which results from repeated collisions between particles. A particle "tied" to a line of force may transfer to another line of force when it suffers a collision, and move progressively toward the reaction chamber wall. From the standpoint of this type of diffusion alone, no "magnetic bottle" can be made completely leakproof.

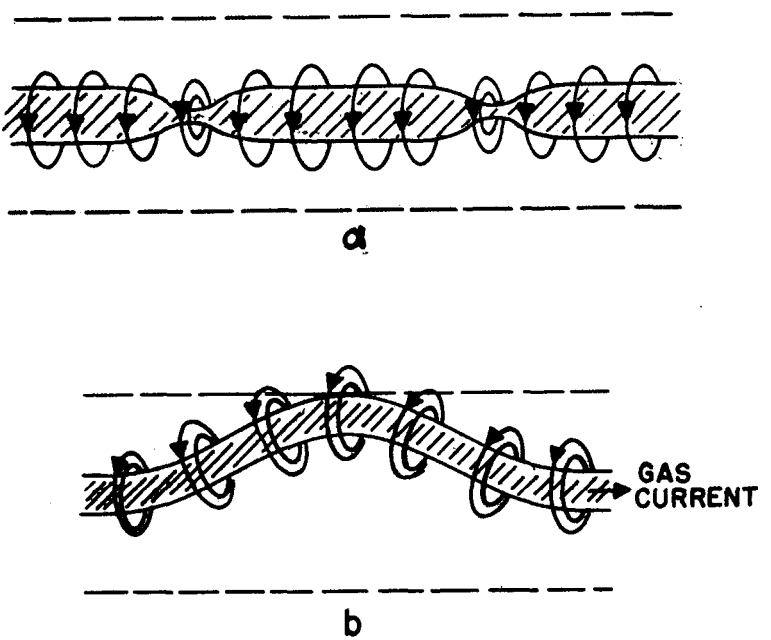
The process of charge-exchange leads to another kind of loss. Fast ions become neutralized by picking up electrons through collisions

with slow neutral atoms or molecules which have wandered into the system. Since magnetic fields bind only charged particles, the fast neutral atoms thus produced quickly escape from the plasma, leaving slow ions behind. This effectively cools the system. The cross section for charge-exchange between a deuteron and a deuterium molecule has a broad peak at about 15 kev where its value is 14×10^{-16} cm^2, or 1.4 billion barns! This is to be compared to the cross section for the fusion reaction, which is of the order of only 1 barn. The deuteron-deuterium cross section falls very steeply as deuteron energy increases beyond 15 kev.

Charge-exchange losses and excitation radiation losses point up the need for minimizing contamination of the plasma, operating with extremely clean systems, and keeping cold neutral atoms out of the system by high-speed vacuum pumps.

Collective motion. Instabilities of the plasma, or imperfect confinement on a gross scale, can obviously cause large losses by throwing plasma bodily into the reaction chamber walls.

One of the most complex problems in the field of plasma physics



Instabilities (fig. 4). Two types of hydromagnetic instabilities observed in pinch discharges: (*a*) the so-called "sausage" instability, and (*b*) the kink instability. Horizontal dotted lines represent the walls of the reaction chamber, the arrowed circular lines the lines of magnetic force.

is the analysis of such cooperative phenomena taking place in a completely ionized gas. These phenomena include a host of macroscopic effects arising from the concerted motion of very large numbers of electrons and ions interacting with electromagnetic fields. Thus, the behavior of a plasma must be studied not only from a single-particle standpoint, but also from a collective, or fluid dynamics, standpoint. One concerns the statistical behavior of large numbers of particles acting independently; the other concerns gross behavior of a large number of particles which are acting collectively as a result of long-range interactions between them.

Two major classes of instabilities plague systems in which hot plasma is confined by magnetic fields.

Hydromagnetic instabilities are associated with an imbalance between the magnetic energy of the field which compresses the plasma, and the compressional energy of the plasma. Under the influence of some perturbation, either force can drive the system away from equilibrium. The kink instabilities which afflict the pinch discharge are of this type.

The other class of instabilities is of an electrostatic nature. Such unstable motions are driven by electrical energy associated with the electric fields in the plasma. Electric fields can lead, for example, to bunching of fast electrons and deleterious secondary effects.

A plasma can become unstable in a variety of ways. Probably some modes of unstable motion have not been discovered, much less understood. The question of stability is a crucial one in the fusion research field and there are many problems which have not been satisfactorily solved.

Extracting Fusion Energy

Extraction of fusion energy becomes a vital objective of the program once ignition temperatures have been attained. Since a considerable portion of the nuclear energy from fusion reactions is released in the form of kinetic energy of charged particles, direct production of electricity may be possible without the intervening step of extracting heat to operate a turbogenerator. For example, the charged particles can be made to react with a confining magnetic field in such a way as to feed energy into the field and thereby into the electrical system which produces it.

The neutrons produced in the fusion reaction will immediately escape from the reaction zone and may be slowed down to thermal energies and captured in a suitable blanket material, such as lithium 6. The moderating action will yield heat as will the capture process which, in the case of lithium 6, could produce tritium as fuel.

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Large amounts of energy will be deposited on the walls of the reaction vessel, primarily as a result of radiation from the plasma and also by particle bombardment.

Problems of Diagnostics

The problems associated with observing the detailed behavior of a hot plasma are very complex, particularly if conditions in the plasma are changing rapidly. It is difficult enough to create a hot plasma in the first place; to find out what is occurring within it, once created, is even more difficult. Diagnosing and analyzing the plasma taxes the experimenter's ingenuity, and a number of new techniques have had to be developed. To obtain information about the plasma, experimenters probe the plasma with beams of millimeter-range microwaves, measure microwave noise from the plasma, study the emission of X-rays from the reaction region, observe the energies and direction of flight of particles escaping from the plasma (particularly the neutrons), employ high-speed photographic techniques, make spectroscopic measurements, insert probes into the reaction zone to measure electric potentials and magnetic fields, and employ many other techniques.

Since particle densities can usually be determined with reasonable accuracy in an experiment, the neutron yield from a hot plasma can be a precise measure of the temperature, provided that the plasma is in a semblance of thermal equilibrium. However, the interpretation of neutron measurements can be misleading at temperatures below about 10 million degrees. It is easy for a small number of deuterons, preferentially accelerated by some process which has little or nothing to do with temperature, to produce a close simulation of the neutron yield from an equilibrium plasma. At this stage of the program, neutron production is of interest only insofar as it can furnish more information about the plasma than the simple fact that fusion reactions are occurring somewhere within it.

Vacuum and Materials Problems

The adverse effects of impurities coming into the plasma from the walls have already been mentioned. In the attempt to obtain clean systems, the controlled thermonuclear research program has been responsible for interesting advances in the field of high vacuum technology. As the operating power levels of the experimental devices increases, wall-connected problems will in many cases become more and more severe, because more and more energy will be deposited on them.

Eventually of course it will be necessary to cope with the radiation damage produced by very energetic neutrons bombarding the walls and structure outside the reaction vessel, and with chemical problems associated with neutron-absorbing blankets. Preliminary studies are being made of these problems. The most serious problems at the moment however are those connected with the proximity of material walls to the plasma and the density of undesirable neutral particles.

The following chapters describe some of the more important classes of experimental devices developed at the four major laboratories working in the field of controlled thermonuclear research, and the principles and methods applied in these machines to overcome the two fundamental problems of attaining extremely high temperatures and of confining the plasma.

III

PINCH PROGRAM

The electromagnetic phenomenon commonly referred to as the "pinch effect" has been known to scientists for a long time, but it was only a few years ago that they began studying it in connection with electrical discharges in gases and as the basis for an approach to controlled thermonuclear reactions. Research programs along these lines were initiated at the Los Alamos Scientific Laboratory in 1951 and at the University of California Radiation Laboratory in 1952.

In the pinch approach, confinement of the plasma is achieved through magnetic fields which result from current flow within the plasma itself. Heating occurs as a result of current flow and of compression of the plasma by the confining field.

The approach possesses a basic simplicity which has great appeal. It does not require elaborate or expensive apparatus in order to obtain interesting experimental information. However, the pinch program has had to cope with severe plasma instability problems.

Neutrons have been produced in pinch devices under conditions which suggest thermonuclear origin. The results have been encouraging. Nevertheless it is sobering to reflect that the number of neutrons produced (up to about 100 million per pulse) falls far short—by a factor of a billion or so—of representing the return of as much energy as was required to produce them. However, the same general situation would exist for any type of device operating at the temperatures which appear to have been reached in pinch devices thus far.

Confinement

As indicated above, the passage of an electric current through a fluid conductor, such as a plasma, in itself produces a magnetic field which acts to constrict or pinch the current channel—in this case, the plasma—down to a slender filament. For example, if a current is caused to build up rapidly in a cylindrical tube containing a gas at low pressure, the current will tend to be carried in a tubular surface layer or sheath. The magnetic field, with circular lines of force concentric with the tube axis, forces the current-carrying sheath to move radially inward, driving the plasma before it. The constriction

continues until the magnetic pressure ($H^2/8\pi$—see footnote 9) outside the sheath is balanced or momentarily exceeded by the particle pressure inside the sheath. The magnetic field distributes itself in an efficient way; it is highest where it needs to be high—adjacent to the plasma—and falls off with increasing distance from the plasma column.

The magnetic field intensity (H) is proportional to the current; therefore the magnetic pressure confining the plasma is proportional to the square of the current. It is easy to show that, in order to confine plasma at the temperatures and densities needed for thermonuclear reactions, the currents required are very high, of the order of millions of amperes. Since it is very difficult to provide sustained currents of this magnitude, it is customary to operate the experiments on a pulse basis through the use of large banks of condensers, which can store energy electrically and deliver it in an extremely short time.

Experimenters working with devices of this type soon found that the duration of confinement was severely limited by instabilities. These instabilities, hydromagnetic in nature, had in fact been predicted by Princeton theoreticians before they were recognized experimentally. Two of them, the pinch (or "sausage") instability and the kink instability, are illustrated on page 240. Both result from perturbations which cause the magnetic pressure to exceed the plasma pressure in some localized region and drive the system away from equilibrium. In the case of sausage type, the plasma column narrows down in a neck and tends to pinch itself off; in the kink type, the plasma can be blown into the wall.

Sausage instabilities are strongly believed to be the source of neutrons observed in the first simple dynamic (unstabilized) pinch experiments.[12] High local electric fields, produced inductively, could accelerate a few deuterons to sufficiently high velocities so that they could bombard and react with other deuterons essentially at rest. It was immediately evident that energy release so intimately related to instability breakup could not lead to useful fusion power.

Ways were found to stabilize the pinch. It was discovered that stability could be greatly enhanced by trapping a relatively weak longitudinal magnetic field (with its lines of force parallel to the axis) and compressing it along with the plasma. This slows down pinch formation time and reduces the compression attainable. The duration of stable confinement depends on how well the magnetic field inside and the field outside can be kept separated, since they tend to diffuse into one another, with disastrous results. Intermixing of the

[12] "Neutron Production in Linear Deuterium Pinches," O. A. Anderson, W. R. Baker, S. A. Colgate, H. P. Furth, J. Ise, Jr., R. V. Pyle, and R. E. Wright; *Physical Review*, 109, 612, (Jan. 15, 1958).

fields is opposed by high electrical conductivity (high electron temperature) in the sheath region. The situation is actually a good deal more complex than this simple picture would indicate, and is the subject of intensive study at the laboratories working on pinch devices. Stability of pinch discharges also is improved if the wall material of the tube is a good electrical conductor, or if a conducting material is placed around a thin insulating liver. Eddy currents then act to repel the plasma if a kink develops to push the plasma column toward the wall.

Comparatively high pressures can be sustained momentarily in pinch devices before the onset of instabilities. In small devices, pinch durations of a few microseconds (millionths of a second) are typical. However the high rate of power input which can be achieved with these small devices tends to compensate for their small size and their brief operating cycle.

Heating

In pinch devices, heating occurs as a result of (*a*) passage of the current (ohmic heating), and (*b*) compressions as the magnetic field drives the plasma in toward the axis. In large, slow, low-density pinches (*a*) predominates; in small, fast, high-density pinches, (*b*) is the more important. In the fast pinch devices the compression may be so rapid that it virtually constitutes shock heating. (See ch. VII.)

The temperature of a hot plasma may be measured or estimated in a number of ways. One method makes use of magnetic probes, tiny coils of wire encased in quartz and inserted into the discharge. These probes are used to determine the magnetic field distribution and current distribution as functions of time. The plasma pressure can then be calculated; the density can be closely estimated, and therefore the temperature can be calculated.

Geometries

Pinch experiments may be carried out with either toroidal (doughnut-shaped) or linear (cylindrical) tubes.

Toroidal geometry has the great advantage of eliminating problems associated with the ends of tubes. A ring of current travels around the tube. The current is established by induction. For example, a closed iron core is threaded through the hole of the doughnut. When a time-varying current is passed through a primary winding on the core, an electromotive force is induced in the secondary, which consists of the gas in the tube, and thereby a current is caused to flow.

However, the current into the tube cannot continue to flow in the same direction indefinitely because the current in the primary cannot increase without limit.

Although the toroidal geometry is generally preferred, linear tubes have some advantages and are therefore used in many experiments. However, there are end losses of particles to be reckoned with, because the current must be passed in through an electrode at one end of the tube, and out through the other end. There is no magnetic confinement of the plasma in the axial direction. Linear devices permit experimentation at generally higher current levels, because the electric fields that can be established along the tube by applying a high voltage between the two electrodes are greater than can be induced in a toroidal tube by the transformer action. Also, a cylindrical tube is simpler geometrically than a torus, and some kinds of data can be interpreted more easily. Linear tubes have been used, for example, in attempts to heat plasma so rapidly—by brute force, so to speak—that thermonuclear conditions can be reached before instabilities have had time to develop.

Los Alamos Program

The program at the Los Alamos Scientific Laboratory was initiated in 1951 under the direction of James L. Tuck. The first experimental device, a torus called the "Perhapsatron," was built in 1952. Since then the name Perhapsatron has become a generic term for the Los Alamos toroidal devices; linear pinch devices belong to the "Columbus" series.

Presumptive temperatures of several million degrees have been attained in some of the discharges at Los Alamos. Neutrons have been observed in several devices and the number produced per pulse is generally in the range from 1 to 100 million.

Magnetic probe techniques have been developed to a high degree of perfection at Los Alamos.[13] The magnetic field and the current density have been determined as functions of time and plasma pressure has been calculated in linear pinched discharges, and also toroidal discharges which are more difficult to study. This probe method has proved valuable in elucidating pinch phenomena.

Interesting results have been obtained during the past year with a high-power pinch apparatus called Columbus II.[14] In view of the fast rate of growth of instabilities in pinch discharges, this device was

[13] "Magnetic Measurement of Plasma Confinement in a Partially Stabilized Linear Pinch," L. C. Burkhardt, R. H. Lovberg, and J. A. Phillips; *Nature 181* 224–225 (Jan. 25, 1958).

[14] "Neutron Production in a High-Power Pinch Apparatus," D. C. Hegerman and J. W. Mather; *Nature 181* 226–228 (Jan. 25, 1958).

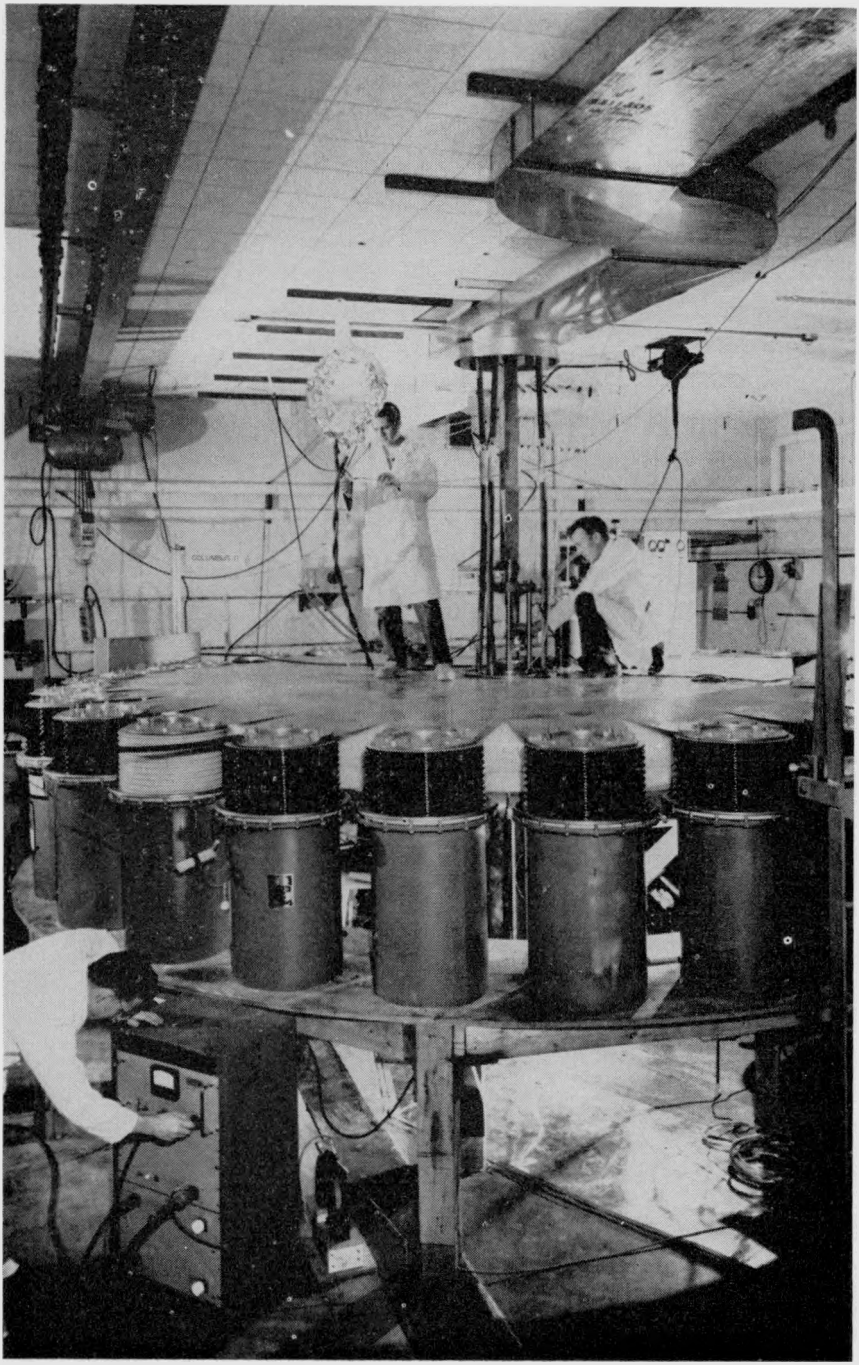
designed to permit the current to reach its maximum value in as short a time as possible. Voltages of 50 to 60 kilovolts can be applied to the ends of the tube, which is 10 cm. in diameter and 30 cm. long. The high voltage and large condenser bank permit reaching a current of 1 million amperes in about two-millionths of a second. Beginning in 1957, the tube has yielded neutrons at the rate of 10 to 100 million per pulse. Neutron pulse durations are one- or two-millionths of a second. Exhaustive tests were undertaken to determine the mode of origin of the neutrons. It was found that the neutrons were emitted from the gas practically uniformly along the tube, except in a small region near the positive electrode. However, careful measurements of the neutron energy distribution showed that neutrons emitted in the direction of the negative electrode had slightly higher energies than those coming out in the opposite direction. This indicated that at least some of the neutrons were probably produced by deuterons travelling at fairly high velocities toward the negative electrode, reacting either with each other or with deuterons at rest. Experiments with this device are continuing. Figure 5 shows a photograph of the Columbus II apparatus.

Interesting experiments also have been conducted in another linear device, Columbus S–4.[15] The S denotes "stabilized." This device was constructed to study the effects of greater tube diameter and length on the behavior of the discharge. Magnetic probe measurements showed that there could be circulating currents at certain times during the discharge, with current flowing in one direction just inside the tube wall and in the opposite direction near the axis. Using initial deuterium pressures of 40 microns of mercury (about 50 one-millionths of an atmosphere), the pressure in the pinched discharge was observed to rise to about 12 atmospheres when the current channel diameter reached its minimum. Particle energies of about 300 electron-volts, corresponding to temperatures of about 3 million degrees, are believed to have been attained. Neutrons are produced in this device.

Perhaps the most outstanding recent advance has been the achievement of an apparently fully stable pinch discharge in the Perhapsatron S–3, which came into operation in December 1957.[16] The tube diameter is a little over 2 inches and the diameter of the torus is a little over a foot. Under suitable conditions this tube has yielded as many as 1 million neutrons per pulse. The main burst of neutrons occurred in a time of about 2 microseconds, but neutron emission continued for a somewhat larger time.

[15] "New Confinement Phenomena and Neutron Production in a Linear Stabilized Pinch," L. C. Burkhardt and R. H. Lovberg; *Nature 181* 228–230 (Jan. 25, 1958).

[16] "Neutrons from a Stabilized Toroidal Pinch," J. Honsaker, H. Karr, J. Osher, J. A. Phillips, and J. L Tuck; *Nature 181* 231–233 (Jan. 25, 1958).

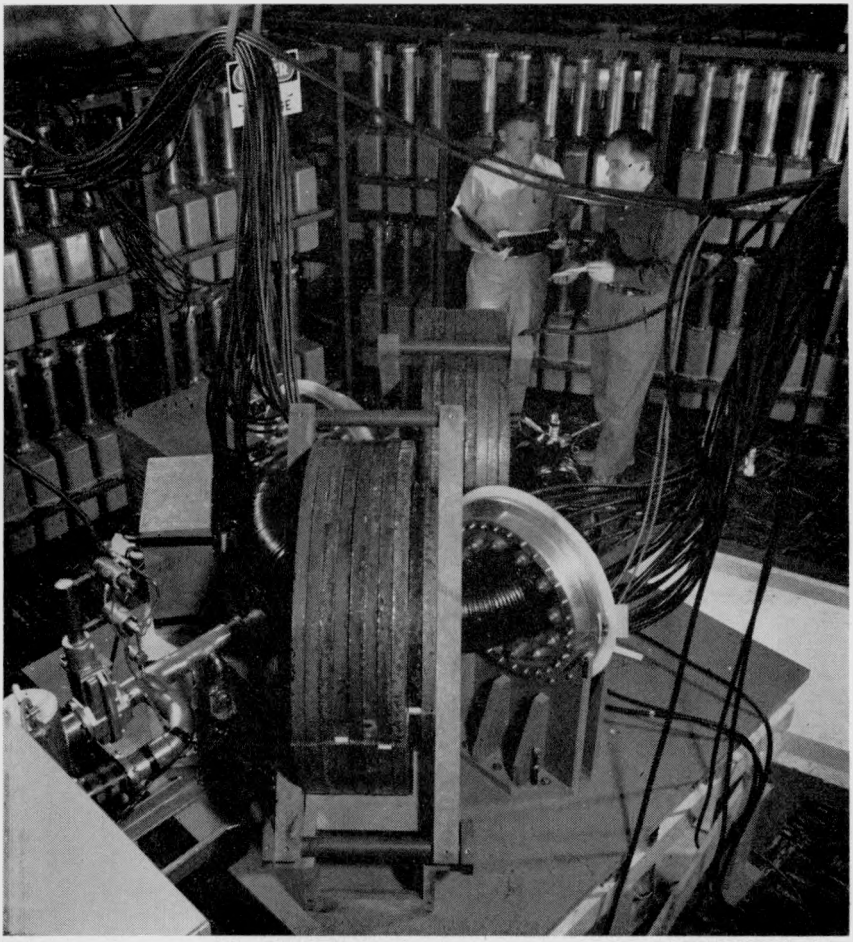


Columbus II (fig. 5). Linear pinch apparatus at Los Alamos Scientific Laboratory.

The putative temperature obtained may be as high as 6 million degrees, as determined magnetically. The neutron yield is consistent with a temperature of this magnitude, but is too small to permit precise determination of the mode of origin of the neutrons. The pinch is observed to stay well-centered in the tube, with only minor undulations.

Perhapsatron S–4, a larger version of the S–3 device is now in operation. (Figure 6 is a photograph of the S–4.) A still larger device, the S–5, is in the design stage. The S–4 is one of several pinch devices which will be exhibited at Geneva.

Los Alamos theoreticians have contributed substantially to an understanding of the complex behavior of pinches.



Perhapsatron S–4 (fig. 6). Toroidal pinch device at Los Alamos Scientific Laboratory.

University of California Radiation Laboratory Program

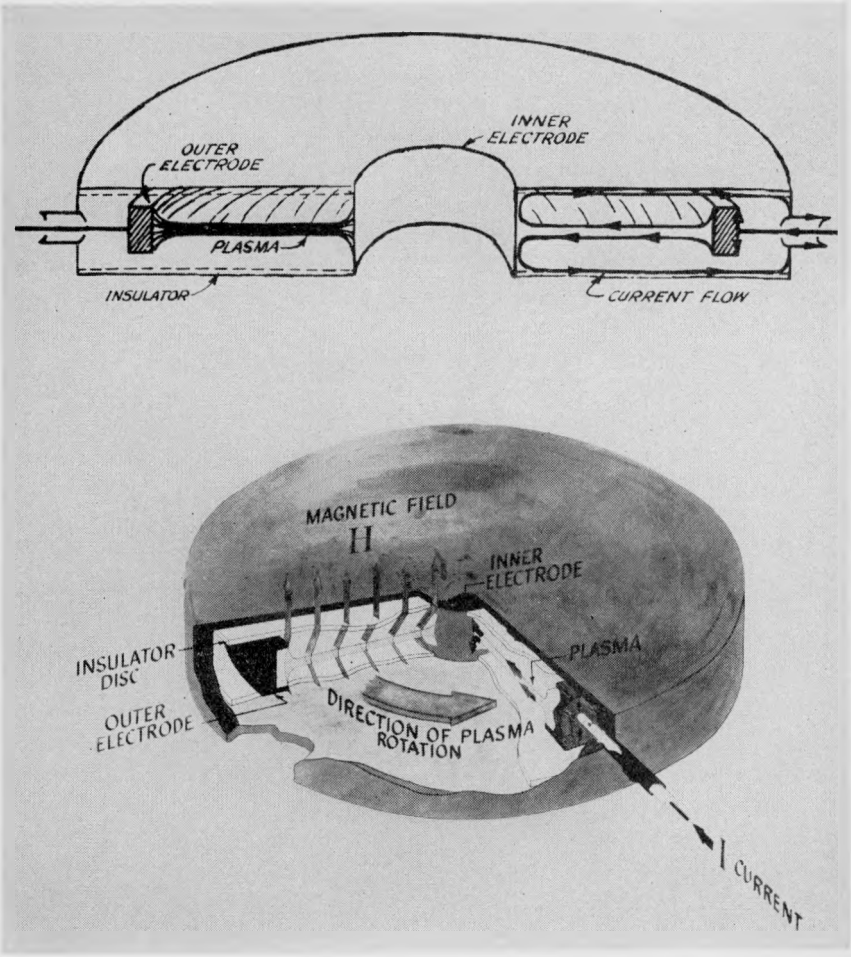
Pinch studies were initiated at the University of California's Radiation Laboratory at Berkeley during 1952, and at its Livermore Laboratory somewhat later. The work at Berkeley led to a clear demonstration early in 1955 that the production of neutrons from a simple dynamic (unstabilized) pinch in deuterium was not due to a thermonuclear effect, but resulted rather from acceleration of a few deuterons by inductive effects during the instability breakup of the pinch column. More stable pinch configurations, as contrasted with a simple dynamic pinch, are being investigated, both at Berkeley (under W. R. Baker) and at Livermore (under S. A. Colgate). The entire Sherwood effort at UCRL is under the direction of C. M. Van Atta.

Among the promising devices being studied at Berkeley are the sheet plasma device (or Triaxial pinch) and the Homopolar device.

The *Triaxial device* is a pinch configuration in which a cylindrical sheet of plasma is formed by a discharge in the annular space between two concentric cylindrical conductors. The plasma is confined and compressed by the magnetic fields created by current flow in the axial or longitudinal direction, one way in the discharge itself and the other direction in the two concentric conductors. This device has exhibited an interesting pattern of plasma oscillations over a period of several microseconds and produces a substantial neutron yield in pure deuterium. Studies are in progress to increase the yield and to determine in detail how the neutrons are produced.

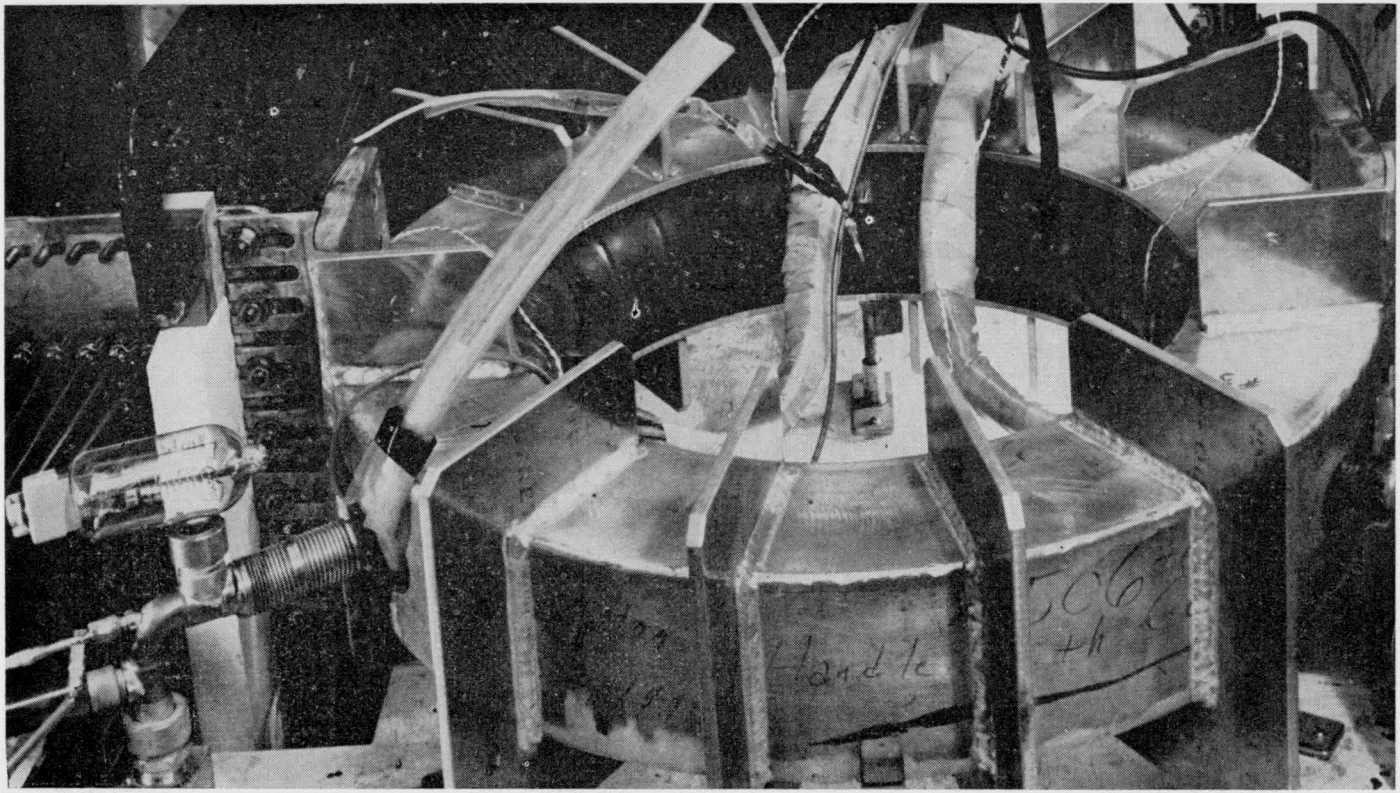
The *Homopolar device,* shown schematically in figure 7, is one in which the plasma is compressed into a disc by the radial flow of current in a magnetic field which is perpendicular to the direction of current flow. Under these conditions, the plasma experiences a torque and spins much like the rotor of a disc-type homopolar motor. As a result of this behavior, the homopolar device provides a means of storing energy, like a very low-inductance condenser. The long-time stability of the rotating plasma (about 100 microseconds) suggests that the technique may be useful in creating and confining a thermonuclear plasma. To achieve this goal, however, it is necessary to find some satisfactory way of converting the relatively well-ordered ion motion, imparted by the rotation, into random or turbulent motion. Studies with a larger device are being undertaken.

The Livermore program has been characterized by a continuing effort to understand the mechanism of magnetic shock heating of a plasma and the stabilizing effect of an axial magnetic field on a linear or toroidal pinch. Two devices stand out as particularly promising.



Homopolar Device (fig. 7). A schematic diagram of the Homopolar Device at the University of California Radiation Laboratory at Berkeley.

The Screw Dynamic Pinch is a linear device in which a cylindrical conductor outside the insulator wall is cut with helical or spiral slots. The current flowing in this conductor—the same current as that flowing—in the tube (but oppositely directed), thus follows a helical path. The configuration permits a new degree of control over the type of magnetic field present in the tube as the pinch begins to form. By proper choice of the pitch of the spiral on the outside conductor and suitable adjustment of other parameters, the magnetic fields existing just outside and just inside the plasma boundary can be caused to develop in a way which will minimize instabilities. It is believed that the "sausage" instability can be suppressed, so that a "cork-



Toroidal Pinch Device (fig. 8). A magnetically stabilized machine at University of California Radiation Laboratory at Livermore.

screw" type of instability, normally slow to develop, will be predominant. If this can be accomplished, it is expected that thermonuclear temperatures will be reached before plasma instabilities develop.

The magnetically stabilized toroidal pinch is believed by the Livermore group to be the most promising of the pinch configurations for the ultimate attainment of controlled thermonuclear power. Such a device is shown in figure 8. The discharge is stabilized through the use of a conducting tube and the presence of an initial axial magnetic field. Several sizes of small, magnetically stabilized toroidal pinch tubes, up to 10 inches in minor diameter (bore), have been operated at Livermore.

IV

STELLARATOR PROGRAM

The essential features of the stellarator approach to the controlled thermonuclear problem were conceived by Lyman Spitzer, Jr., of Princeton University, an astrophysicist by background. A research program based on the stellarator concept was initiated under Spitzer's direction at Princeton's Forrestal Research Center in 1951. The term "stellarator" was coined to indicate a particular class of devices in which it is hoped that stellar temperatures can be generated. Stellarators may be described briefly as devices in which ionized gas is confined in an endless tube by means of a very strong externally-applied magnetic field.

Confinement

Since charged particles are "tied" to magnetic lines of force and execute tight spirals around the lines, they can be kept away from the walls of a tube through establishment of a very strong longitudinal magnetic field, which can be produced by current-carrying coils encircling the vacuum chamber containing the low-density plasma.

The field will not inhibit the motion of particles in the longitudinal direction along the lines of force. The problem of end leaks might be solved by simply bending the vacuum chamber or tube into a torus (i. e., a doughnut). The magnetic lines of force then would be closed circles and the confinement should be perfect except for particle diffusion, or drift, across the field as a result of repeated collisions. However, a simple toroidal geometry will not work, because the magnetic field intensity is not uniform over the cross section of the tube. This non-uniformity leads to another type of particle drift, toward the walls, ions in one direction and electrons in another. The separation of electrical charges, which cannot be readily neutralized, produces a strong electric field which, together with the magnetic field, pushes both positive ions and negative electrons toward the outer wall of the tube.

This difficulty was foreseen and a way was found to avoid it and still utilize the basic confinement characteristics of a strong longitudinal field. It was shown theoretically that the electromagnetic

drift described could be prevented by twisting the toroidal tube into the form of a figure-eight. The magnetic field then is characterized by an abstract property called a "rotational transform." In such a geometry a single magnetic line of force, if followed along the stellarator tube, does not close on itself in a single turn, as in the case of the simple torus, but is displaced by an angle related to the degree of twist built into the tube. In following the lines of force along the tube, they thus rotate slowly about the magnetic axis, which lies close to the axis of the tube; the lines resemble the twisted strands of a rope. This permits charge separations to be neutralized by a flow of charged particles (i. e., a current) along lines of force, the direction in which they can move freely. Consequently the rotational transform plays a vital role in the operation of the stellarator.

Subsequently it was found that a rotational transform could be introduced without twisting the tube. Two sets of external magnetic coils are required in this alternative arrangement—an outer circular set, and an additional inner set of spiral coils having a very large pitch. The helical coils cause spiraling of the lines of force, and therefore accomplish the same end as twisting the tube. This second method has the advantage that it also provides a configuration which tends to be stable against those disturbances known as hydromagnetic instabilities, defined earlier.

Detailed theoretical studies have shown that a stellarator should be capable of confining a plasma for an experimentally interesting length of time, provided the heated gas remains relatively quiescent—motionless in a gross sense. However, if turbulence, oscillations or other forms of unsteadiness appear, the effectiveness of the magnetic field in confining the particles is reduced, and the plasma may cool off through contacts with the wall.

For the sake of experimental convenience, the confining magnetic field is usually applied in pulses, but there is no basic reason why the field has to vary with time. The stellarator, in its ultimate form, once ignited, is envisioned as a steady-state device.

Heating

Two stages appear to be necessary in heating the plasma in the stellerator. The first stage is "ohmic heating."

To produce the current, an iron core is used to encircle the tube. A time-varying current is passed through an auxiliary winding around the core. The ionized gas in the stellarator tube forms the secondary winding of this transformer, and a current is thereby induced in the gas. This form of current production also is used in toroidal pinch devices. However, the stellarator currents are of smaller magnitude, since the

current does not also have to provide the means of confinement. The pinch type of magnetic fields in the stellarator are weak compared to the main longitudinal magnetic field. However,the current must be kept below the so-called "Kruskal limit" in order to avoid cancellation of the rotational transform. Figure 9 is a simplified schematic diagram of a stellarator device.

Calculations indicated that ohmic heating should result in achieving temperatures of about 1 million degrees. This was found to be true, but at higher temperatures than this the resistance of the gas falls to such low values that little heating can be obtained with the induced currents which can be achieved in practice. At this point, the ability of the plasma to conduct electricity is about 20 times as great as copper under ordinary conditions.

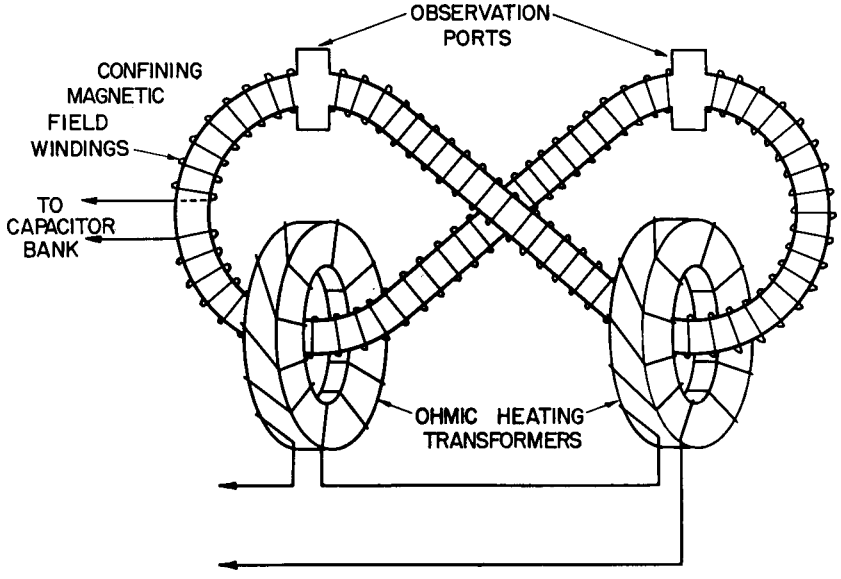
To achieve the 100 million degree temperatures required, the Princeton group plans to utilize a method called "magnetic pumping," which has been the subject of small-scale experimentation, but which requires a fairly high temperature plasma to start with. This method consists of using a rapidly pulsating magnetic field in one section of the tube. Heat is produced by repeated compression and expansion of the plasma at radio frequencies which are of the order of millions of cycles per second. It appears that energy can be added to the gas at the most rapid rate if the pulsation period agrees with one of the natural periods of the gas, such as the time between collisions for a single particle or the time required for a particle to pass through the magnetic pumping section. Other radio frequency heating methods which are being investigated involve the ion-cyclotron resonance frequency—the frequency with which the ion moves in a circular path in the presence of the magnetic field.

Other Features

The stellarator is basically a fairly low density device and is therefore very sensitive to impurities which tend to contaminate and cool the plasma. This has led to very intensive ultra-high vacuum work at Princeton, in an effort to insure clean operating systems.

Another approach to enhancing the purity of the gas involves the use of an additional modification of the complex magnetic field, called a "divertor." In a short section of the stellarator the magnetic field is shaped, by means of a bucking coil, so that the outermost lines of force are led radially out of the tube into a separate chamber. The purpose is to ensure that particles drifting slowly toward the tube wall, or from the wall toward the plasma, will be guided into this divertor. Impurities liberated by collisions of these particles with

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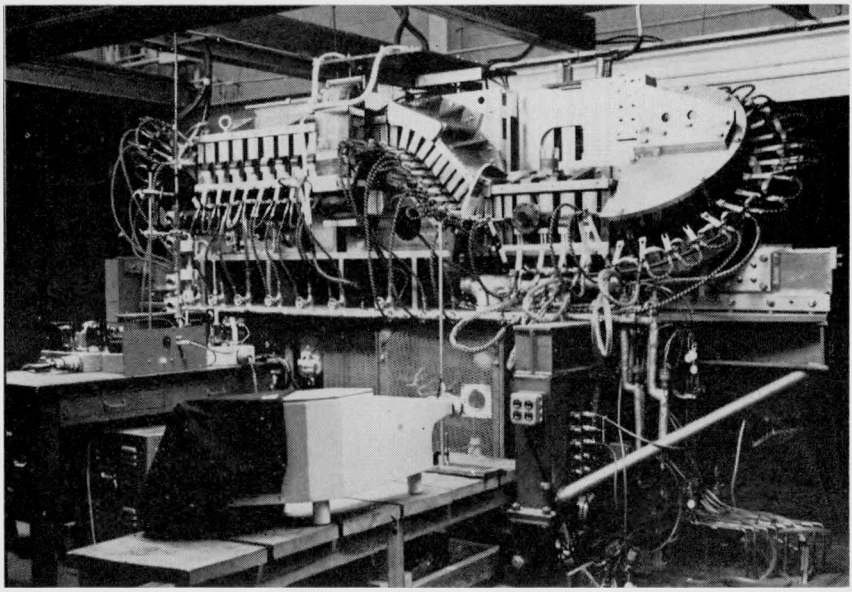
Stellarator diagram (fig. 9). A schematic of a Stellarator Device, Princeton University.

the wall will then be confined to the divertor chamber. They can be pumped away before they make their way back into the main discharge tube.

Research Program

A number of small-scale stellarator devices have been built to investigate experimentally the central ideas of this approach. The, first device was the Model A, built in 1952. Since then there have been a succession of B machines. Stellarators, with their novel magnetic field configurations and elaborate heating schemes, are inherently very complex machines, which require a great deal of careful design and fabrication. The B machines operate on a pulsed basis and are powered by relatively slow capacitor banks. They operate in the millisecond range. Figure 10 is a photograph of the B–3 machine. An earlier device, B–2, will be exhibited at Geneva. Also to be exhibited at Geneva are two small demonstrational stellarator devices, one a figure-8 and the other a "racetrack," or elongated torus. Electron beams will be used to illustrate the action of the magnetic fields produced by the several types of coils.

The experimental program has demonstrated the basic validity of the confinement scheme. The devices are observed to retain plasma for a considerable time after ohmic heating currents have decayed.



Stellarator B–3 (fig. 10). Model B–3 in the series of Stellarator Devices being developed at Princeton University.

Ohmic heating has been demonstrated and studied in great detail. Interesting studies have been made of "runaway electrons"—electrons which somehow acquire abnormally high velocities; the higher an electron's velocity the less likely it is to transfer energy to slower-moving ions. Radio frequency heating techniques have not as yet been conclusively demonstrated, but are the subject of much effort at present. The beneficial effects of the divertor have been successfully demonstrated.

The theoretical group at Princeton has made outstanding contributions to plasma theory in general, and to the study of instability phenomena in particular. For example, pinch instabilities were predicted in advance by Princeton theoreticians. The experimental group is making strong efforts to gather experimental information on the initiation and growth of instabilities, especially those of the electrostatic variety which may possibly affect present stellarator devices.

Model C

As part of a long-range program centered on the stellarator approach, a new laboratory complex is being established at Princeton. The first device to be housed in the new facility will be the model C,

a "racetrack" tube about 40 feet in circumference and 8 inches inside diameter, equipped with helical stabilizing windings. In line with the fundamental nature of stellarators, the power supplies for energizing the confining field and for heating the plasma will be very large.

Under a contract with Princeton, the Allis-Chalmers Manufacturing Co. and the Radio Corp. of America are engaged jointly in the design, fabrication, installation and test of the device and the associated power supplies. Exploratory or preliminary experiments with the device are expected to begin late in 1959. Completion of the device is scheduled for late 1960.

Model C, appreciably larger and more powerful than the present B devices, will open the way for new and more meaningful studies of plasma behavior. It is hoped that much longer confinement will be achieved and that temperatures of the order of 50 million degrees will be reached. Model C will be strictly a research facility; it is not expected to be a net power producer. It should help provide valuable information on the hot plasmas which will be essential to planning full-scale machines.

V

MAGNETIC MIRROR PROGRAM

The tendency for charged particles moving in a nonuniform magnetic field to be repelled from regions where the magnetic field is strongest has been known for a great many years. The use of this general principle as the basis for a method of confining an ionized plasma—the method designated as the magnetic mirror approach—was suggested by H. F. York, and developed largely by R. F. Post's group at the University of California Radiation Laboratory, Livermore. The program based on the magnetic mirror principle has been in existence since 1952.

Confinement

In its simplest form, a mirror machine consists of a long straight tube provided with current-carrying coils which produce a strong magnetic field inside the tube. In the central transverse plane, the magnetic lines of force are parallel to the axis of the tube. At the ends of the tube, however, the magnetic field is made much stronger, through the use of extra coils or higher currents. These regions of stronger field, where the magnetic lines of force are brought closer together, are called "magnetic mirrors." A charge particle spiraling around a magnetic field line tends to be reflected from the mirror regions. Thus the relatively weak field region between the two mirrors effectively traps charged particles.

The magnetic field configurations of mirror devices led to the term "magnetic bottle", for the field is really shaped like a two-ended bottle, with the mirrors defining the necks at either end. Figure 11 gives a schematic diagram of a typical mirror device.

Magnetic mirror devices, or Pyrotrons as they are sometimes called, are similar to stellarators in that both rely on strong externally applied fields. In a stellarator, end leads are prevented by getting rid of the ends, i. e., by bringing the ends together to form a continuous tube. In a mirror machine, end leaks are minimized through use of the mirrors, i. e., the strong regions at either end. While mirrors do not provide perfect containment, they do allow the vacuum chamber of the device to retain the very considerable advantages of being cylindrical rather than toroidal in shape.

Containment of particles in a mirror device is most perfect for those particles which have relatively high components of velocity at right angles to the magnetic lines of force and relatively low components of velocity along the field lines. Particles satisfying these conditions could remain trapped essentially indefinitely, if it were not for inter-particle collisions. Collisions cause repeated deflections of particles into paths with insufficient spiral to insure containment of the particles, and hence particles eventually escape along lines of force through the mirrors.

No instabilities have been observed in magnetic mirror devices at the temperatures and densities attained thus far. It is not known with certainty, however, whether or not the plasma will be fully stable at the much higher densities and temperatures which are ultimately required.

Heating

The principal heating process used in the mirror program is that associated with compression of the plasma through an increase in the intensity of the magnetic field. This works in the following way:

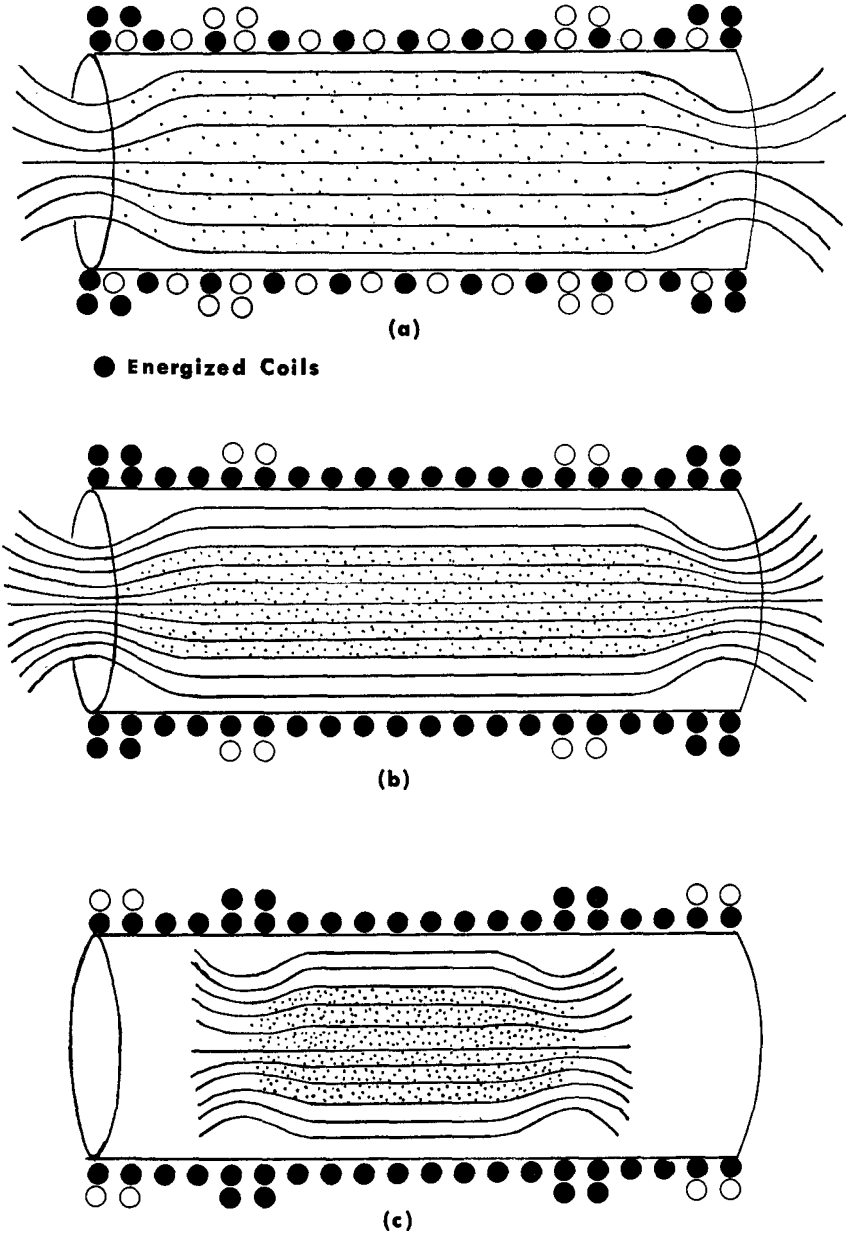
As a magnetic field is caused to increase, an electromotive force is set up which acts to increase the velocity of particles spiraling around the lines of force. Actually only the component of velocity in the plane perpendicular to the field is increased; velocity along the lines of force is unaffected. The following expression holds to a good approximation:

$$W_n/H = \text{a constant}$$

Where W_n is the kinetic energy associated with motion normal, or perpendicular to the field, and H is the field intensity. Thus increasing the field adiabatically (i. e., slowly compared to the time it takes an ion to complete a turn in its orbit) adds energy to the particles, and in a way which enhances the confinement. Increasing the field also makes the particle orbits smaller and can be said to bring all the field lines closer to the axis of the device. Hence a physical compression of the plasma accompanies the heating. (See fig. 11b.)

Another way to compress and heat the plasma is to compress it longitudinally, i. e., to control the currents in the external coils so as to cause the magnetic mirrors to move toward each other. The plasma is then compressed as though it were caught between two moving pistons and strong heating ensues. (See fig. 11c.)

The attainment of high plasma temperatures can be made easier through injection of fairly energetic ions. Typically, injection occurs through the ends of the device--the necks of the bottle. Causing the



Magnetic mirror diagrams (fig. 11). Schematic diagrams showing heating in a magnetic mirror device: (*a*) plasma injected while field is weak; (*b*) field intensity increased with radial compression of plasma; (*c*) longitudinal compression by inward movement of magnetic mirrors.

field to increase continuously during the injection period prevents particles reflected at the other end from coming back and striking the source. The field cannot be made to rise indefinitely, however, and there is a limit to injection currents; therefore, there is a limit to the ion density that can be built up in the device by this process.

Experimental Program

Three main lines of development are being pursued in the Pyrotron program at Livermore, high-compression experiments, transfer and multiple compression and end-injection of energetic ions.

High compression experiments. In this set of experiments, relatively cold plasma is trapped in a weak magnetic field and subsequently heated by compression. The compression time is made short compared to the times anticipated for the loss of the trapped particles. The main losses to be considered are due to collision leakage through the mirrors and to charge-exchange, which was explained earlier.

These experiments have demonstrated the confinement of plasma for periods of several milliseconds, the radial compression of plasma, and the heating of electrons in the plasma to temperatures of about 10 million degrees. A continuing effort is devoted to developing means of measuring the energy distribution of the positive ions, and of injecting plasma with higher initial temperatures. It is hoped that these efforts will lead to final plasma temperatures of the order of tens of millions of degrees, with sufficient plasma density to produce a substantial yield of thermonuclear neutrons.

Transfer and multiple compression. In this experiment, compression of initially cold plasma occurs in three stages. Plasma is injected into an 18-inch diameter vessel provided with a weak mirror field. The plasma is then compressed radially by increasing the field. Through manipulation of the confining field, the plasma is then transferred to a neighboring smaller (9-inch diameter) vessel, there compressed further, and transferred to a third still smaller (3-inch diameter) vessel, where a high field compression is applied. This transfer sequence moves the plasma several feet from the point of origin and is intended to separate the deuterium ions from heavy ion and neutral atom contaminants.

Plasma diagnostics performed during the operation show that compressions and transfers of the plasma occur substantially as intended. A new method of plasma injection, using a gun which emits a blob of plasma at high velocity has been developed. It is expected to provide a relatively hot plasma at the first state so that, after compression,

very high plasma temperatures and densities can be attained in the small volume.

Figure 12 shows a photograph of the apparatus being used in this type of experiment.

End-injection of energetic ions. In this experiment, relatively high energy (5-10 kev.) deuterium ions are injected from a source just inside one of the magnetic mirrors. The ions are injected in a direction nearly perpendicular to the magnetic lines of force (which are parallel to the axis) and spiral onward into the longitudinal center of the device. The field intensity must increase steadily during the injection period in order to provide positive trapping. At the end of the injection period, the magnetic field continues to rise so that the ions are heated adiabatically by compression to about five times their initial energy, which in the case of the device being used at present should be about 25 kev.

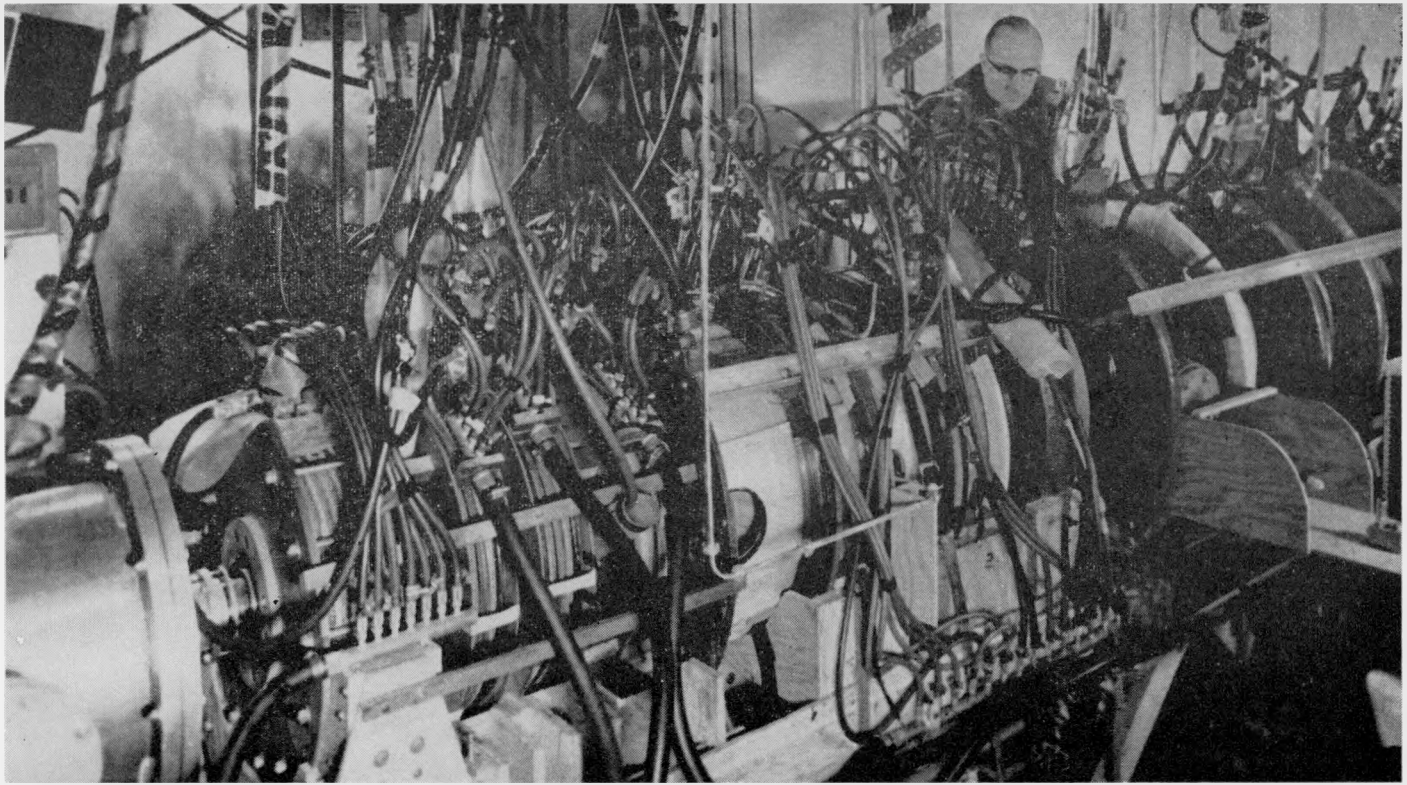
This method of injection insures that ions retained for the full cycle will automatically have energies corresponding to about 300 million degrees. The main problem is to inject and retain enough energetic ions to form a plasma of sufficient density for the production of an interesting thermonuclear yield.

Discussion

Transient mirror devices of the type being used at University of California Radiation Laboratory are very complicated pieces of apparatus and experimentation with them is beset with the usual assortment of difficulties. The devices are particularly sensitive to the effects of impurities and a great deal of effort has gone into finding ways to minimize the influx of contaminants. Post's group has been responsible for studying the excitation radiation problem in some detail. Much stress is laid on careful diagnostic work. In spite of present technological difficulties, the magnetic mirror devices are considered very promising. They make excellent devices for research in plasma physics and incorporate a high degree of flexibility.

The mirror geometry, because of its simplicity and convenience has found applications elsewhere. It is used at Oak Ridge in connection with the study of high energy injection, and also at Los Alamos and at the Naval Research Laboratory for the confinement of plasmas produced by colliding shock waves.

Several of the Geneva exhibits will demonstrate key features of the magnetic mirror approach.



Magnetic mirror device (fig. 12). Mirror device used for transfer and multiple compression experiments at University of California Radiation Laboratory at Livermore.

VI

HIGH ENERGY INJECTION

The problems involved in heating a low temperature plasma up to the extreme temperatures required for thermonuclear reactions are known to be formidable. Great difficulties have been encountered in reaching the relatively modest temperatures achieved thus far. By adding energy to charged particles moving essentially at random within a confining field, attempts are made to bring the plasma up to high temperatures through intermediate regions in which (*a*) the confinement may be inadequate (in general, the higher the plasma temperature, the better magnetic confinement becomes), and (*b*) other energy loss processes such as excitation radiation and charge exchange, are particularly detrimental. There is some evidence also that heating processes can encourage the initiation of instability phenomena.

However, in principle, there exists a second method, other than heating a low temperature plasma for obtaining high temperature ions. It consists of first adding energy directly to ions, and then trapping or confining them and allowing their motion to become random. One can easily produce a beam of ions having sufficiently high kinetic energy by means of a conventional particle accelerator. The problem then becomes one of using these energetic ions to construct a hot plasma, in which ion motion will be random rather than unidirectional as in accelerator beams.

The mirror machine program at University of California Radiation Laboratory has made use of moderately energetic ions trapped by increasing the intensity of magnetic fields. However, the use of highly energetic ions is the key principle in the approach to thermonuclear power being investigated by Oak Ridge National Laboratory. It was perhaps a natural path for this laboratory to pursue in view of the extensive experience developed at Oak Ridge over the past 15 years in the electromagnetic separation of isotopes.

Injection Process

The most promising methods of trapping a charged particle in a magnetic field appear to involve either: (*a*) using a time-varying field, as discussed earlier, or (*b*) causing the charge-to-mass ratio of the

particle to change while it is moving through the field which then need not be changing with time. The latter method is being employed in experimental work at Oak Ridge in the following way:

Molecular deuterium ions each consisting of two deuterons and one electron, are supplied at high energy in the form of a beam from an accelerator, and injected across a magnetic field into a vacuum chamber. Ordinarily an ionized molecule so injected will move in a large circle, if the field is uniform, and return to strike the source from which it was injected. Trapping can occur, however, if the molecular ion is dissociated or broken up at some suitable point in its orbit thereby altering the charge-to-mass ratio.

The molecular ion can be dissociated into two particles: a single positively charged deuteron, and a neutral deuterium atom, consisting of the remaining deuteron and the electron.

$$D_2^+ \rightarrow D^+ D^\circ$$

The neutral atom is not acted upon by the magnetic field and immediately escapes. The positive deuteron, on the other hand, with the same charge and velocity but only half the mass of the original molecular ion, will move in a new orbit which has a radius only half as large (See footnote 9). Consequently it cannot come back and strike the source; it will continue to circulate in a circular orbit.

The scheme would be of merely academic interest unless highly efficient means were actually available for dissociating molecular ions at the proper point. The means was suggested by John S. Luce who discovered that an unusual type of electrical discharge—a high-current vacuum arc—could dissociate molecular ions with remarkably high efficiency over a wide range of ion energies. Complete breakup of the molecular deuterium ion into two deuterons and an electron also is observed.

Experimental Program

Oak Ridge has undertaken an experimental program based on dissociative trapping of energetic ions. The program makes use of magnetic mirror geometry, rather than a uniform field, in order to provide a degree of confinement in the direction of the magnetic lines of force.

Figure 13 gives a simplified diagram of this method. In practice the arc is not situated on the axis of the vacuum chamber as shown, but is off-center so that the trapped atomic ions initially follow a circular path concentric with the axis of the device and stay well away from the walls. The injection current and magnetic field remain constant in time. This has led to calling the Oak Ridge device

DCX, which stands for Direct Current Experiment. In the present DCX device, molecular ions are injected at 600 kev., yielding 300 kev. atomic ions. Injection currents are in the milliampere range. Figure 14 is a photograph of the DCX machine.

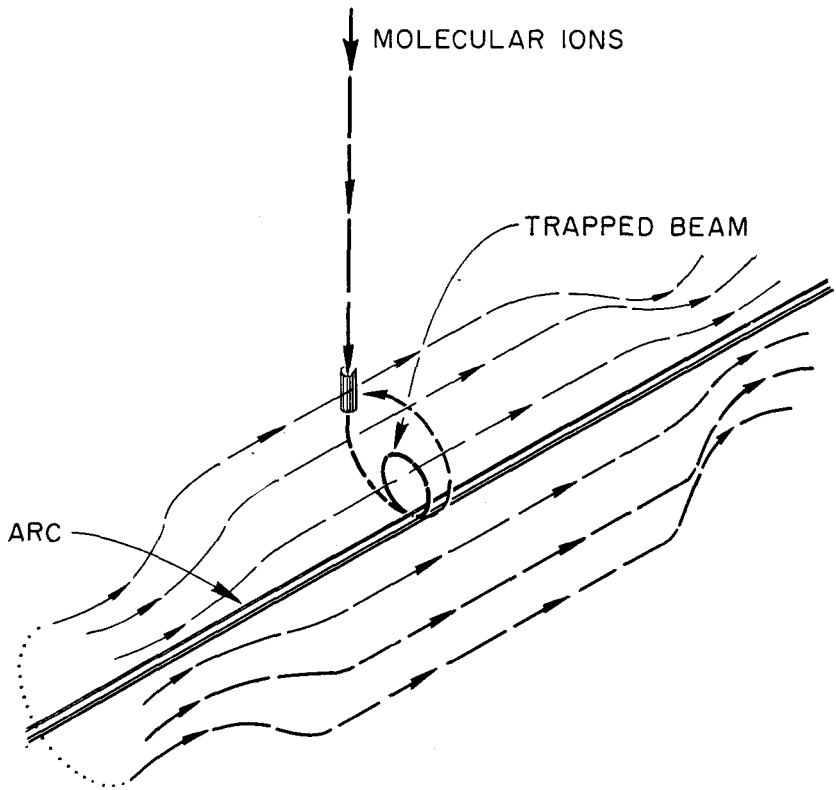
The trapped ions do not stay in an organized ring indefinitely. The orbits spread out somewhat due to energy losses and the nonuniform nature of the confining magnetic field. Moreover there are competing processes which serve to limit the buildup of the circulating beam of particles. The most important one is charge-exchange, in which a fast ion picks up an electron from a slow neutral atom, becomes neutralized, and so escapes from the magnetic bottle. At 300 kev., the charge-exchange cross section is very low compared to its value at lower energies, but it is still to be reckoned with. Charge exchange losses are minimized by pumping the system down to very low pressures initially and keeping the density of neutrals as low as possible. The trapped beam has a pumping action since the fast ions can ionize neutrals with little loss in energy. At 300 kev., the ionization and charge-exchange cross sections are such that, on the average, a fast deuteron will ionize about 20 atoms before being lost through charge-exchange.

By decreasing the neutral background pressure of the vacuum chamber, or increasing the ion injection rate, or a combination of both, a critical condition known as *burnout* can be reached—the neutral atoms are being ionized as fast as they enter. The ion density can then be built up rapidly. With a spherical plasma volume whose radius is that of a 300 kev. deuteron in a magnetic field of 10,000 gauss, and with a background pressure of 10^{-6} mm. of mercury, an atomic ion injection rate of 80 milliamperes is required to achieve burnout. The better the vacuum, the lower the injection current can be.

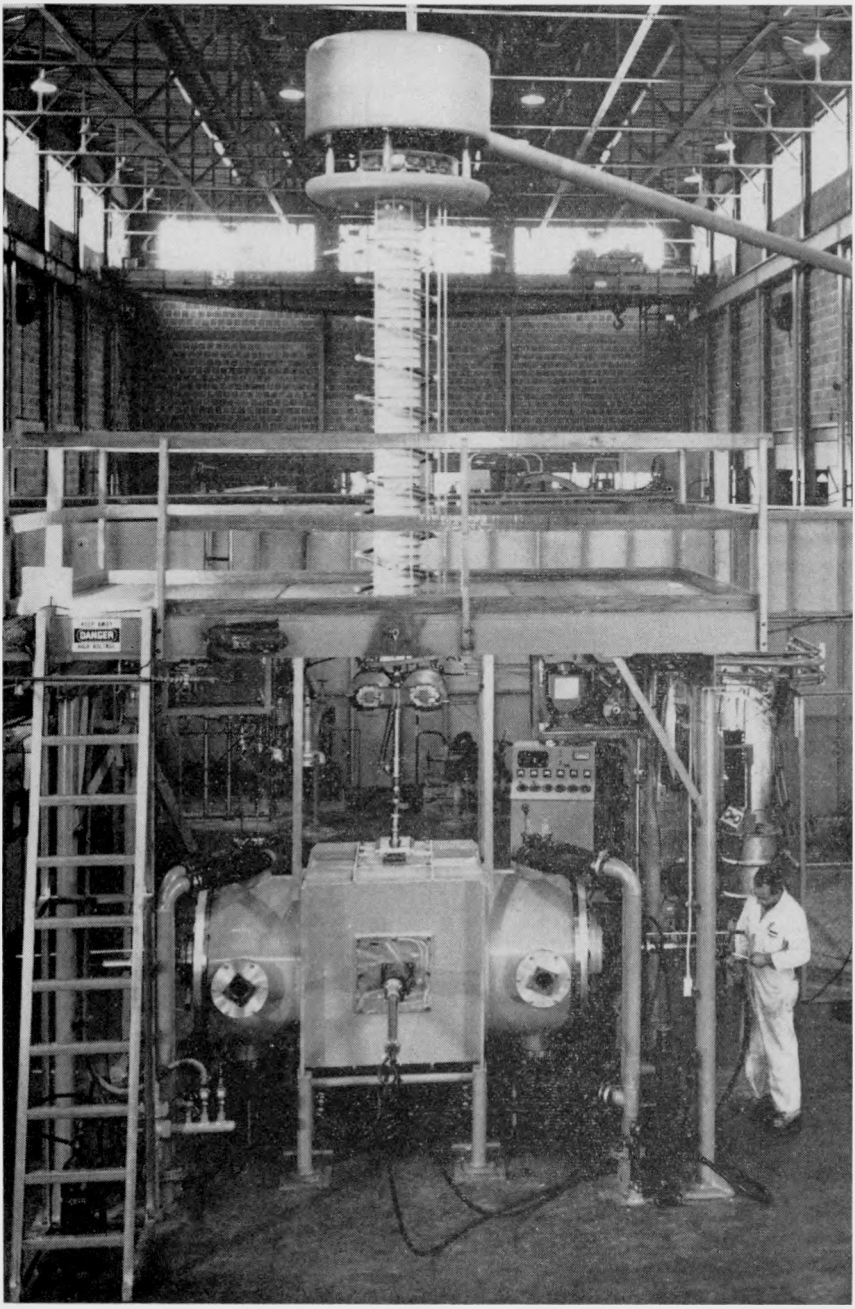
Plasma Formation

Following burnout, the ions are expected to lose energy by colliding with and heating cold ions and the cold electrons that will be drawn in to provide the overall charge neutralization. While this degradation of energy is taking place, the density of ions also builds up; they will scatter by collision and their motion will tend to randomize. Thus far, ion densities have been insufficient to explore experimentally the randomizing of particle motion.

As the plasma forms it will of course be subject to particle losses through the magnetic mirrors and to bremsstrahlung losses. It is not yet known whether the system will exhibit any serious instabilities.



Direct Current Experiment diagram (fig. 13). Simplified schematic diagram of trapping of ions by dissociation of molecules in a mirror field. Oak Ridge National Laboratory.



Direct Current Experiment (fig. 14). Photograph of Direct Current Experiment (DCX) at Oak Ridge National Laboratory.

It is extremely difficult, on the basis of present knowledge, to estimate what the final densities and temperatures will be in a device like DCX. If a plasma can be formed in it at all, one might expect ion temperatures of the order of 100 kev. This is well above the D–D ignition temperature, but the DCX is strictly a research device, cannot contain charged reaction products, and will not come within many orders of magnitude of being a net power producer. The general method virtually insures the presence of ions far superior in energy to those needed for thermonuclear reactions, and the hot low-density plasma should have good confinement properties.

Potentialities

After the arc has helped to form the hot plasma, it could be turned off and the plasma could be fed by breakup of molecular ions in the plasma or even by injection of cold gas. Compression of the plasma, as in the University of California Radiation Laboratory magnetic mirror program, would probably be necessary if a DCX-like machine were to be made capable of containing its reaction products, thereby making ignition of the plasma possible. This general method of igniting a plasma does not appear to be limited to a magnetic mirror geometry.

VII

OTHER RESEARCH PROGRAMS

Shock Heating

In addition to the four major approaches outlined in the previous sections, there are a number of other ideas which have been considered at one time or another. Some of the ideas have been carried to a point of preliminary experimentation and dropped for lack of promise, or perhaps put on the shelf for the time being in favor of more promising efforts. Some are undergoing active investigation at the present time and may well lead to results of appreciable significance.

Among the small but noteworthy efforts now being pursued are those which involve shock heating of the gas. The use of shock waves (pressure waves similar to, but much more intense than, ordinary sound waves) was considered at an early stage in the Sherwood program, but shock techniques were not sufficiently developed at the time to make the method attractive.

The Naval Research Laboratory, in a program cosponsored by the Commission, undertook a small shock tube program in 1955, aimed at studying the properties of high temperature plasma and investigating the use of shock tubes for the production of such plasmas. Substantial advances have been made by way of increasing the temperatures attainable by shock techniques, and finding a method of propagating shocks at appreciably lower densities than had previously been thought possible. With the achievement of temperatures of the order of 1 million degrees through the colliding shocks, attention has turned to the possibility of magnetically confining and compressing the shock-heated plasma. This work has been rather fully described in the literature.[17] Neutrons are now being produced at the Naval Research Laboratory in plasmas operated on in this fashion.

Los Alamos Scientific Laboratory recently has been conducting an experiment on shocks produced within a magnetic mirror field.[18] In this experiment, neutrons have been produced by what appears to be shock ionization and adiabatic compression in a mirror geometry.

[17] "Propagation of Strong Shock Waves in Pulsed Longitudinal Magnetic Fields," A. C. Kolb; *Physical Review 107* (4) 1197–1198 (Aug. 15, 1957).

[18] "Neutrons of Possible Thermonuclear Origin," W. C. Elmore, E. M. Little, and W. E. Quinn, *Physical Review Letters, 1* 32 (July 1, 1958).

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The apparatus was designed to operate with deuterium which had been ionized by shocks passing in the axial direction. However, the induced electric field associated with the time-rising magnetic field produced by the single-turn mirror coils themselves appears adequate for the initial ionization, so that about 1,000 to 10,000 neutrons per pulse are produced without the preheating shocks.

If the mirror symmetry is spoiled by energizing the two mirror coils at slightly different times, no neutrons appear. This suggests that plasma is indeed confined between the mirrors. The experiment is fairly new, and further studies are required to establish how many of the neutrons, if any, are produced by a direct acceleration in the tangential electric field and how many, if any, by thermonuclear reactions between deuterons confined during the peak of the magnetic field.

Theoretical Program at New York University

Theoretical work is a continuing effort at all the major laboratories engaged in experimental programs. Among the major areas of theoretical interest are the stability of various configurations of plasma confined by magnetic fields; the nature and structure of boundary layers established between plasma and magnetic fields; the electrical and thermal conductivities of plasma in the presence of a magnetic field, and the structure and heating effects of shocks.

In addition to the on-site programs, the Commission sponsors a theoretical program at New York University under the direction of H. Grad. The University's Institute of Mathematical Sciences has contributed to a theoretical understanding of shock wave phenomena and fluid dynamics in general. The New York University group is developing information in the complex field of magnetohydrodynamics, which deals with the motion of conducting fluids in magnetic fields.

Other Programs

In addition to the major programs, the Commission supports a variety of smaller contracts with universities and industrial companies. Some of this work is concerned with fundamental research in fields where the contractors have unique skills or experience. Other contracts involve the pioneering development of particular components needed at one or another of the Commission's major laboratories.

Industrial organizations are taking an increasing interest in the controlled thermonuclear research program. Some industrial companies, notably the General Dynamics Corporation, are undertaking research and development programs in the field without Federal support. Others have a more limited interest and are concerned primarily with making use of their particular talents in some restricted phase of the program.

APPENDIX 1

Organization and Principal Staff of U. S. Atomic Energy Commission

Atomic Energy Commission	Lewis L. Strauss, *Chairman.*[1] John F. Floberg. John S. Graham. Willard F. Libby. Harold S. Vance.
General Manager	K. E. Fields.[2]
Special Assistant to General Manager (Congressional).	Bryan F. LaPlante.
Special Assistant to General Manager	Charles Vanden Bulck.
Deputy General Manager	R. W. Cook.
Assistant General Manager	Harry S. Traynor.
Assistant General Manager for Administration.	Robert E. Hollingsworth.
Assistant General Manager for International Activities.	Paul F. Foster.
Assistant General Manager for Manufacturing.	*Vacancy.*
Assistant General Manager for Research and Industrial Development	A. Tammaro.
Controller	Don S. Burrows.
General Counsel	Loren K. Olson.
Secretary to Commission	W. B. McCool.
Director, Office of Industrial Development.	Frank K. Pittman.
Director, Office of Operations Analysis and Planning.	Paul C. Fine.
Director, Office of Special Projects	Edward R. Gardner.
Director, Division of Biology and Medicine.	Charles L. Dunham, M. D.
Director, Division of Classification	C. L. Marshall.
Director, Division of Construction and Supply.	John A. Derry.

[1] Mr. Strauss was Chairman of the Commission during the period covered by this report. His term expired June 30, 1958. On July 14, John A. McCone, of California, was sworn in as Commissioner and appointed Chairman by the President. His term will run to June 30, 1963.

[2] Mr. Fields was General Manager during the period covered by this report. His resignation took effect June 30, 1958. Mr. Paul F. Foster became General Manager on July 1 to serve until the appointment of Maj. Gen. Alvin R. Luedecke, currently on a military assignment, becomes effective.

Director, Division of Information Services.	MORSE SALISBURY.
Director, Division of Inspection	CURTIS A. NELSON.
Director, Division of Intelligence	C. H. REICHARDT.
Director, Division of International Affairs	JOHN A. HALL.
Director, Division of Licensing and Regulation.	HAROLD L. PRICE.
Director, Division of Military Application.	Brig. Gen. ALFRED D. STARBIRD.
Director, Division of Nuclear Materials Management.	D. F. MUSSER.
Director, Division of 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	JOHN H. WILLIAMS.
Director, Division of Security	JOHN A. WATERS, Jr.

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Albuquerque (N. Mex.) Operations Office	KENNER F. HERTFORD.
Burlington (Iowa) Area	E. W. GILES.
Dayton (Miamisburg, Ohio) Area	JOHN H. ROBERSON.
Kansas City (Mo.) Area	WALTER C. YOUNGS, Jr.
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Pinellas (Fla.) Area	HENRY A. NOWAK.
Rocky Flats (Colo.) Area	SETH R. WOODRUFF, Jr.
Sandia (N. Mex.) Area	A. E. UEHLINGER.
South Albuquerque (N. Mex.)	WALTER W. STAGG.
Chicago, (Ill.) Operations Office	KENNETH A. DUNBAR.
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Hanford (Wash.) Operations Office	J. E. TRAVIS.
Idaho (Idaho Falls) Operations Office	ALLAN C. JOHNSON.
Lockland (Ohio) Aircraft Reactors Operations Office.	HARRY H. GORMAN.
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Oak Ridge (Tenn.) Operations Office	S. R. SAPIRIE.
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Puerto Rico (Mayaguez) Area	JOHN I. THOMAS.
St. Louis (Mo.) Area	FRED H. BELCHER.
Pittsburgh (Pa.) Naval Reactors, Operations Office.	LAWTON D. GEIGER.
San Francisco (Calif.) Operations Office	HAROLD A. FIDLER.
Savannah River (Aiken, S. C.) Operations Office.	ROBERT C. BLAIR.
Schenectady (N. Y.) Naval Reactors, Operations Office.	JON D. ANDERSON.

APPENDIX 2

MEMBERSHIP OF COMMITTEES

STATUTORY COMMITTEES AND BOARD

Joint Committee on Atomic Energy—Eighty-fifth Congress

This committee was established by the Atomic Energy Act of 1946, and continued under the Atomic Energy Act of 1954, to make "continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy." The committee is kept fully and currently informed with respect to the Commission's activities. Legislation relating primarily to the Commission or to atomic energy matters is referred to the committee. The committee's membership is composed of 9 Members of the Senate and 9 Members of the House of Representatives.

Representative CARL T. DURHAM (North Carolina), *Chairman.*
Senator CLINTON P. ANDERSON (New Mexico).
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 WILLIAM F. KNOWLAND (California).
Senator JOHN W. BRICKER (Ohio).
Senator HENRY C. DWORSHAK (Idaho).
Representative CHET HOLIFIELD (California).
Representative MELVIN PRICE (Illinois).
Representative PAUL J. KILDAY (Texas).
Representative WAYNE N. ASPINALL (Colorado).
Representative JAMES E. VAN ZANDT (Pennsylvania).
Representative JAMES T. PATTERSON (Connecticut).
Representative THOMAS A. JENKINS (Ohio).
Representative CRAIG HOSMER (California).
JAMES T. RAMEY, *Executive Director.*

Military Liaison Committee

Under section 27 of the Atomic Energy Act of 1954, "there is hereby established a Military Liaison Committee consisting of—*a.* a Chairman, who shall be the head thereof and who shall be appointed by the President, by and with the advice and consent of the Senate, who shall serve at the pleasure of the President, and who shall receive compensation at the rate prescribed for an Assistant Secretary of Defense; and *b.* a representative or representatives from each of the Departments of the Army, Navy, and Air Force, in equal numbers as determined by the Secretary of Defense, to be assigned from each Department by the Secretary thereof, and who will serve without additional compensation. The Chairman of the Committee may designate one of the members of the Committee as Acting Chairman to act during his absence. The Commission shall advise

and consult with the Department of Defense, through the Committee, on all atomic energy matters which the Department of Defense deems to relate to military applications of atomic weapons or atomic energy including the development, manufacture, use, and storage of atomic weapons, the allocation of special nuclear material for military research, and the control of information relating to the manufacture or utilization of atomic weapons; and shall keep the Department of Defense, through the Committee, fully and currently informed of all such matters before the Commission. The Department of Defense, through the Committee, shall keep the Commission fully and currently informed on all matters within the Department of Defense which the Commission deems to relate to the development or application of atomic energy. The Department of Defense, through the Committee, shall have the authority to make written recommendations to the Commission from time to time on matters relating to military applications of atomic energy as the Department of Defense may deem appropriate. If the Department of Defense at any time concludes that any request, action, proposed action, or failure to act on the part of the Commission is adverse to the responsibilities of the Department of Defense, the Secretary of Defense shall refer the matter to the President whose decision shall be final."

Hon. HERBERT B. LOPER, *Chairman.*
Maj. Gen. DWIGHT E. BEACH, United States Army.
Maj. Gen. JOHN P. DALEY, United States Army.
Capt. JOSEPH D. BLACK, United States Navy.
Capt. JOSEPH A. JAAP, United States Navy.
Maj. Gen. JOHN S. MILLS, United States Air Force.
Maj. Gen. RICHARD T. COINER, 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 section 26 of the Atomic Energy Act of 1954. The nine civilian members are appointed by the President to advise the Commission on scientific and technical matters relating to materials, production, and research and development. Under the Atomic Energy Act, the committee shall meet at least four times in every calendar year.

Dr. WARREN C. JOHNSON, *Chairman;* dean of physical sciences, University of Chicago, Chicago, Ill.
Dr. JESSE W. BEAMS, chairman, physics department, University of Virginia, Charlottesville, Va.
Dr. J. B. FISK, executive vice president, Bell Telephone Laboratories, Murray Hill, N. J.
Dr. T. KEITH GLENNAN, president, Case Institute of Technology, Cleveland, Ohio.
Dr. EDWIN M. MCMILLAN, professor of physics, University of California Radiation Laboratory, Berkeley, Calif.
EGER V. MURPHREE, president, ESSO Research & Engineering Co., New York, N. Y.
Dr. EDWARD TELLER, associate director, University of California Radiation Laboratory, Berkeley, Calif.
Dr. J. C. WARNER, president, Carnegie Institute of Technology, Pittsburgh, Pa.
Dr. ROBERT E. WILSON, Standard Oil Co., Chicago, Ill.
Dr. JANE H. HALL, secretary; Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Patent Compensation Board

This board was established in April 1949 pursuant to Section 11 of the Atomic Energy Act of 1946, and is the Board designated under Section 157a of the Atomic Energy Act of 1954. Section 157 provides that upon application for just compensation or awards or for the determination of a reasonable royalty fee certain proceedings shall be held before such a board.

CASPER W. OOMS, chairman; firm of Casper W. Ooms, Chicago, Ill.
JOHN V. L. HOGAN, consulting engineer, Hogan Laboratories, Inc., New York, N. Y.
LAWRENCE E. KINGSLAND, Kingsland, Rogers & Ezell, St. Louis, Mo.

Advisory Committee on Reactor Safeguards

The committee reviews safety studies and facility license applications referred to it and makes reports thereon, advises the Commission with regard to the hazards of proposed or existing reactor facilities and the adequacy of proposed reactor safety standards, and performs such other duties as the Commission may request. The committee's reports on applications for facility licenses become a part of the record of the application and available to the public, except for security material. Members are appointed by the Commission for a term of 4 years each, and one member is designated by the committee as its chairman. This statutory committee replaced the former Advisory Committee on Reactor Safeguards in 1957.

Dr. C. ROGERS MCCULLOUGH, chairman; project specialist, research and engineering division, Monsanto Chemical Co., Washington, D. C.
Dr. MANSON BENEDICT, professor of nuclear engineering, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. HARVEY BROOKS, dean of engineering and applied physics, Harvard University, Cambridge, Mass.
Dr. WILLARD P. CONNER, manager, physical chemical division, research department, Hercules Powder Co., Wilmington, Del.
Dr. R. L. DOAN, manager, atomic energy division, Phillips Petroleum Co., Idaho Falls, Idaho.
K. R. OSBORN, manager of industrial development, general chemical division, Allied Chemical & Dye Corp., New York, N. Y.
D. A. ROGERS, manager, central engineering, Allied Chemical & Dye Corp., Morristown, N. J.
REUEL C. STRATTON, vice chairman; assistant director, department of research, the Travelers Insurance Cos. of Hartford, Conn.
Dr. ABEL WOLMAN, head, department of sanitary engineering and water resources, Johns Hopkins University, Baltimore, Md.
R. H. GRAHAM, technical secretary; Lockheed Aircraft Corp., Palo Alto, Calif.
J. B. GRAHAM, executive assistant, Atomic Energy Commission, Washington, D. C.

ATOMIC ENERGY LABOR MANAGEMENT RELATIONS PANEL

The members of this panel were selected by the President to assist in arriving at peaceful adjustments of labor-management disputes which would imperil the Government's atomic energy program when the normal process of collective bargaining and mediation have been fully utilized without constructive results.

The panel operates under procedures designed to accomplish this purpose. It reports annually to the President on its activities.

CYRUS S. CHING, chairman; industrial relations consultant and former Director of the Federal Mediation and Conciliation Service, Washington, D. C.

Rev. LEO C. BROWN, S. J., professor of economics and director of the Institute of Social Order, St. Louis University, St. Louis, Mo.

Vice Adm. O. S. COLCLOUGH, USN, Retired, dean of faculties, the George Washington University, Washington, D. C.

THOMAS W. HOLLAND, professor of labor economics, the George Washington University, arbitrator and consultant on labor relations, Washington, D. C.

ARTHUR M. ROSS, professor of industrial relations and director of the Institute of Industrial Relations, University of California, Berkeley, Calif.

RUSSELL A. SMITH, professor of law and secretary of the University of Michigan Law School, Ann Arbor, Mich.

ADVISORY BODIES TO THE ATOMIC ENERGY COMMISSION

Advisory Committee for Biology and Medicine

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

Dr. SIMEON T. CANTRIL, chairman; director, Tumor Institute of Swedish Hospital, Seattle, Wash.

Dr. SHIELDS WARREN, vice chairman; pathologist, New England Deaconess Hospital, Boston, Mass.

Dr. JOHN C. BUGHER, director, medical education and public health, Rockefeller Foundation, New York, N. Y.

Dr. CHARLES H. BURNETT, professor of medicine, University of North Carolina, Chapel Hill, N. C.

Dr. H. BENTLEY GLASS, professor of biology, Johns Hopkins University, Baltimore, Md.

Dr. JAMES G. HORSFALL, director, Connecticut Agricultural Experiment Station, New Haven, Conn.

Dr. LEONIDAS D. MARINELLI, associate director, division of radiological physics, Argonne National Laboratory, Lemont, Ill.

Dr. HARLAND G. WOOD, department of biochemistry, school of medicine, Western Reserve University, Cleveland, Ohio.

Dr. HENRY I. KOHN, scientific secretary; clinical professor of experimental radiology, radiological laboratory, school of medicine, University of California Medical Center, San Francisco, Calif.

Advisory 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 Commission 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 judicial 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, school of business administration, University of Michigan, Ann Arbor, Mich.

Advisory Committee on Industrial Information

The committee, formed in 1949, advises and assists in the planning and execution of the Atomic Energy Commission's industrial information program.

E. E. THUM, chairman; editor-in-chief, *Metal Progress*, American Society for Metals, Cleveland, Ohio.

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

Dr. ALLEN G. GRAY, editor, *Metal Progress*, American Society for Metals, Cleveland, Ohio.

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

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

NORMAN H. JACOBSON, *Electric Light and Power*, Haywood Publishing Co., Chicago, Ill.

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

ANDREW W. KRAMER, editor, *Atomics*, The Technical Publishing Co., Barrington, Ill.

JOHN W. LANDIS, assistant manager, atomic energy division, The Babcock & Wilcox Co., representing American Nuclear Society, Chicago, Ill.

Dr. WALTER J. MURPHY, editorial director, Applied Publications, American Chemical Society, Washington, D. C.

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

KARL T. SCHWARTZWALDER, director of research, A-C sparkplug division, General Motors Corp., representing The American Ceramic Society, Inc., Columbus, Ohio.

GEORGE F. SULLIVAN, editor, *The Iron Age*, Chilton Publication, Inc., Philadelphia, Pa.

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

BERNARD M. FRY, secretary; assistant director for technical information service, division of information services, Atomic Energy Commission, Washington, D. C.

Advisory Committee on Isotope Regulation

This committee was originally appointed by the Manhattan Engineer 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. REYNOLDS F. BROWN, department of radiology, University of California Medical School, San Francisco, Calif.

Dr. JOHN A. D. COOPER, assistant dean, Northwestern University Medical School, Chicago, Ill.

Dr. DONALD S. CHILDS, Jr., department of radiology, Mayo Clinic, Rochester, Minn.

Dr. HENRY J. GOMBERG, assistant director, Phoenix Memorial Laboratory, University of Michigan, Ann Arbor, Mich.

Dr. H. R. NELSON, department of physics, Battelle Memorial Institute, Columbus, Ohio.

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

JAMES R. MASON, secretary; chief, isotopes branch, division of licensing and regulation, Atomic Energy Commission, Washington D. C.

Advisory Committee on Reactor Physics

This committee is appointed to consider the status of the development of reactor physics information required for the development of reactor concepts and the design and construction of reactors. Nuclear physics data and reactor physics studies required for the design and development of reactors is reviewed and evaluated. The committee's recommendations and advice are used in planning the research and development work in the field of reactor physics.

Dr. ROBERT A. CHARPIE, chairman; assistant director, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. IRA F. ZARTMAN, vice chairman; engineering development branch, division of reactor development, Atomic Energy Commission, Washington, D. C.

Dr. E. RICHARD COHEN, research adviser, Atomics International, North American Aviation, Inc., Canoga Park, Calif.

DESLONDE DEBOISBLANC, director, reactor physics and engineering, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. GERHARD DESSAUER, director, physics section, E. I. du Pont de Nemours & Co., Inc., Aiken, S. C.

Dr. MILTON EDLUND, manager, physics and math department, Babcock & Wilcox, Lynchburg, Va.

Dr. PAUL F. GAST, manager, physics and instrument research and development, General Electric Co., Richland, Wash.

Dr. IRVING KAPLAN, professor of nuclear engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. HERBERT J. C. KOUTS, experimental reactor physics group leader, Brookhaven National Laboratory, Upton, Long Island, N. Y.

Dr. SIDNEY KRASIK, manager, central physics and math department, Westinghouse Electric Corp., Pittsburgh, Pa.

Dr. THEODORE MERKLE, division leader, "R" division, University of California Radiation Laboratory, Livermore, Calif.

Dr. JOHN W. MORFITT, manager, nuclear development laboratory, General Electric Co., Cincinnati, Ohio.

Dr. HUGH PAXTON, group leader, N2, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. THOMA M. SNYDER, manager, physics—APED, General Electric Co., Pleasanton, Calif.

Dr. BERNARD I. SPINRAD, director, reactor engineering division, Argonne National Laboratory, Lemont, Ill.

Dr. PAUL F. ZWEIFEL, consulting physicist, General Electric Co., Schenectady, N. Y.

Dr. ALVIN RADKOWSKY, secretary; naval reactors branch, division of reactor development, Atomic Energy Commission, Washington, D. C.

Advisory Committee for Standard Reference Materials and Methods of Measurement

The committee was originally established by the Commission in March 1956 as the Committee for Uranium Isotopic Standards. The Commission approved its reconstitution in January 1958 under its present title to reflect the broadened scope of its activities. The committee reviews, evaluates and recommends means for providing standard reference materials (i. e., certified chemical and isotopic standards for uranium, plutonium, etc.) and approved methods of measurement for materials of special importance to atomic energy activities.

DONALD F. MUSSER, chairman; director, division of nuclear materials management, Atomic Energy Commission, Washington, D. C.

Dr. MARK G. INGHRAM, professor of physics, University of Chicago, Chicago, Ill.

Dr. SAMUEL C. T. MCDOWELL, chief, chemistry and physics branch, division of nuclear materials management, Atomic Energy Commission, Washington, D. C.

Dr. CHARLES F. METZ, group leader, analytical chemistry group, chemistry and metallurgical research division, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. HORACE W. NORTON, III, professor of statistical design and analysis, University of Illinois, Urbana, Ill.

Dr. EDWIN F. ORLEMANN, professor of chemistry and chemical engineering, University of California, Berkeley, Calif.

Dr. LEONARD P. PEPKOWITZ, vice president, Nuclear Materials and Equipment Corp., Apollo, Pa.

C. J. RODDEN, area manager, New Brunswick Area Office, Atomic Energy Commission, New Brunswick, N. J.

C. D. W. THORNTON, assistant to the president for atomic energy, Farnsworth Electronics Co., Fort Wayne, Ind.

Dr. EDWARD WICHERS, associate director, National Bureau of Standards, Department of Commerce, Washington, D. C.

Advisory Committee of State Officials

This committee was established by the Commission in September 1955 as a means of obtaining the views and advice of State regulatory agencies in connection with the Atomic Energy Commission's regulatory activities in the field of public health and safety.

Dr. DANIEL BERGSMA, commissioner of health, Trenton, N. J.

A. C. BLACKMAN, chief, division of industrial safety, California Department of Industrial Relations, San Francisco, Calif.

Dr. ROY L. CLEERE, executive director, Colorado State Department of Public Health, Denver, Colo.
CURTISS M. EVERTS, Jr., State sanitary engineer, Oregon State Board of Health, Portland, Oreg.
JAMES G. FROST, deputy attorney general of Maine, Augusta, Maine.
Dr. ALBERT E. HEUSTIS, commissioner of health, Lansing, Mich.
Dr. JAN LIEBEN, director, division of industrial hygiene, Department of Health, Harrisburg, Pa.
WILLIAM T. LINTON, executive director, water pollution control authority, South Carolina State Board of Health, Columbia, S. C.
B. A. POOLE, director, bureau of environmental sanitation, State Board of Health, Indianapolis, Ind.
DONALD P. ROBERTS, chief, industrial hygiene section, Tennessee Department of Health, Nashville, Tenn.

Committee 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.

THOROLD F. FIELD, consulting mining engineer, Duluth, Minn.
FRANCIS C. FRARY, technical adviser, aluminum research laboratory, Aluminum Co. of America, New Kensington, Pa.
J. K. GUSTAFSON, consulting geologist, M. A. Hanna Co., Cleveland, Ohio.
ERNEST ROSE, metallurgist, Koppers Co., Pittsburgh, Pa.
WALTER O. SNELLING, research chemist, Allentown, Pa.
ORVIL R. WHITAKER, consulting mining engineer, Denver, Colo.
CLYDE WILLIAMS, president and director, Battelle Memorial Institute, Columbus, Ohio.

Committee of Senior Reviewers

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

Dr. ALVIN C. GRAVES, chairman; J division leader, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. JOHN P. HOWE, chief, research department, Atomics International, North American Aviation, Inc., Downey, Calif.
Dr. FRANK C. HOYT, physics division manager, missiles system division, Lockheed Aircraft Corp., Palo Alto, Calif.
Dr. WARREN C. JOHNSON, dean of physical sciences, University of Chicago, Chicago, Ill.
Dr. WINSTON M. MANNING, director, chemistry division, Argonne National Laboratory, Lemont, Ill.
Dr. J. R. RICHARDSON, professor of physics University of California at Los Angeles, Calif.

Metallurgy and Materials Advisory Panel

This panel was established in October 1955 to advise on the Commission's research program on metallurgy, solid state physics, and ceramics.

Dr. HARVEY BROOKS, division of engineering sciences, Harvard University, Cambridge, Mass.

Dr. MORRIS COHEN, department of metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. MAXWELL GENSAMER, professor of metallurgy, Columbia University, New York, N. Y.

Dr. JOHN P. HOWE, chief, research department, Atomics International, a division of North American Aviation, Inc., Downey, Calif.

Dr. ALBERT R. KAUFMAN, vice president, Nuclear Metals, Inc., Cambridge, Mass.

Dr. FREDERICK SEITZ, department of physics, University of Illinois, Urbana, Ill.

Dr. JOHN C. SLATER, department of physics, Massachusetts Institute of Technology, Cambridge, Mass.

Dr. DONALD K. STEVENS, division of research, Atomic Energy Commission, Washington, D. C.

Nuclear Cross Sections Advisory Group

This group is appointed on a yearly basis to make a continuing review of the Commission's program of nuclear cross-section measurements, and to evaluate the needs for cross-section information in the various activities of the Commission. The following members were appointed to serve from July 1957 to July 1958.

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

Dr. GEORGE A. KOLSTAD, vice chairman; division of research, Atomic Energy Commission, Washington, D. C.

Dr. LOWELL M. BOLLINGER, Argonne National Laboratory, Lemont, Ill.

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

Dr. BENJAMIN C. DIVEN, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

Dr. REX G. FLUHARTY, Phillips Petroleum Co., Idaho Falls, Idaho.

Dr. HERBERT GOLDSTEIN, Nuclear Development Corp. of America, White Plains, N. Y.

Dr. JOHN A. HARVEY, physics division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Dr. BOWEN R. LEONARD, General Electric Co., Richland, Wash.

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

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

Dr. MAX L. YEATOR, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.

Dr. IRA F. ZARTMAN, division of reactor development, Atomic Energy Commission, Washington, D. C.

Dr. VANCE L. SAILOR, secretary; reactor division, Brookhaven National Laboratory, Upton, Long Island, N. Y.

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.

Jo. Baily Brown; Brown, Critchlon, Flick & Peckham, Pittsburgh, Pa.
John A. Dienner; 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 also advises the Commission on the broader considerations regarding personnel security, such as criteria for determining eligibility for security clearance and personnel security procedures.

Ganson Purcell, chairman; Purcell & Nelson, Washington, D. C.
Dr. Paul E. Klopsteg, associate director, National Science Foundation, Washington, D. C.
John J. Wilson, firm of Whiteford, Hart, Carmody & Wilson, Washington, D. C.

Sherwood Steering Committee

This committee was approved by the Commission in January 1954. The committee meets as the need arises to analyze the overall problem, recommend new projects to be undertaken, suggest who might do the work, review progress and proposals, and recommend desirable emphasis and levels of support of research on peaceful uses of controlled thermonuclear reactions.

Dr. John H. Williams, chairman; director, division of research, Atomic Energy Commission, Washington, D. C.
Dr. Arthur E. Ruark, division of research, Atomic Energy Commission, Washington, D. C.
Dr. Lyman Spitzer, Jr., Forrestal Research Center, Princeton University, Princeton, N. J.
Dr. James L. Tuck, technical director, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. Hilliard Roderick, secretary; division of research, Atomic Energy Commission, Washington, D. C.

Stack Gas Problem Working Group

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

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

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

A. E. GORMAN, consultant, Atomic Energy Commission, Washington, D. C.

Dr. H. FRASER JOHNSTONE, professor of chemical engineering, University of Illinois, Urbana, Ill.

Dr. CHARLES E. LAPPLE, Stanford Research Institute, Menlo Park, Calif.

Dr. J. A. LIEBERMAN, division of reactor development, Atomic Energy Commission, Washington, D. C.

Dr. WILLIAM P. YANT, director of research and development, Mine Safety Appliances Co., Pittsburgh, Pa.

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

APPENDIX 3

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

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

Director	Dr. Frank H. Spedding
Associate Director	Dr. H. A. Wilhelm
Assistant to Director	Dr. 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), Lemont, Ill.

Director	Dr. Norman Hilberry
Assistant Director	Dr. James R. Gilbreath
Business Manager	John H. McKinley
Manager, Technical Services	John T. Bobbitt

The participating institutions are:

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

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

Plant Manager, Westinghouse Electric Corp	JOHN W. SIMPSON
Manager, PWR Project	JOSEPH C. RENGEL
Manager, S3W Project	ALEXANDER SQUIRE
Manager, A1W Project	JOHN T. STIEFEL
Manager, S5W Project	DOUGLAS C. SPENCER
Manager, C1W Project	KARL W. SCHWANEKAMP
Manager, S1W Site, Naval Reactor Test Facility (NRTS), Idaho.	JOHN M. YADON

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

Chairman, Board of Trustees	JOSEPH C. ELGIN
President, AUI	LLOYD V. BERKNER
Vice President, AUI and Laboratory Director	Dr. LELAND J. HAWORTH
Deputy Laboratory Director	Dr. GERALD F. TAPE
Associate Director	WILLIAM H. FIELDS
Assistant Director	Dr. ROBERT A. PATTERSON
Assistant Director	R. CHRISTIAN
Assistant to Director	SAMUEL M. TUCKER

The participating institutions are:

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

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

General Manager	F. E. CREVER
Manager, D1G Project	K. A. KESSELRING
Manager, S3G Project	B. W. CALDWELL, Jr.
Manager, S1G Project	W. N. OBERLY
Manager, Technical Operations	Dr. H. J. PLUMBLEY
Manager, Advanced Development	Dr. W. R. KANNE
Manager, Operational Analysis	W. N. OBERLY
Manager, Auxiliary Operation	S. B. STROM

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

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

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

President of Institute	Dr. PAUL M. GROSS
Vice President of Institute	Dr. W. C. JOHNSON
Executive Director of Institute	Dr. WILLIAM G. POLLARD
Chairman of Council	Dr. MARTEN TEN HOOR
Vice Chairman of Council	Dr. R. T. LAGEMANN

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
Meharry Medical College
Mississippi State College
North Carolina State College
North Texas State College
Rice Institute
Southern Methodist University
Tulane University of Louisiana
Tuskegee Institute
University of Alabama
University of Arkansas
University of Florida
University of Georgia
University of Kentucky
University of Louisville
University of Maryland
University of Miami
University of Mississippi
University of North Carolina
University of Oklahoma
University of Puerto Rico
University of South Carolina
University of Tennessee
University of Texas
University of Virginia
Vanderbilt University
Virginia Polytechnic Institute
West Virginia University

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

Director	Dr. A. M. WEINBERG
Deputy Director	Dr. J. A. SWARTHOUT
Assistant Laboratory Director	Dr. G. E. Boyd
Assistant Laboratory Director	Dr. R. A. CHARPIE
Assistant Laboratory Director	Dr. A. H. SNELL
Assistant Laboratory Director	Dr. R. W. JOHNSON
Assistant Laboratory Director	Dr. C. E. WINTERS
Assistant Laboratory Director	M. E. RAMSEY

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

Technical Director and Manager	CHARLES K. MCARTHUR

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

President	JAMES W. MCRAE
Vice President and General Manager	MAX H. HOWARTH

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

Director	Dr. STAFFORD WARREN
Project Manager	(Vacancy)

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

Director	Dr. ROBERT S. STONE

University of California 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 and Director, Livermore Laboratory	Dr. EDWARD TELLER
Assistant Director	Dr. ROBERT L. THORNTON
Director, Donner Laboratory of Medical Physics	Dr. J. H. LAWRENCE
Business Manager and Managing Engineer	WALLACE B. REYNOLDS

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

Director	Dr. HENRY A. BLAIR
Business Manager	C. S. THOMPSON

National Reactor Testing Station (NRTS), Idaho Falls, Idaho

Nevada Test Site, Las Vegas, Nev.

Eniwetok Proving Ground, Marshall Islands

APPENDIX 4

Radioactive Isotope Distribution Data [1]

Radioactive Isotope	Aug. 2, 1946–Dec. 31, 1957		Jan. 1, 1958–May 31, 1958		Total to May 31, 1958	
	Activity (Curies)	Shipments	Activity (Curies)	Shipments	Activity (Curies)	Shipments
Iodine 131	4,866	37,596	587	1,648	5,453	39,244
Phosphorus 32	1,262	21,955	114	1,068	1,376	23,023
Carbon 14	59	2,910	4	101	63	3,011
Tritium	12,228	597	5,332	61	17,560	658
Strontium 89, 90	438	1,252	6	73	444	1,325
Cobalt 60	336,504	1,681	59,104	106	395,608	1,787
Cesium 137	11,348	922	1,929	85	13,277	1,007
Iridium 192	16,672	462	1,814	61	18,486	523
Others	2,449	22,457	1,469	2,504	3,918	24,961
Irradiated Units [2]	----------	14,692	----------	571	----------	15,263
Total	385,826	104,524	70,359	6,278	456,185	110,802
Shipments to AEC installations	----------	12,011	----------	568	----------	12,579

[1] Domestic shipments from Oak Ridge National Laboratory.
[2] Includes irradiated units of Iodine 131 and Phosphorus 32.

LOCATION AND TYPE OF NEW USERS

(Jan. 1, 1958–May 31, 1958)

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska	0	0	0	1	0	0	1
Alabama	3	0	2	2	0	0	7
Arizona	0	0	0	0	0	0	0
Arkansas	2	0	0	1	0	0	3
California	16	0	16	0	0	2	34
Colorado	0	0	2	4	0	0	6
Connecticut	1	0	1	3	0	1	6
Delaware	1	0	0	0	0	0	1
District of Columbia	5	0	0	3	0	1	9
Florida	4	1	0	0	0	0	5
Georgia	4	1	1	1	0	0	7
Hawaii	2	0	0	1	0	0	3
Idaho	0	0	0	0	0	0	0
Illinois	6	0	6	0	1	0	13
Indiana	3	0	3	0	0	0	6
Iowa	2	1	1	0	0	1	5
Kansas	2	0	2	1	0	0	5
Kentucky	1	0	0	0	0	0	1
Louisiana	1	0	2	0	0	0	3
Maine	0	0	0	0	0	0	0
Maryland	2	1	2	2	0	0	7
Massachusetts	6	0	7	0	0	0	13
Michigan	7	1	5	1	0	1	15
Minnesota	2	0	1	25	0	0	28
Mississippi	0	0	0	0	0	0	0
Missouri	1	2	1	0	1	0	5
Montana	0	0	1	0	0	0	1
Nebraska	0	0	0	0	0	1	1
Nevada	0	0	0	0	0	0	0
New Hampshire	0	1	0	0	0	0	1
New Jersey	6	0	5	3	0	2	16
New Mexico	2	0	0	1	0	0	3
New York	16	1	14	4	0	1	36
North Carolina	4	0	0	1	0	0	5
North Dakota	0	0	0	0	0	0	0
Ohio	7	0	5	3	0	0	15
Oklahoma	1	0	0	3	0	0	4
Oregon	3	0	0	1	0	0	4
Panama	0	0	0	0	0	0	0
Pennsylvania	5	0	18	4	0	0	27
Puerto Rico	1	0	0	2	0	0	3
Rhode Island	1	0	0	0	0	0	1
South Carolina	0	0	0	1	0	0	1
South Dakota	0	0	0	3	0	0	3
Tennessee	3	0	3	1	0	0	7
Texas	8	2	6	10	0	0	26
Utah	1	0	0	1	0	0	2
Vermont	0	0	0	0	0	0	0
Virginia	3	1	2	0	0	1	7
Washington	0	0	3	0	0	0	3
West Virginia	1	0	1	1	0	0	3
Wisconsin	2	0	3	0	0	0	5
Wyoming	1	0	0	0	0	0	1
Total	136	12	113	84	2	11	358

LOCATION AND TYPE OF ALL USERS

(Feb. 10, 1956–May 31, 1958)

States and Territories	Medical Institutes and Physicians	Colleges and Universities	Industrial Firms	Federal and State Laboratories	Foundations and Institutes	Other	Total
Alaska	2	1	0	2	0	0	5
Alabama	19	4	20	5	0	0	48
Arizona	6	2	4	0	0	0	12
Arkansas	16	1	7	3	0	0	27
California	180	9	149	27	3	4	372
Colorado	25	4	12	9	0	3	53
Connecticut	19	4	35	14	2	1	75
Delaware	2	1	7	3	0	0	13
District of Columbia	22	3	2	18	0	1	46
Florida	41	6	10	5	0	1	63
Georgia	22	3	13	4	0	0	42
Hawaii	7	1	2	3	2	0	15
Idaho	3	2	2	0	0	0	7
Illinois	96	18	89	17	5	2	227
Indiana	40	5	36	1	0	0	82
Iowa	25	5	8	0	0	1	39
Kansas	22	2	8	3	0	0	35
Kentucky	17	3	10	2	0	2	34
Louisiana	23	3	25	1	0	2	54
Maine	5	2	14	5	1	1	28
Maryland	21	4	19	14	0	1	59
Massachusetts	48	24	75	7	6	2	162
Michigan	67	8	45	11	3	1	135
Minnesota	31	6	16	26	0	1	80
Mississippi	6	3	4	1	0	0	14
Missouri	52	8	16	11	1	4	92
Montana	9	2	2	0	0	0	12
Nebraska	15	1	2	1	0	1	20
Nevada	4	0	0	2	0	0	6
New Hampshire	4	3	1	4	0	0	12
New Jersey	62	4	104	11	1	2	185
New Mexico	11	2	6	3	0	0	22
New York	255	21	150	30	4	5	465
North Carolina	30	6	12	6	0	1	55
North Dakota	7	2	0	0	0	0	9
Ohio	88	9	67	11	4	0	179
Oklahoma	23	2	29	5	2	1	62
Oregon	17	2	4	5	0	0	28
Panama	0	0	0	0	0	0	0
Pennsylvania	85	15	130	28	2	0	260
Puerto Rico	7	2	0	2	0	0	11
Rhode Island	8	2	12	3	0	0	25
South Carolina	6	2	3	1	0	0	12
South Dakota	11	1	0	4	0	0	16
Tennessee	32	7	16	3	0	2	60
Texas	113	8	87	17	3	1	229
Utah	9	3	4	4	0	1	21
Vermont	2	1	2	1	0	0	6
Virginia	30	5	22	8	0	3	68
Washington	19	4	13	8	0	1	45
West Virginia	19	1	8	2	0	0	30
Wisconsin	45	3	31	2	4	0	85
Wyoming	6	1	1	0	0	0	8
Total	1,734	241	1,334	353	43	45	3,750

SHIPMENTS OF RADIOACTIVE ISOTOPES TO FOREIGN COUNTRIES

Country	Jan. 1, 1958–May 31, 1958	Total Jan. 1, 1947 to May 31, 1958	Country	Jan. 1, 1958–May 31, 1958	Total Jan. 1, 1947 to May 31, 1958
Argentina	5	140	Italy	7	93
Australia	9	135	Japan	97	778
Austria	1	5	Korea	0	1
Belgian Congo	4	7	Lebanon	18	25
Belgium	31	243	Mexico	51	389
Bermuda	0	16	Monaco	1	1
Brazil	73	722	Netherlands	41	176
British West Indies [1]	3	12	Netherlands West Indies	1	1
Burma	0	6	New Zealand	2	18
Canada	376	2,422	Nicaragua	8	15
Chile	14	189	Norway	13	96
Colombia	5	68	Pakistan	1	11
Costa Rica	3	6	Peru	19	145
Cuba	70	673	Philippines	48	136
Denmark	28	295	Portugal	5	19
Dominican Republic	16	23	Republic of China	15	29
Ecuador	14	31	Russia	0	1
Egypt	5	16	Scotland	1	1
El Salvador	3	4	Southwest Africa [2]	1	5
England	57	279	Spain	8	31
Federal Republic of Germany	52	181	Sweden	100	441
Finland	6	34	Switzerland	11	111
France	27	234	Syria	0	2
Gold Coast	0	1	Thailand	1	15
Greece	8	17	Trieste	0	4
Guatemala	3	44	Turkey	2	7
Honduras	1	4	Union of South Africa	2	41
Iceland	0	5	Uruguay	0	13
India	8	77	Venezuela	114	453
Indonesia	0	6	Yugoslavia	8	19
Iran	2	8	Total	1,415	9,038
Israel	16	58			

Kind of Isotope	Jan. 1, 1958–May 31, 1958	Total Jan. 1, 1958 to May 31, 1958	Kind of Isotope	Jan. 1, 1958–May 31, 1958	Total Jan. 1, 1958 to May 31, 1958
Phosphorus 32	80	1,214	Strontium 89, 90	35	243
Iodine 131	570	3,448	Calcium 45	18	190
Carbon 14	50	569	Other	436	2,089
Sulfur 35	8	168	Total	1,415	9,039
Iron 55, 59	71	430			
Cobalt 60	147	687			

[1] Includes those shipments previously reported as shipments to Trinidad.
[2] Includes those shipments previously reported as shipments to British West Africa.

APPENDIX 5

COMMISSION-OWNED PATENTS

PATENTS ISSUED TO THE COMMISSION WHICH ARE AVAILABLE FOR LICENSING [1]

The following 135 U. S. Letters Patents owned by the United States Government as represented by the Atomic Energy Commission are in addition to the 126 patents listed in the Twenty-third Semiannual report. The patents listed have been made available for licensing at periodic intervals. The total number of patents available for licensing is 1,480. Licenses are granted on a nonexclusive, royalty-free basis.

PATENT NO.	TITLE	PATENTEE
2,472,645	Thermal Conductivity Analysis of Gases	W. J. Clark, Norton-on-Tees, England.
2,473,911	Production of Fluorocarbons	N. F. Sarsfield, Runcorn, England.
2,478,666	Production of Fluorine-Containing Hydrocarbon Derivatives.	N. F. Sarsfield, Runcorn, England.
2,650,085	Apparatus for the Purification of Calcium	R. L. Burnett, Overton, England.
2,650,153	Process for the Production of Ammonium *Uranium Fluoride*.	A. S. Ellis, Runcorn, and R. B. Mooney, *Liverpool, England*.
2,653,856	Preparation of Beryllium Fluoride	Guy Barr, Teddington, England.
2,654,654	Process for the Production of Uranium Tetrafluoride.	A. S. Leah, Runcorn, and R. B. Mooney, Liverpool, England.
2,684,898	Distillation of Calcium	James Barton, Widnes, England.
2,686,474	Electromagnetic Pump	O. O. Pulley, Abingdon, England.
2,687,995	Electrolytic Production of Uranium Tetrafluoride.	E. Lofthouse, Runcorn, England.
2,689,165	Process for Producing Uranium Tetrafluoride	B. G. Harvey, Liverpool, England.
2,703,366	Timing of Shock Waves	J. L. Tuck, Oxford, England.
2,711,361	Process for the Recovery of Uranium	G. O. Morris, Rainhill, England.
2,742,577	Quartz Fiber Electroscopes	R. P. Henderson, Abingdon, England.
2,745,985	Pulse Amplitude Analysers	I. A. Darroch Lewis, Wantage, Berkshire, England.
2,770,781	Wave Delaying Structure for Rectangular Wave-Guides.	R. B. Robertson-Shersby-Harvie, Great Malvern, and John Dain, Abingdon, England.
2,790,149	Dielectric-Loaded Wave Guides	R. B. Robertson-Shersby-Harvie, Great Malvern, and L. B. Mullett, Melvern Wells, England.
2,807,857	Production of Thoria Ware	P. Murray, Abingdon, I. E. Denton, Chilton, and D. Wilkinson, Nelson, England.
2,808,312	Process for Treating Volative Metal Fluorides	A. J. Rudge, Frodsham, and A. J. Lowe, Atherton, England.
2,814,849	Process of Producing Refractory Uranium Oxide Articles.	N. E. Hamilton, Ames, Iowa.
2,814,857	Ceramic Fuel Element Material for a Neutronic Reactor and Method of Fabricating Same.	W. H. Duckworth, Columbus, Ohio.
2,815,261	Uranium Precipitation Process	A. Thunaes, E. A. Brown, H. W. Smith, and R. Simard, Ottawa, Canada.
2,815,262	Separation Process for Thorium	G. L. Bridger, M. E. Whatley, and K. G. Shaw, Ames, Iowa.
2,815,264	Processing of Monazite Sand	G. D. Calkins, Columbus, Ohio; E. G. Bohlmann, Oak Ridge, Tenn.
2,815,265	Metal Recovery Process	L. B. Werner and O. F. Hill, Richland, Wash.
2,815,266	Method of Preparing PuF_4	R. E. Heath, Grosse Ile, Mich.; A. E. Florin, Los Alamos, N. Mex.
2,815,277	Method for Removing Sodium Oxide from Liquid Sodium.	W. H. Bruggeman, Watervliet, and B. G. Voorhees, Schenectady, N. Y.
2,815,319	Fast Neutronic Reactor	A. H. Snell, Oak Ridge, Tenn.
2,815,321	Isotope Conversion Device	E. P. Wigner, L. A. Ohlinger, and G. J. Young, Chicago, Ill.
2,815,968	Seal for Rotating Shaft	R. T. Coffman, Richland, Wash.
2,816,005	Extraction of Uranyl Nitrate from Aqueous Solutions.	N. H. Furman, Princeton, and R. J. Mundy, Perth Amboy, N. J.
2,816,042	Refractory Article and Process of Manufacturing Same.	N. E. Hamilton, Ames, Iowa.
2,816,068	Reactor Control	W. J. Ruano, Chicago, Ill.

[1] Patents listed as of May 6, 1958. Applicants for licenses should apply to Chief, Patent Branch, Office of the General Counsel, U. S. Atomic Energy Commission, 1717 H St., N. W., Washington 25, D. C., identifying the subject matter by patent number and title.

PATENT No.	TITLE	PATENTEE
2,816,122	Method of Recovering Thorium	R. W. Fisher, Ames, Iowa.
2,816,476	High-Speed Camera	B. T. Rogers, Jr., and W. C. Davis, Los Alamos, N. Mex.
2,816,704	Seal for High Speed Centrifuge	C. W. Skarstrom, Pearl River, N. Y.
2,816,813	Fractional Distillation Separation of Plutonium Values from Light Element Values.	B. B. Cunningham, Chicago, Ill.
2,816,860	Means for Controlling a Nuclear Reactor	V. C. Wilson and I. Slatin, Santa Fe, N. Mex.; W. P. Overbeck, Richland, Wash.; D. K. Froman, Denver, Colo.
2,817,019	Shock-Excited Oscillator	R. Creveling, Albuquerque, N. Mex.
2,817,036	Spark Gap Switch	R. B. Neal, Palo Alto, Calif.
2,817,060	Non-Destructive Flaw Detection Apparatus	M. J. Stateman, Wantaugh, and H. R. Halloway, Fresh Meadows, N. Y.
2,817,350	Device for Control of Oxygen Partial Pressure	H. Bradner, Berkeley, and H. S. Gordon, Lafayette, Calif.
2,817,605	Method for Sealing the Pores in a Carbon Body	M. C. Sanz, C. R. Malmstrom, J. M. Nuding, Los Angeles, and H. P. Yockey, Inglewood, Calif.
2,817,763	Ion Source for a Calutron	J. G. Backus, Berkeley, Calif.
2,818,208	Gas Metering Pump	C. M. George, Maracaibo, Venezuela.
2,818,324	Liquid-Liquid Extraction Columns	J. D. Thornton, Abingdon, England.
2,818,504	Logarithmic Amplifier	J. A. DeShong, Jr., Elmhurst, Ill.
2,818,507	Velocity Selector Method for the Separation of Isotopes.	R. J. Britten, Washington, D. C.
2,818,605	Method of Making a Refractoy Material	H. I. Miller, New York, N. Y.
2,818,726	Automatic Calibrating System for Pressure Transducers.	E. L. Amonette and G. W. Rodgers, Albuquerque, N. Mex.
2,819,053	Acceleration Integrator	K. E. Pope, Albuquerque, N. Mex.
2,819,143	Plutonium Separation Method	J. L. Dreher, El Cerrito and S. G. Thompson, Richmond, Calif.
2,819,144	Separation of Plutonium From Uranium and Fission Products by Adsorption.	G. T. Seaborg and J. E. Willard, Chicago, Ill.
2,819,280	Plutonium Compounds and Process for Their Preparation.	F. J. Wolter, Cleveland, Ohio; H. C. Diehl, Jr., Ames, Iowa.
2,819,396	Electronic Trigger Circuit	J. A. G. Russell, El Cerrito, Calif.
2,819,401	Apparatus for Controlling Position of an Ion Beam in a Calutron.	E. O. Lawrence, Berkeley, Calif.
2,819,944	Purification Process	H. L. Wibbles, Joliet, Ill.; E. I. Miller, St. Louis, Mo.
2,820,182	Photosensitive Relay Control Circuit	C. F. Martin, Albuquerque, N. Mex.
2,820,192	Tube Tester	H. T. Gittings, Jr., Los Alamos, N. Mex.; J. F. Kalbach, Altadena, Calif.
2,820,367	Device for Conveying and Rotating Objects	C. E. Frants, Richland, Wash.; J. Roslund Hayward, Calif.
2,820,692	Process of Dissolving Zirconium Alloys	R. S. Shor and S. Vogler, Chicago, Ill.
2,820,751	Process for Producing Jacketed Bodies	H. A. Saller (deceased).
2,820,753	Nuclear Reactor	H. I. Miller, New York, N. Y.; R. C. Smith, Washington, D. C.
2,820,759	Method of Separating Froths From Liquid	G. P. Monet, Wilmington, Del.
2,820,895	Pulse Height Analyzer	C. W. Johnstone, Los Alamos, N. Mex.
2,820,896	Multichannel Pulse-Height Analyzer	J. T. Russell, Seattle, and H. W. Lefevre, Richland, Wash.
2,821,505	Process of Coating Metals With Bismuth or Bismuth-Base Alloys.	J. G. Beach, Columbus, Ohio.
2,821,632	Apparatus for Producing Ions of Vaporizable Materials.	B. T. Wright, Berkeley, Calif.
2,821,636	Go-Devils	S. Jefferson, Abingdon, England.
2,821,662	Ion Source	W. A. Bell, Jr., and L. O. Love, Oak Ridge; W. K. Prater, Fountain City, Tenn.
2,822,239	Method of Separating Plutonium	H. S. Brown and O. F. Hill, Oak Ridge, Tenn.
2,822,260	Decontamination of Uranium	H. M. Feder, Park Forest, and N. R. Chellew, Joliet, Ill.
2,822,472	Negative Gate Generator	C. S. Jones, Los Angeles, Calif.; T. E. Eaton, Los Alamos, N. Mex.
2,822,473	Pulse Duration Lengthener	W. R. Aiken, Berkeley, Calif.
2,822,479	Radiation Counter	W. W. Goldsworthy, Orinda, Calif.
2,822,578	Injection-Moulding Apparatus	G. M. Lobell, Midlothian, Ill.
2,823,116	Method of Preparing Sintered Zirconium Metal From its Hydrides.	R. P. Angier, New York, N. Y.
2,823,179	Detection of Coating Failures in a Neutronic Reactor.	Arthur H. Snell, Oak Ridge, Tenn.; Samuel K. Allison, Chicago, Ill.
2,823,350	Method of Locating Grounds	K. Macleish, Oak Ridge, Tenn.
2,823,976	Recovery of Thorium and Uranium Values From Aqueous Solutions.	G. D. Calkins, Worthington, Ohio
2,823,977	Method of Dissolving Uranium Metal	L. A. Slotin, Oak Ridge, Tenn.
2,823,978	Precipitation Method of Separating Plutonium From Contaminating Elements.	J. B. Sutton, Wilmington, Del.
2,824,056	Reactor Unloading	M. C. Leverett, Oak Ridge, Tenn.
2,824,234	Method and Means for Radiation Dosimetry	J. W. Schulte, Los Alamos, and J. F. Suttle, Albuquerque, N. Mex.
2,824,252	Ionization Chamber	W. C. Redman, Hinsdale, and F. R Shonka, Riverside, Ill.

PATENT NO.	TITLE	PATENTEE
2,824,365	Soldering of Aluminum Base Metals	G. F. Erickson, Chicago, Ill.
2,824,732	Apparatus for Melting and Pouring Metal	F. A. Harris, Oak Ridge, Tenn.
2,824,783	Separation of Scandium From Aqueous Solutions.	D. F. Peppard, Oak Park, and E. S. Nachtman, Park Forest, Ill.
2,824,784	Method for the Preparation of Stable Actinide Metal Oxide-Containing Slurries and of the Oxides Therefor.	R. S. Hansen, Ames, Iowa; R. E. Minturn, Oak Ridge, Tenn.
2,824,841	Scintillator Composition for Counters and Method of Making.	W. L. Buck, Park Forest, and R. K. Swank, Downers Grove, Ill.
2,824,967	Calutron	M. D. Kamen, Berkeley, Calif.
2,824,973	Radiation Detector System	J. S. Gundlach, Loudon County, and G. G. Kelley, Kingston, Tenn.
2,825,105	Metal Production and Casting	T. T. Magel, Cambridge, Mass.
2,825,599	Grab Mechanisms	K. H. Dent, Warrington, England.
2,825,688	Power Generating Neutronic Reactor System	H. C. Vernon, Wilmington, Del.
2,825,689	Neutronic Reactor and Fuel Element Therefor	L. Szilard, Chicago, Ill.; G. J. Young, Hawthorne, N. Y.
2,825,818	Gas Phototube Circuit	J. H. Richardson, Los Alamos, N. Mex.
2,826,495	Alloy for Use in Nuclear Fission	F. H. Spedding and Harley A. Wilhelm, Ames, Iowa.
2,826,624	Vapor Shield for Induction Furnace	S. L. Reese, Baltimore, Md.; S.O. Samoriga, Hamilton, Ohio.
2,826,708	Plasma Generator	J. S. Foster, Jr., Livermore, Calif.
2,827,429	Cooled Neutronic Reactor	C. R. Binner, Highland Park, Ill.; C. B. Wilkie, East Point, Ga.
2,827,569	Stabilized Oscillator	P. L. Jessen, Albuquerque, N. Mex.; H. J. Price, N. Weymouth, Mass.
2,828,425	Pulse Amplitude Analyzer	M. H. Greenblatt, Princeton, N. J.
2,828,875	Remote Handling Arrangements	D. W. Ginns, Welwyn Garden City, England.
2,829,293	Lead Severing Contrivance	Wm. Widmaier, Lancaster, Pa.
2,829,316	Control and Fault Detector Circuit	C. N. Winningstad, San Lorenzo, Calif.
2,829,408	Centrifugal Casting Machine	A. B. Shuck, Wheaton, Ill.
2,830,066	Separation Process for Transuranic Element and Compounds Thereof.	L. B. Magnusson, Richmond, Calif.
2,830,871	Uranium Recovery Process	D. Kaufman, Cambridge, and C. S. Abrams, Boston, Mass.
2,830,873	Fluoride Volatility Process for the Recovery of Uranium.	J. J. Katz and H. H. Hyman, Chicago, and I. Sheft, Oak Park, Ill.
2,830,874	Ion Exchange Process for the Recovery and Purification of Materials.	R. S. Long, Vallejo, and R. H. Bailes, Walnut Creek, Calif.
2,830,894	Production of Uranium	F. H. Spedding and H. A. Wilhelm, Ames, Iowa; W. H. Keller, St. Louis, Mo.
2,830,896	Uranium Alloys	Alan U. Seybolt, Scotia, N. Y.
2,830,921	Production of Uranium Tubing	E. C. Creutz, Chicago, Ill.
2,830,939	Process of Separating Plutonium Values by Electrodeposition.	A. C. Wahl, St. Louis County, Mo.
2,830,944	Neutronic Reactor	E. P. Wigner, A. M. Weinberg and G. J. Young, Chicago, Ill.
2,831,122	Radiation Sources	M. H. Brucer, Oak Ridge, Tenn.
2,831,162	Time-Interval Measuring Device	J. E. Gross, Albuquerque, N. Mex.
2,831,750	Separating Protoactinium With Manganese Dioxide.	G. T. Seaborg, Chicago, Ill.; J. W. Gofman, Berkeley, Calif.; R. W. Stoughton, Oak Ridge, Tenn.
2,831,806	Neutronic Reactor	E. P. Wigner, Princeton, N. J.
2,831,807	Neutronic Reactor	R. J. McGarry, Rutland, Vt.
2,831,990	Electromagnetic Apparatus for Moving a Rod	J. N. Young, Chicago, Ill.
2,831,996	Ion Source	E. F. Martina, Castro Valley, Calif.
2,832,002	Time Calibrated Oscilloscope Sweep	H. M. Owren, Livermore, B. M. Johnson, Berkeley, and V. L. Smith, Livermore, Calif.
2,832,113	Ingot Mold	A. J. Mangold, Delhi Township Hamilton County; J. W. Mahaffey, Harrison, and S. L. Reese, Cincinnati, Ohio.
2,832,732	Fuel Assembly for a Neutronic Reactor	E. P. Wigner, Princeton, N. J.
2,832,733	Heavy Water Moderated Neutronic Reactor	L. Szilard, Chicago, Ill.
2,832,793	Process for Separation of Heavy Metals	R. B. Duffield, Asbury Park, N. J.
2,833,616	Separation of Uranium From Zirconium and Niobium by Solvent Extraction.	E. E. Voiland, Richland, Wash.
2,833,617	Fluorine Process for Separation of Materials	G. T. Seaborg, and H. S. Brown, Chicago, Ill.
2,833,618	Separating Uranium Containing Solids Suspended in a Liquid.	E. C. Creutz, Santa Fe, N. Mex.; E. P. Wigner, Chicago, Ill.
2,833,799	Recovery of Tetravalent Cations From Aqueous Solutions.	R. L. Moore, Richland, Wash.
2,833,800	Process for Purifying Plutonium	D. F. Mastick, Napa, Calif.; A. C. Wahl, University City, Mo.
2,833,927	Method of Separating Isotopes of Uranium in a Calutron.	F. A. Jenkins, Berkeley, Calif.
2,833,965	Electrical Protective Device	W. R. Baker, Orinda, Calif.

APPENDIX 6

Publications of the U. S. Atomic Energy Commission

Listed here are a number of special publications sponsored by the Atomic Energy Commission. In addition, the Commission encourages project scientists to submit nonclassified articles for publication in the established scientific and technical journals. Hundreds of reports, not published elsewhere, may be obtained from the Office of Technical Services, Department of Commerce, Washington 25, D. C. Lists of titles and prices of these reports are available from the Office of Technical Services. Essentially complete collections of the Commission's nonclassified reports are available in a number of libraries (see pp. 317–318). Guides to the published and report literature may be found in Nuclear Science Abstracts (see page 313).

SEMIANNUAL REPORTS TO CONGRESS

The Commission's 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.

Eighteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1955*, July 1955. 50 cents.

Nineteenth Semiannual Report, *Major Activities in the Atomic Energy Programs, July–December, 1955*, January 1956. 60 cents.

Twentieth Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1956*, July 1956. $1.25.

Twenty-first Semiannual Report, *Radiation Safety and Major Activities in the Atomic Energy Programs, July–December 1956*, January 1957. $1.25.

Twenty-second Semiannual Report, *Major Activities in the Atomic Energy Programs, January–June 1957*, July 1957. 75 cents.

Twenty-third Semiannual Report, *Progress in Peaceful Uses of Atomic Energy, July–December 1957*, January 1958. $1.25.

Cumulative Index to the First Fifteen Semiannual Reports to Congress, January 1947–December 1953. 35 cents.

Cumulative Index to the Sixteenth Through the Twentieth Semiannual Reports to Congress, January 1954–June 1956. 30 cents.

Index to the Twenty-first Semiannual Report to Congress, July–December 1956. 15 cents.

Index to the Twenty-second Semiannual Report to Congress, January–June 1957. 15 cents.

Index to the Twenty-third Semiannual Report to Congress, July–December 1957. 15 cents.

GENERAL PUBLICATIONS

The following is a list of semitechnical and nontechnical publications of interest to the general reader.

Selected Readings on Atomic Energy. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, November 1955. 53 pages, 25 cents. A bibliography of official publications, books, magazines, pamphlets and teaching units for educators, and indexes and bibliographies on atomic energy.

Prospecting for Uranium. U. S. Atomic Energy Commission and U. S. Geological Survey. Revised January 1957. Washington, U. S. Government Printing Office, 1957. 217 pages. 75 cents. A nontechnical booklet describing the uranium-bearing minerals, where to look for them, and instruments to use in prospecting and in laboratory testing and analysis of ores. It contains six color plates of principal minerals. Laws, regulations, and price schedules for uranium-bearing ores are included.

Prospecting With a Counter. Robert J. Wright. U. S. Atomic Energy Commission. Revised July 1954. Washington, U. S. Government Printing Office, 1954. 68 pages. 30 cents. A summary of information on field counters, their operation, use, abuse, and their application to prospecting, mining and geologic problems.

Selling to AEC. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1956. 31 pages. 25 cents. This publication provides certain basic information helpful to those who want to do business with the Commission or its contractors. It indicates who does the buying, what is bought, where procurement offices are located, and other general information.

A Guide for Contracting of Construction and Related Engineering Services. U. S. Atomic Energy Commission. Revised March 1955. Washington, U. S. Government Printing Office, 1955. 16 pages. 15 cents. This booklet gives the Commission's policy on awarding contracts for construction and architect-engineering services, procedures followed when requests for bids are formally advertised and when contracts are negotiated. Operations offices and officials responsible for letting such contracts are listed.

Atoms for the World. Laura Fermi. Chicago, University of Chicago Press, 1957. 227 pages. $3.75. An intimate and informative account, by the historian for the United States delegation, of United States participation in the International Conference on the Peaceful Uses of Atomic Energy, which was held in 1955 at Geneva, Switzerland.

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. New York, D. Van Nostrand Co., 1955. 861 pages. $7.95. A text written for the student and the practicing engineer. An overall review of the fundamental scientific principles upon which reactor engineering is based.

The Elements of Nuclear Reactor Theory. Samuel Glasstone and Milton C. Edlund. New York, D. Van Nostrand Co., 1952. 416 pages. $4.80. This is an introduction to nuclear reactor theory intended for the use of scientists, engineers, and advanced students interested in the field of nuclear reactors. It explains the physical concepts and processes involved in a nuclear chain reaction and the methods for calculating critical conditions for chain reacting systems.

Sourcebook on Atomic Energy, Second Edition (revised and updated). Samuel Glasstone. New York, D. Van Nostrand Co., 1958. 641 pages. $4.40. This is considered the standard sourcebook on atomic and nuclear science today. It presents a comprehensive technical description of the theory, history, development, and uses of atomic and nuclear energy. Chapters are included on the structure of the atom, radioactivity, isotopes, nuclear reactors, neutron research, acceleration of charged particles, new elements, radiation protection and health physics, and other phases of nuclear science.

Energy in the Future. Palmer Cosslett Putnam. New York, D. Van Nostrand Co., 1953. 556 pages. $12.75. This book presents a study of the problem of where we can find sources of low-cost energy in an abundance equal to the maximum plausible demands by the expanding and industrializing populations of the future, and what is the maximum plausible role that nuclear fuels may be called on to play in the next 50 to 100 years.

The Metal Beryllium. Edited by D. W. White and J. E. Burke. Cleveland American Society for Metals, 1955. 703 pages. $8.00. Presents basic information on the element beryllium, and covers all aspects of beryllium technology for the use of workers in the field, with emphasis on the possible uses of beryllium in atomic energy work.

Manuals, Handbooks and Reports

Isotopes—an 8-Year Summary of Distribution. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 357 pages. $2.00. A detailed account of isotope utilization during the first 8 years of the Commission's distribution program. It is also a supplement of the 3-year and 5-year reports of similar title issued by the Commission in 1949 and 1951. This report is a useful reference to the uses of isotopes and a bibliography of published articles on isotope work.

Introduction to the Theory of Neutron Diffusion. Vol. 1. K. M. Case, F. de Hoffmann, and G. Placzek. Numerical work by B. Carlson and M. Goldstein. Washington, U. S. Government Printing Office, 1954. 174 pages. $1.25. A monograph intended for purposes of research in physics and mathematics as well as teaching on the graduate level. This monograph, presenting work sponsored by the Los Alamos Scientific Laboratory, gives a detailed discussion of the general equations of one-velocity neutron diffusion theory and of their solution for the special case of a homogeneous infinite medium with isotropic scattering. Emphasis is placed on fairly complete tables and graphs.

Nuclear Power Reactor Technology. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1953. 88 pages. 25 cents. This publication contains reports to the U. S. Atomic Energy Commission by four separate teams of industrial representatives appraising the prospect for possible nuclear power development. Studies were made to determine the engineering feasibility for designing, constructing and operating dual-purpose reactors to produce fissionable material and power, and to recommend industry's role in designing, building, and operating such reactors.

Nuclear Power Reactors. Vol. 2. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, March 1955 (submitted October 1953). 30 pages. 15 cents. This publication contains reports to the U. S. Atomic Energy Commission of two teams of industrial representatives. Appraises the practicability of building a nuclear reactor for the generation of central-station power. The study group undertook to determine whether any of the known reactor systems can be shown to be technically and economically feasible, and competitive for central-station power. Studies were made on the projected possibilities of different reactor systems.

Handbook on Air Cleaning—Particulate Removal. Sheldon K. Friedlander, Leslie Silverman, Philip Drinker, and Melvin W. First. Harvard University and U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, September 1952. 89 pages. 45 cents. 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.

Liquid Metals Handbook (NAVEXOS–P–733, Rev.). Richard N. Lyon, Editor-in-chief. Sponsored by the Committee on Basic Properties of Liquid Metals, Office of Naval Research, Department of the Navy, in cooperation with the Atomic Energy Commission and the Bureau of Ships, Department of the Navy. Second edition (Revised). Washington, Government Printing Office, 1954. 269 pages. $1.25. This volume 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.

Liquid Metals Handbook; Sodium (NaK) Supplement (TID–5277). Carey B. Jackson, Editor-in-Chief. Sponsored by the Atomic Energy Commission and the Bureau of Ships, Department of the Navy. Washington, U. S. Government Printing Office, 1955. 445 pages. $2.00. This volume, which supplements the *Liquid Metals Handbook* above, presents a significant amount of experimental data and analysis of thermal shock and thermal stresses, convective flow and mass transfer, mainly applicable to Sodium and NaK.

Meteorology and Atomic Energy (AECU–3066). Prepared by U. S. Department of Commerce, Weather Bureau, for U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 169 pages. $1.00. This volume summarizes some of the meteorological techniques that are available and describe their application to problems of atmospheric pollution that might arise in connection with the operation of atomic energy installations.

Handling Radioactive Wastes in the Atomic Energy Program. U. S. Atomic Energy Commission. Revised August 1951. Washington, U. S. Government Printing Office, 1951. 30 pages. 15 cents. Discusses the sources and types of radioactive wastes in atomic energy operations, methods developed for their safe handling and disposal, and methods specified for the safe handling of radioisotopes by private users.

Neutron Cross Sections (BNL–325). Donald J. Hughes, John A. Harvey, et al. Brookhaven National Laboratory. Washington, U. S. Government Printing Office, 1955. 328 pages. $3.50. This is an updated edition of a compilation of data in tabular and graphic form prepared by the Atomic Energy Commission Neutron Cross Section Advisory Group originally issued as report AECU–2040. Cross section values for nuclides, elements, and compounds are given for neutrons ranging in energy from 0.0001 electron volts to 100 Mev. Second edition in Press.

Neutron Cross Sections, Supplement 1. Brookhaven National Laboratory. Washington, U. S. Government Printing Office, 1957. 129 pages. $1.75. This brings *Neutron Cross Sections* (BNL–325) up to date. All data available up to October 1, 1956, have been considered, as well as fission data available up to November 15, 1956. In addition, all of the material presented in the addendum to BNL–325 has been included.

Reactor Handbook: Vol. I (AECD–3645)—Physics; Vol. II (AECD–3646)—Engineering; Vol. III (AECD–3647)—Materials. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. Vol. I, 304 pages. $4.25; Vol. II, 1,088 pages. $5.50; Vol. III, 614 pages. $3.50. These volumes provide a condensed and reliable source of nuclear reactor data. Contents: Vol. I—Reactor physics and radiation shielding; Vol. 2—Light- and heavy-water cooled systems, liquid-metal cooled systems, gas-cooled systems, aqueous fuel systems, liquid-metal fuel systems, fused salt systems, handling and control, and reactor designs; Vol. 3—General properties of materials.

High Voltage Problems (TID–5211). J. D. Trimmer and Harry Pearlman. U. S. Atomic Energy Commission, 1951. 226 pages. $1.85. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This report 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.

Vacuum Problems and Techniques (TID–5210). C. E. Normand, Frank A. Knox, G. W. Monk, et al. U. S. Atomic Energy Commission, 1950. 265 pages.

$1.75. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This report describes and evaluates the original vacuum equipment required in the operation of the electromagnetic separation process. It presents significant improvements in efficiency resulting from changes in operating techniques, and brings together information widely spread throughout the literature.

Research Reactors; Selected Reference Material (TID–5275). U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 442 pages. $2.00. This volume presents detailed descriptions of six types of research reactors developed in the national atomic energy program; selected design drawings of reactors, components, and supporting facilities are included. The document was prepared to present the details of the U. S. program to delegates attending the International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955.

Chemical Processing and Equipment; Selected Reference Material (AECD–5276). U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 302 pages. $2.00. Describes the chemical and engineering aspects of processing materials associated with nuclear reactors. It includes descriptions of radio-chemical laboratories, remote control handling equipment. Like *Research Reactors* described above, this volume was prepared for the benefit of delegates to the International Conference.

Reactor Shielding Design Manual (TID–7004). Edited by Theodore Rockwell III. U. S. Atomic Energy Commission, 1956. 466 pages. $2.10. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Describes the procedures and data which are used in the design, construction and testing of shielding for the reactor plants of the naval reactors program and for the Shippingport pressurized water reactor.

Nuclear Level Schemes (TID–5300). K. Way, R. W. King, C. L. McGinnis, R. van Lieshout. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1955. 240 pages. $1.75. A ready reference source of nuclear information consisting of a collection of diagrams showing positions and properties of nuclear energy levels, characteristics of radioactive decay and nuclear reactions, together with a tabular compilation of the experimental data and bibliographic references to the original paper.

The Chemistry and Metallurgy of Miscellaneous Materials (TID–5212). Edited by Laurence L. Quill. U. S. Atomic Energy Commission, 1955. 172 pages. $1.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Consists of individual papers dealing with miscellaneous chemical, metallurgical and structural subjects.

Determination of the Isotopic Composition of Uranium (TID–5213). Edited by A. E. Cameron. U. S. Atomic Energy Commission, 1950. 166 pages. $1.52. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Presents some of the solutions to problems encountered in the adaptation of known methods and principals to the routine determination of the isotopic composition of uranium.

Electrical Equipment for Tanks and Magnets (TID–5214). Edited by C. R. Baldock and E. D. Hudson. U. S. Atomic Energy Commission, 1947. 401 pages. $2.65. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Presents an account of the electrical engineering phases of the electromagnetic separation process as they related to electrical equipment used in the separation of isotopes.

Magnets and Magnetic Measuring Techniques (TID–5215). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 213 pages. $1.45. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, with emphasis upon magnets and associated measuring techniques.

Electrical Circuits for Calutrons (TID–5216). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 280 pages. $1.85. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, with emphasis upon electrical circuiting.

Electromagnetic Separation of Isotopes in Commercial Quantities (TID–5217). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 434 pages. $2.65. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, and describes the production of isotopes by the electromagnetic separation process in commercial quantities.

Sources and Collectors for Use in Calutrons (TID–5218). Edited by R. K. Wakerling and A. Guthrie. U. S. Atomic Energy Commission, 1949. 273 pages. $1.85. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A report of the successful adaptation of the mass spectrographic method of separating uranium isotopes to an electromagnetic separation plant, and describes the sources and collectors for use in calutrons.

Problems of Physics in the Ion Source (TID–5219). Edited by Arthur H. Barnes, S. M. MacNeille, and Chauncey Starr. U. S. Atomic Energy Commission, 1951. 294 pages. $1.50. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Presents the fundamental processes involved in the operation of calutron source units, and describes the experiments that enabled the investigators to determine these processes.

Biological Effects of External X- and Gamma Radiation (TID–5220, Part 2). Edited by R. E. Zirkle. U. S. Atomic Energy Commission, 1956. 477 pages. $2.10. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) The work reported was part of a large radiobiological research program pursued during World War II under the auspices of the Plutonium Project of the Manhattan District at the Metallurgical Laboratory, University of Chicago, and Clinton Laboratories, Oak Ridge, Tenn. All of the investigations reported were directed toward an understanding of the actions of high-energy radiations on mammals and ultimately on man in particular.

Polonium (TID–5221). Edited by Harvey V. Moyer. U. S. Atomic Energy Commission, 1956. 392 pages. $1.75. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This is a history of the polonium program. Chemical separation methods and separation by distillation are studied for extraction of polonium from irradiated bismuth. Biological research related to polonium and health physics concerned with personnel protection and waste disposal are discussed.

Production and Separation of U^{233}-Survey (TID–5222). Edited by Glenn T. Seaborg and Leonard I. Katzin. U. S. Atomic Energy Commission, 1951. 219 pages. $5.50. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This report presents a historical record of early project work done on uranium 233 and is based on a survey of the properties of uranium with mass 233 and the methods for its production. The report brings together in one place most of the known information about uranium 233 up to 1945.

Production and Separation of U^{233}-Collected Papers (TID–5223, Parts 1 & 2). Edited by Leonard I. Katzin. U. S. Atomic Energy Commission, 1952. Part 1—420 pages; Part 2—323 pages. Total price $3.25. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This is the assembled record of the significant work relating to uranium 233 done on the Manhattan Project up to July 1945.

Some Effects of Ionizing Radiation on Human Beings; A Report on the Marshallese and Americans Accidentally Exposed to Radiation from Fallout and a Discussion of Radiation Injury in the Human Being (TID–5358). Edited by Drs. E. P. Cronkite, V. P. Bond, and C. L. Dunham. U. S. Atomic Energy Commission, 1956. 106 pages. $1.25. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Presents an authoritative treatise on the observed effects of the accidental deposition of radioactive materials on inhabited islands and Task Force ships following the detonation of a thermonuclear devise at the Pacific Proving Ground on March 1, 1954.

Trilinear Chart of Nuclides, Second Edition (completely revised and updated). W. H. Sullivan. U. S. Atomic Energy Commission, January 1957. $2.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Especially designed for convenient classroom and desk reference use. It presents systematics and physical constants data for all experimentally identified nuclides known from information available as of July 1956.

The Effects of Nuclear Weapons. Edited by Dr. Samuel Glasstone. Washington, U. S. Government Printing Office, June 1957. 579 pages. $2.00. A publication prepared by the Armed Forces Special Weapons Project of the Department of Defense at the request of the Atomic Energy Commission. It updates information appearing in *The Effects of Atomic Weapons*, 1950, and provides the latest knowledge of weapons effects obtained by observation and experiment in laboratory work and nuclear test detonations since 1950. It also includes data on radiological, blast and heat effects of nuclear detonations. Requirements of the Federal Civil Defense Administration for information necessary for civil defense planning are taken into account.

Atomic Energy Facts. Washington, U. S. Government Printing Office, 1957. 216 pages. $2.00. A handbook of the Commission's and atomic energy activities. Chapters include production of uranium and thorium, power reactors, fuel cycles, reactor materials, research reactors and radioisotopes. The organization and functions of the Atomic Energy Commission are described. A chapter, Government and Atomic Energy, covers technical information services; the access permit program; materials, services, and facilities and licenses available from the Commission; Government atomic energy patents available for licensing; and doing business abroad. Illustrated with photographs, flow diagrams, etc.

The Experimental Boiling Water Reactor. Washington, U. S. Government Printing Office, 1957. 232 pages. $2.25. A detailed engineering description of this experimental atomic powerplant written by the designers at the Argonne National Laboratory.

Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants (WASH–740). U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1957. 105 pages. 65 cents. This is a study of possible consequences if certain assumed accidents, theoretically possible but highly improbable, were to occur in large nuclear powerplants. The study was made in order to gain a more comprehensive understanding of the potential public hazards of nuclear power reactors.

A Directory to Nuclear Data Tabulations. R. C. Gibbs and Katharine Way. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1958. 185 pages. 70 cents. This is a compilation of comprehensive tabulations of experimental and theoretical information in the fields of basic nuclear physics and chemistry which have been published in the last few years. Tabulations described in the publication are grouped into 34 sections covering 295 tables. In addition to the usual bibliographical information, each entry includes authors' institutions, prices and details on availability and ordering procedures for the data cited. A topical index and an author index have been included to aid the reader in locating entries of special interest. Among the topics covered are abundances, coulomb functions, cross sections, fission, masses and mass differences, nuclear properties, radiochemistry and X-rays.

Radioactive Contamination of Certain Areas in the Pacific Ocean from Nuclear Tests. Edited by Gordon M. Dunning. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1957. 53 pages. 40 cents. This publication brings together the principal data on environmental contamination from the radioactive fallout following the March 1, 1954 thermonuclear detonation at the Eniwetok Proving Ground. It collates ten radiological surveys made in the Pacific by the Applied Fisheries Laboratory of the University of Washington, U. S. Naval Radiological Defense Laboratories, Health and Safety Laboratory at the New York Operations Office and the Office of Naval Research. It also contains pertinent excerpts of the findings of American medical teams who examined the exposed Marshallese.

The Attenuation of Gamma Rays and Neutrons in Reactor Shields. Herbert Goldstein, Nuclear Development Corp. of America. Washington, U. S. Government Printing Office, 1957. 295 pages. $2.00. This is a thorough exposition of the fundamental processes involved in shielding against neutron and gamma radiation. The book is intended to serve as a solid scientific base for the steadily advancing art of reactor shield design covering the factors affecting permissible radiation levels; the sources and characteristics of the radiation encountered; bulk shielding facilities and measurements; and, at greatest length, the methods for calculating—either theoretically or empirically—the attenuation of neutron and gamma rays in shield materials.

Neutron and Gamma Irradiation Facilities. Compiled by John H. Martens and F. G. Minuth. Washington, U. S. Government Printing Office, 1957. 79 pages. 60 cents. A compact reference on high level nuclear irradiation facilities in the United States. Forty facilities, currently operative or scheduled to become operative soon, are described, along with information on the services provided and how to obtain them.

U. S. Research Reactors. U. S. Atomic Energy Commission. 73 pages. $1.50. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) A compact summary of technical information on the major types of research reactors developed in the United States. Thirty-three reactor facilities are described. A list of research reactors built, building or planned in the United States, including those for foreign locations, is also included.

Hot Laboratory Equipment. Compiled by Brookhaven National Laboratory, Washington, U. S. Government Printing Office. A descriptive, illustrated catalog of enclosures for radioactive operations, manipulators, viewing and optical equipment, chemical equipment, physical-measurement equipment, materials-handling equipment, decontamination and monitoring instruments, shielding devices, and machine tools. (In press.)

Proceedings of Meetings and Symposia

Radioisotopes in Medicine (ORO–125). Edited by Gould A. Andrews, Marshall Brucer, and Elizabeth B. Anderson. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office, 1953. 817 pages. $5.50. This is the published proceedings of the second advanced training course given by the Oak Ridge Institute of Nuclear Studies. The course was concerned with specialized medical application emphasizing more direct clinical uses of radioisotopes. Chapters include tumor localization, diagnostic and therapeutic uses of radioiodine, therapy with radioactive colloids and other phases of medical utilization of radioisotopes.

A Conference on Radioactive Isotopes in Agriculture (TID–7512). U. S. Atomic Energy Commission, 1957. 416 pages. $3.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Comprises a collection of papers presented at the January 1956 Conference on Radioactive Isotopes in Agriculture held at the Michigan State University and treats such major topics as waste disposal in agricultural research installations, radiobiological studies, new techniques in tracer use, ionizing radiation in food preservation and lactation.

Reactor Heat Transfer (TID–7529, Part 1—Books 1 and 2). U. S. Atomic Energy Commission, 1957. 635 pages. $7.75. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Comprises a collection of papers and reports presented at the November 1956 Conference on Reactor Heat Transfer held at New York. Some of the major topics covered are a review of methods used in control rod analysis for reactor design at the Bettis Plant of Westinghouse Electric Co., formulas for control rod worth in thermal reactors, half-group theories for control rods, the general application of burnable poisons, experiments with control rods and voids in a pool type reactor, and many other reactor control problems and experiments.

Shielding of High-Energy Accelerators (TID–7545). U. S. Atomic Energy Commission, 1957. 231 pages. $2.75. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Comprises a collection of papers presented at the April 1957 Conference on Shielding of High-Energy Accelerators held at New York and treats such major topics as the shielding facilities of accelerators existing at present; factors influencing shielding design and accelerator location; shielding computations; biological effects of high-energy radiation and tolerance levels; and shielding design for accelerators now under construction.

Fifth Tripartite Instrumentation Conference (TID–7543). U. S. Atomic Energy Commission, 1958. 179 pages. $3.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Comprises the collection of 55 papers presented at a meeting of delegates of the United States, Canada and Great Britain held October 1956 at Brookhaven National Laboratory, New York. Papers are included which deal with trends and recent developments in reactor instrumentation and control; recent advances in reactor instrumentation in England; fission counter; radiation monitors; dosimeters; recent work at Chalk River; data printer; and other topics on instrumentation.

Boiling Water Reactor Program (TID–7535). U. S. Atomic Energy Commission, 1957. 164 pages. $2.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Comprises a collection of papers presented at the May 1957 Technical Briefing Session on Boiling Water Reactor Program held at Argonne National Laboratory and treats such major topics on the EBWR as general description; economic aspects; pressure-vessel design rules, installation history and preliminary performance; physics experiments; plant equipment, leakage and radioactivity; and other aspects on boiling water reactors including program planning for civilian power reactors.

Reprocessing of Irradiated Fuels (TID–7534—Books 1, 2 and 3). U. S. Atomic Energy Commission, 1957. 1,165 pages. $10.50. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) Comprises a collection of papers presented at the May 1957 International Symposium on the Reprocessing of Irradiated Fuels held at Brussels, Belgium and treats an area of separations development capable of immediate application to the design and operation of facilities for reprocessing irradiated reactor fuels. Five sessions were held covering aqueous reprocessing; auxiliary processes; disposal of plant effluents; nonaqueous processes and engineering and economics.

Fixation of Radioactivity in Stable, Solid Media (TID–7550). U. S. Atomic Energy Commission, 1957. 102 pages. $2.50. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This is the published proceedings of the June 1957 working meeting held at the Johns Hopkins University on development and progress in treating liquid radioactive wastes so as to fix radioactivity and transform liquids in solid form. Associated problems such as heat evolution and dissipation, air cleaning, and transporting are also discussed.

Engineering Education and Nuclear Energy (TID–7527). U. S. Atomic Energy Commission, 1957. 206 pages. $1.00. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This is the published proceedings of the September 1956 Conference on Engineering Education and Nuclear Energy held at Gatlinburg, Tenn. Papers are included on the scientific manpower needs in atomic energy programs, the Oak Ridge School of Reactor Technology curriculum, the educational program at Argonne National Laboratory, and educational programs in nuclear science at various universities.

Nuclear Powered Ships for American Ship Operators (TID–7539). U. S. Atomic Energy Commission, 1957. 190 pages. $3.50. (Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.) This is the published proceedings of the July 1957 Symposium on Nuclear Powered Ships for American Ship Operators held at Washington, D. C. Marine applications of nuclear power are discussed with regard to maritime regulations

and marine insurance. The designs of the first nuclear merchant vessel and its pressurized water reactor are given. Other reactor designs proposed for merchant ship applications are boiling water, organic moderated, and gas cooled reactors.

Periodicals and Catalogs

Nuclear Science Abstracts. U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office. Available on subscription for $12.00 per year domestic; $15.00 foreign. Published bi-monthly. This bi-monthly publication contains abstracts of all current Commission declassified and unclassified reports, of non-Commission reports related to atomic energy, and of articles appearing in both foreign and domestic periodical literature.

Isotopes—Catalog and Price List. Oak Ridge National Laboratory, Oak Ridge, Tenn., January 1957. $1.00. This publication lists and describes radioactive and stable isotopes available from ORNL and includes prices and instructions for ordering the isotopes.

Reactor Core Materials (Technical Progress Review). Prepared by Battelle Memorial Institute for U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office. Available on subscription for $2.00 per year domestic; $2.50 foreign; 55 cents per copy. Published quarterly. This quarterly review covers significant developments in the field of solid reactor core materials. It provides a convenient condensed source of information to two types of readers: (1) those who wish to keep abreast of developments in a general way and (2) those interested in learning where to find detailed accounts of work in particular areas. Complete bibliographies are provided at the end of each section.

Power Reactor Technology (Technical Progress Review). Prepared by the General Nuclear Engineering Corp. for U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office. Available on subscription for $2.00 per year domestic; $2.50 foreign; 55 cents per copy. Published quarterly. This quarterly review of reactor development is intended to assist interested organizations in the task of keeping abreast of new results in reactor technology for civilian application. Each issue of the journal reviews reactor development progress on a current basis.

Reactor Fuel Processing (Technical Progress Review). Prepared by Argonne National Laboratory for U. S. Atomic Energy Commission. Washington, U. S. Government Printing Office. Available on subscription for $2.00 per year domestic; $2.50 foreign; 55 cents per copy. Published quarterly. This quarterly review of reactor fuel processing is intended to assist interested organizations in keeping abreast of progress in this field. Each review covers those particular subjects in which significant advances have been made.

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 Commission 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. Covers 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. $5.00.

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. $2.00.

Division III: Special Separations Project

The Theory of Isotope Separation, vol. 1B. 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. I. Kirschenbaum, 1951. Describes the physical properties of heavy water, chemical equilibria or exchange reactions and methods of isotopic analysis. 438 pages. $6.00.

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. Presents laboratory pilot-plant studies for various separation processes investigated and engineering surveys of actual production plants with descriptions of their operations. 394 pages. $5.25.

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 related 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 labora-

tory 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, continue 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). $18.00.

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. $7.00.

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. $10.00.

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.

Medical Effects of the Atomic Bomb in Japan, vol. 8, edited by Ashley W. Oughterson and Shields Warren. Is based upon the 6-volume report of the

Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan. It presents a great mass of unique and authoritative information of importance to national defense, and is a valuable contribution to fundamental medical knowledge. 477 pages. $8.00.

DEPOSITORY LIBRARIES

In order to make the nonclassified results of Commission research and development available to the public, the following libraries serve as depositories for essentially all the Commission's nonclassified reports. A number of other university and public libraries also receive copies of the reports that are sold by the Office of Technical Services.

ALABAMA
- Auburn, Alabama Polytechnic Institute.
- Birmingham, Birmingham Public Library.

ARIZONA
- Tucson, University of Arizona.

ARKANSAS
- Fayetteville, University of Arkansas.

CALIFORNIA
- Berkeley, University of California General Library.
- Los Angeles, University of California Library.
- Menlo Park, Stanford Research Institute.
- San Diego, San Diego Public Library.

COLORADO
- Denver, The Public Library, The City and County of Denver.

CONNECTICUT
- New Haven, Yale University Library.

DISTRICT OF COLUMBIA
- Washington, Library of Congress.

FLORIDA
- Coral Gables, University of Miami Library.
- Gainesville, University of Florida Library.

GEORGIA
- Atlanta, Georgia Institute of Technology Library.

ILLINOIS
- Chicago, John Crerar Library.
- Chicago, University of Chicago Library.
- Evanston, Northwestern University Library.
- Urbana, University of Illinois Library.

INDIANA
- Indianapolis, Indianapolis Public Library.
- Lafayette, Purdue University Library.

IOWA
- Ames, Iowa State College Library.

KANSAS
- Manhattan, Kansas State College School of Engineering and Architecture.

KENTUCKY
- Lexington, University of Kentucky Library.
- Louisville, University of Louisville Library.

LOUISIANA
- Baton Rouge, Louisiana State University Library.
- New Orleans, Tulane University Library.

MARYLAND
- Baltimore, The Johns Hopkins University Library.
- College Park, University of Maryland Engineering and Physical Sciences Library.

MASSACHUSETTS
- Cambridge, Harvard University Library.
- Cambridge, Massachusetts Institute of Technology Library.

MICHIGAN
- Ann Arbor, University of Michigan Library.
- Detroit, Detroit Public Library.

MINNESOTA
- Minneapolis, University of Minnesota Library.

MISSOURI
- Kansas City, Linda Hall Library.
- Rolla, University of Missouri School of Mines and Metallurgy Library.
- St. Louis, Washington University Library.

NEW JERSEY
- Princeton, Princeton University Library.

NEW MEXICO
- Albuquerque, University of New Mexico Library.

NEW YORK
- Buffalo, University of Buffalo, Lockwood Memorial Library.
- Ithaca, Cornell University Library.
- New York, Atomic Industrial Forum.
- New York, Columbia University Library.
- New York, New York Public Library.
- Rochester, University of Rochester Library.
- Schenectady, Union College Library.
- Troy, Rensselaer Polytechnic Institute Library.

NORTH CAROLINA
- Charlotte, Charlotte and Mecklenburg County Public Library.
- Durham, Duke University Library.
- Raleigh, North Carolina State College Library.

OHIO
- Cincinnati, University of Cincinnati Library.
- Cleveland, Cleveland Public Library.
- Columbus, Ohio State University Library.
- Toledo, University of Toledo Library.
- Youngstown, Youngstown University Library.

OKLAHOMA
- Stillwater, Oklahoma State University Library.

OREGON
- Corvallis, Oregon State College Library.
- Portland, Portland Public Library.

PENNSYLVANIA
- Philadelphia, University of Pennsylvania Library.

PENNSYLVANIA—Continued
- Pittsburgh, Carnegie Library of Pittsburgh.
- University Park, Pennsylvania State University, Pattee Library.

PUERTO RICO
- Rio Piedras, University of Puerto Rico Main Library.

RHODE ISLAND
- Providence, Brown University.

SOUTH CAROLINA
- Columbia, University of South Carolina, McKissick Memorial Library.

TENNESSEE
- Knoxville, University of Tennessee Library.
- Memphis, Cossett Memorial Library.
- Nashville, Joint University Libraries.

TEXAS
- Austin, University of Texas Library.
- College Station, Agricultural and Mechanical College of Texas Library.
- Dallas, Southern Methodist University.
- Houston, Rice Institute.
- San Antonio, San Antonio Public Library.

UTAH
- Salt Lake City, University of Utah Library.

VIRGINIA
- Blacksburg, Virginia Polytechnic Institute.
- Charlottesville, University of Virginia, Alderman Library.

WASHINGTON
- Pullman, State College of Washington Library.
- Seattle, University of Washington Library.

WEST VIRGINIA
- Morgantown, West Virginia University Library.

WISCONSIN
- Madison, University of Wisconsin Library.
- Milwaukee, Milwaukee Public Library.

CLASSIFIED DEPOSITORIES

The Commission established a series of depository libraries where the access permit holders participating in the Civilian Applications Program can consult classified reports made available to them. These depositories have been located at the Massachusetts Institute of Technology for the Boston area; at the Argonne National Laboratory for the Chicago area; at the National Reactor Testing Station, Idaho Falls, Idaho; at the New York Operations Office, New York City; at the Reference Center, Technical Information Service Extension, Oak Ridge, Tenn.; at the Stanford Research Institute, Palo Alto, Calif.; and at the Atomic Energy Commission Headquarters, Washington, D. C.

APPENDIX 7

Regulations of the U. S. Atomic Energy Commission [1]

Part 20—Standards for Protection Against Radiation

Part 40—Control of Source Material

Part 50—Licensing of Production and Utilization Facilities

Part 70—Special Nuclear Material

Part 112—Eniwetok Nuclear Test Series, 1958

MISCELLANEOUS AMENDMENTS

These amendments to Title 10, Chapter I, eliminate the former address of the Atomic Energy Commission and substitute therefor the new mailing address. They also provide that communications and papers may be delivered in person either at 1717 H Street NW., Washington, D. C., or at Germantown, Md.

The amendments further provide for appropriate recognition of the organizational units created upon dissolution of the Division of Civilian Application.

Because the amendments are corrective only, and because interested persons will not be adversely affected, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon are unnecessary; and that good cause exists why these amendments should be made effective upon publication in the Federal Register without the customary 30-day period of notice.

1. Sections 20.7 of Part 20, 25.5 of Part 25, 37.5 of Part 37, 40.52 of Part 40, 55.4 of Part 55, 70.5 of Part 70, 81.3 of Part 81, 95.4 of Part 95, 110.4 of Part 110, 140.5 of Part 140 are amended by deleting the words "1901 Constitution Avenue NW." and adding "Communications and reports may be delivered in person at the Commission's offices at 1717 H Street NW., Washington, D. C., or its offices at Germantown, Md." at the end of each of the designated sections.

2. Sections 2.700 of Part 2, 25.11 (a) of Part 25, 40.20 of Part 40, 50.30 of Part 50, 70.21 (a) of Part 70 are amended by deleting the words "1901 Constitution Avenue NW." and adding "Papers may be filed in person at the Commission's offices at 1717 H Street NW., Washington, D. C., or its offices at Germantown, Md." at the end of each of the designated sections.

3. Parts 2, 20, 30, 40, 50, 55, 70, 110, and 140 are amended by substituting "Division of Licensing and Regulation" wherever the name "Division of Civilian Application" appears.

4. The title "Office of Industrial Development" is substituted for the name "Division of Civilian Application" wherever it appears in Parts 25 and 95.

5. Effective February 15, 1958, § 30.22 of Part 30 is amended by deleting "Post Office Box E, Oak Ridge, Tennessee" and substituting therefor "1717 H Street NW., Washington, D. C."

Dated at Germantown, Md., this 11th day of February 1958.

For the Atomic Energy Commission.

K. E. Fields,
General Manager.

Part 40—Control of Source Material

ELIMINATION OF PROHIBITION ON CERTAIN USES OF URANIUM

The regulations in Part 40, "Control of Source Material", 10 CFR, contain a

[1] Policies and regulations of the U. S. Atomic Energy Commission announced prior to July 1958 can be found in the Federal Register and in the following semiannual reports: Fifth, Sixth, Ninth through the Seventeenth, and Nineteenth through the Twenty-third.

provision that unless justified by exceptional circumstances, licenses will not be issued for transfers of uranium for use in the manufacture of or for incorporation in ceramic products, glass products, or photographic film, negatives and prints (§§ 40.28 and 40.61). This restriction on the use of uranium was promulgated as a means of conserving the supply of uranium for essential uses.

At the present time the supply of uranium is such that it is no longer deemed necessary or appropriate to continue this restriction in effect.

Inasmuch as this amendment is intended to relieve from, rather than to impose, restrictions under regulations currently in effect, the AEC has found that general notice of proposed rule making and public procedures thereon are unnecessary and that good cause exists why this amendment should be made effective without the customary period of notice.

Part 40 is amended in the following respects:

1. Section 40.28 *Licenses to transfer uranium for certain uses* is deleted.

2. Section 40.61 *Schedule II. Prohibited uses of uranium (see § 40.28)* is deleted.

Dated at Germantown, Md., this 19th day of June 1958.

For the Atomic Energy Commission.

R. W. Cook,
Deputy General Manager.

Part 50—Licensing of Production and Utilization Facilities

Filing of Applications for Licenses, Oath or Affirmation

Effective 30 days after publication in the Federal Register, § 50.30 is amended to read as follows:

§ 50.30 *Filing of applications for licenses, oath or affirmation*—(a) *Place of filing.* Each application for a license, including whenever appropriate a construction permit, or amendment thereof should be filed with the Atomic Energy Commission, Attention: Division of Licensing and Regulation. Filings made by mail should be addressed to the Commission at Washington 25, D. C. Filings may be made in person at the Commission's offices at 1717 H Street NW., Washington, D. C., or its offices at Germantown, Maryland.

(b) *Oath or affirmation.* Each application for a license, including whenever appropriate a construction permit or amendment thereof, should be executed in three signed originals by the applicant or duly authorized officer thereof under oath or affirmation.

(c) *Number of copies of applications.* Each filing of an application for license authorizing export only or amendment thereof should include, in addition to the three originals, three copies of the application. Each filing of any other application under this section should include, in addition to the three signed originals, 19 copies of the application, except that with respect to that portion of the application containing the information required by § 50.34 (Hazards Summary Report) the filing should include 40 copies.

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Germantown, Md., this 2d day of May 1958.

For the Atomic Energy Commission.

K. E. Fields,
General Manager.

Part 70—Special Nuclear Material

Elimination of Requirement for Signature Under Oath or Affirmation

This amendment to Title 10, Chapter I, Part 70, "Special Nuclear Material," eliminates the requirement that applications for licenses and statements must be signed under oath or affirmation. Because this amendment eliminates a present procedural requirement, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon are unnecessary and would be contrary to the public interest; and that good

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cause exists why this amendment should be made effective without the customary 30-day period of notice.

Paragraph (b) of § 70.22 is amended be deleting the words "under oath or affirmation."

(Sec. 161, 68 Stat. 948; 42 U. S. C. 2201)

Dated at Washington, D. C., this 28th day of February 1958.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 112—ENIWETOK NUCLEAR TEST SERIES, 1958

On February 14, 1958, the Atomic Energy Commission issued public notice of the danger area to be established April 5, 1958, in connection with the forthcoming HARDTACK nuclear test series to be conducted at the Eniwetok Proving Ground in the Marshall Islands. The efficient and early completion of this test series, which is to begin in April 1958, is of major importance to the defense of the United States and of the free world.

To avoid any unnecessary delay or interruption of that test activity, and to protect the health and safety of the public, the Atomic Energy Commission is issuing the following regulations which will be effective until the HARDTACK test series is completed:

In view of the importance of these tests to the national defense, the potential hazard to the health and safety of individuals who enter the danger area, and the early starting date of the tests, the Atomic Energy Commission has found that general notice of proposed rule making the public procedure thereon would be contrary to the public interest; and that good cause exists why these rules should be made effective without the customary period of notice.

Pursuant to the Administrative Procedure Act, Public Law 404, 79th Congress, 2d Session, the following rules are published as a document subject to codification, to be effective upon filing with the Federal Register:

Sec.

112.1 Purpose.
112.2 Scope.
112.3 Definitions.
112.4 Prohibition.

AUTHORITY: §§ 112.1 to 112.4 issued under sec. 161, 68 Stat. 948, as amended; 42 U. S. C. 2201. Interpret or apply secs. 2, 3, 91, 68 Stat. 921, as amended, 922, 936; 42 U. S. C. 2012, 2013, 2121. For the purposes of sec. 223, 68 Stat. 958; 42 U. S. C. 2273; § 112.4 issued under sec. 161 i, 68 Stat. 949, 42 U. S. C. 2201 (i).

§ 112.1 *Purpose.* The regulations in this part are issued in order to permit the Atomic Energy Commission in the interest of the United States to exercise its authority pursuant to section 91. a. of the Atomic Energy Act of 1954, as efficiently and expeditiously as possible with a minimum hazard to the health and safety of the public.

§ 112.2 *Scope.* This part applies to all United States citizens and to all other persons subject to the jurisdiction of the United States, its Territories and possessions.

§ 112.3 *Definitions.* As used in this part:

(a) "Danger area" means that area established, effective April 5, 1958, encompassing the Bikini and Eniwetok Atolls, Marshall Islands and which is bounded by a line joining the following geographic coordinates:

18°30′ N., 156°00′ E.
18°30′ N., 170°00′ E.
11°30′ N., 170°00′ E.
11°30′ N., 166°16′ E.
10°15′ N., 166°16′ E.
10°15′ N., 156°00′ E.

(b) "HARDTACK test series" means that series of nuclear tests to be conducted by the Atomic Energy Commission and the Department of Defense at the Eniwetok Proving Ground located within the danger area as defined in paragraph (a) of this section and which are to begin in April 1958, and end at an announced time during the calendar year 1958.

§ 112.4 *Prohibition.* No United States citizen or other person who is within the scope of this part shall enter, attempt to enter or conspire to enter the danger area during the continuation of the HARDTACK test series, except with the express approval of appropriate officials of the Atomic Energy Commission or the Department of Defense.

Dated at Germantown, Md., this 9th day of April 1958.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART 112—HARDTACK NUCLEAR TEST SERIES, 1958

MISCELLANEOUS AMENDMENTS

On June 26, 1958, the Atomic Energy Commission issued public notice of the danger area to be established July 25, 1958, in connection with the forthcoming phase of the HARDTACK nuclear test series to be conducted in the area surrounding Johnston Island. The efficient and early completion of this test series, the initial phase of which is currently in progress at the Eniwetok Proving Ground in the Marshall Islands, is of major importance to the defense of the United States and of the free world.

To avoid any unnecessary delay or interruption of this test activity, and to protect the health and safety of the public, the Atomic Energy Commission is issuing the following amendments to Part 112, which amendments will be effective until the HARDTACK test series is completed.

In view of the relationship of these tests to the national defense, the potential hazard to the health and safety of individuals who enter the danger area, and the early starting date of the tests, the Atomic Energy Commission has found that general notice of proposed rule making and public procedure thereon would be contrary to the public interest; and that good cause exists why these rules should be made effective without the customary period of notice.

Pursuant to the Administrative Procedure Act, Public Law 404, 79th Congress, 2d Session, the following amendments are published as a document subject to codification, to be effective upon filing with the *Federal Register.*

1. Section 112.3 is amended as follows:

§ 112.3 *Definitions:* As used in this part:

(a) "Danger area" means the following:

(1) That area established, effective April 5, 1958, encompassing the Bikini and Eniwetok Atolls, Marshall Islands and which is bounded by a line joining the following geographic coordinates:

18°30′ N., 156°00′ E.
18°30′ N., 170°00′ E.
11°30′ N., 170°00′ E.
11°30′ N., 166°16′ E.
10°15′ N., 166°16′ E.
10°15′ N., 156°00′ E.

(2) That area established effective July 25, 1958, encompassing Johnston Island and which is a circle of 400 nautical miles radius centered at the following geographic coordinates: longitude 169°31′00″ West and latitude 16°45′00″ North.

(b) "HARDTACK test series" means that series of nuclear tests conducted and to be conducted by the Atomic Energy Commission and the Department of Defense at the Eniwetok Proving Ground and at Johnston Island, within the danger areas as defined in paragraph (a) of this section, which tests began in April 1958 and will end at an announced time during the calendar year 1958.

2. Section 112.4 is amended as follows:

§ 112.4 *Prohibition.* No United States citizen or other person who is within the scope of this part shall enter, attempt to enter, conspire to enter or remain in either of the defined danger areas (§ 112.3 (a)) during the continuation of the HARDTACK test series, except with the express approval of appropriate officials of the Atomic Energy Commission or the Department of Defense.

3. The part head of this part is hereby amended to read as set forth above.

(Sec. 161, 68 Stat. 948, as amended; 42 U. S. C. 2201. Interpret or apply secs. 2, 3, 91, 68 Stat. 921, as amended, 922, 936; 42 U. S. C. 2012, 2013, 2121. For the purposes of sec. 223, 68 Stat. 958; 42 U. S. C. 2273, § 112.4 issued under sec. 161i, 68 Stat. 949, 42 U. S. C. 2201 (i))

Dated at Germantown, Md., this 25th day of June 1958.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

TREATMENT OF CERTAIN NUCLEAR MATERIALS

CHARGES

1. This notice, which supplements the notice published in 22 F. R. 1591, "Commission Services in Chemical Processing", specifies the Commission's charges for the conversion of purified nitrate salts of uranium and plutonium, produced by the Commission in its processing of spent reactor fuels, into forms for which credits or fair prices have been established by the Commission.

2. The following charges will be incorporated in Commission contracts to process spent reactor fuel:

a. Conversion of purified low-enrichment uranyl nitrate into UF_6: $5.60 per kilogram contained uranium.

b. Conversion of purified high-enrichment uranyl nitrate into UF_6: $32 per kilogram contained uranium.

c. Conversion of purified plutonium nitrate into plutonium metal: $1.50 per gram contained plutonium.

As used in this section, "low-enrichment uranium", means 5 percent (by weight) and less of U–235 in total uranium, and "high-enrichment uranium" means more than 5 percent (by weight) of U–235 in total uranium.

3. The schedules of charges and credits which the Commission has established for uranium hexafluoride and the schedules of guaranteed fair prices which the Commission will pay for plutonium metal are available from: United States Atomic Energy Commission, Office of Industrial Development, Washington 25, D. C.

Dated at Germantown, Md., this 3d day of March 1958.

For the Atomic Energy Commission.

R. W. COOK,
Acting General Manager.

APPENDIX 8

Licenses and Access Permits Applications Filed and Actions Taken

Summary of Licensing Actions

Facilities [1]	Permits and Licenses Issued			Permits and licenses in effect as of June 30, 1958
	Sept. 1, 1954 to June 30, 1957	July 1, 1957 to Dec. 31, 1957	Jan. 1, 1958 to June 30, 1958	
Power Reactors:				
Construction permits	4	1	0	4
Licenses to operate	0	1	0	1
Test Reactors:				
Construction permits	0	1	1	2
Licenses to operate	0	0	0	0
Research Reactors:				
Construction permits	[2] 9	[3] 9	[4] 5	[5] 8
Licenses to operate	9	10	10	19
Licenses to acquire, possess and operate	1	8	0	[6]
Research and Test Reactors for export	9	7	5	[7] N. A.
Critical Experiment Facilities:				
Construction permits	7	3	2	1
Licenses to operate	1	5	[6] 4	[6] 9
Operators' Licenses	54	94	111	251
Special Nuclear Material Licenses	94	57	63	192
Source Material Licenses	3,195	546	682	1,143
Source Material Export Licenses	2,075	381	364	[7] N. A.

[1] Applications to construct and operate are filed simultaneously; conversions from construction permits to licenses to operate are made upon satisfactory completion of construction.
[2] Permits authorize construction of 11 reactors.
[3] Permits authorize construction of 25 reactors.
[4] Permits authorize construction of 23 reactors.
[5] Permits authorize construction of 31 reactors.
[6] Two of the licenses authorize possession only.
[7] Export licenses terminate upon completion of shipment.

FACILITY LICENSES [1]

Applicant and Location of Facility	Description of Facility	Date Filed	Status
POWER REACTORS			
Power Reactor Development Co. Lagoona Beach, Mich.	100,000-kilowatt fast breeder type power reactor.	Jan. 7, 1956	Construction permit issued Aug. 4, 1956.[2]

[1] During the period January 1, 1958 thru June 30, 1958.
[2] Petitions for leave to intervene were granted October 9, 1956, and a hearing was ordered on the application. The record of hearing has been certified by the Hearing Examiner to the Commission. The Commission heard oral argument by the parties regarding the conditional construction permit issued PRDC.

FACILITY LICENSES—continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
	TEST REACTORS		
General Electric Co. Vallecitos Atomic Lab., Alameda County, Calif.	30,000-kilowatt pressurized water test reactor.	June 14, 1957	Construction permit issued Mar. 11, 1958.
National Advisory Committee for Aeronautics, Sandusky, Ohio.	60,000-kilowatt pressurized water test reactor.	Aug. 20, 1956	The NACA hearing regarding the proposed construction of a 60-megawatt testing reactor at Sandusky, Ohio, was concluded and on June 24, 1958 the Hearing Examiner ordered that a construction permit be issued, effective July 21, 1958, unless exceptions to his decision are filed on or before July 18, 1958, or the Commission reviews his decision on its own motion.
	RESEARCH REACTORS		
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Twelve 100-milliwatt self-contained research reactors (Model AGN-201, serials 109 through 120).	Feb. 12, 1957	Construction permit issued July 8, 1957; six licenses issued Aug. 23, 1957, Oct. 28, 1957, and Jan. 22, 1958, May 16, June 3, and June 30.
Aerojet-General Nucleonics Div. of Aerojet-General Corp., San Ramon, Calif. (for sale to licensees).	One 1-watt pool-type research reactor (Model AGN-211, serial 100).	Nov. 12, 1957	Construction permit issued Jan. 24, 1958; license issued Feb. 12, 1958.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Fifteen 100-milliwatt self-contained research reactors (Model AGN-201, serials 126 through 140).	Dec. 2, 1957	Construction permit issued Feb. 20, 1958.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Five 5-watt self-contained research reactors (Model AGN-201M, serials 121 through 125).	Dec. 3, 1957	Construction permit issued Feb. 20, 1958.
Aerojet-General Nucleonics, San Ramon, Calif. (for sale to licensees).	Ten 1-watt pool-type research reactors (Model AGN-211, serials 101 through 110).[3]	Apr. 14, 1958	Pending.
American Machine & Foundry Co. Plainsboro, N.J.	5,000-kilowatt pool-type research reactor.	Jan. 12, 1956	Construction permit issued Jan. 22, 1957; amended June 3, 1958.[4]
American Radiator & Standard Sanitary Corp., Mountain View, Calif.	1-watt (UTR-1) graphite-moderated research reactor (Argonaut-type).	July 12, 1957	Construction permit issued Oct. 31, 1957; license issued May 21, 1958.
The Babcock & Wilcox Co., Lynchburg, Va.	10-kilowatt pool-type research reactor.	Mar. 28, 1958	Pending.
Cornell University, Ithaca, N. Y.	10-kilowatt dual core, pool-type research and training reactor.	Feb. 21, 1958	Pending.
Curtiss-Wright Corp., Quehanna, Pa.	1,000-kilowatt pool-type research reactor.	Oct. 29, 1956	Construction permit issued June 20, 1957; license issued Apr. 29, 1958.
Daystrom, Inc., West Caldwell, N. J.	10-kilowatt, Argonaut-type research reactor.	Dec. 11, 1956	Construction permit issued Oct. 11, 1957.[5]

[3] The application was subsequently amended to increase the power level to 15 watts.

[4] The construction permit was amended at the applicant's request to transfer right, title and interest in the construction permit and facility being constructed from the American Machine & Foundry Co. to the Industrial Reactor Laboratories, Inc.

[5] At the applicant's request the construction permit was revoked Feb. 14, 1958 without prejudice to filing of new application.

FACILITY LICENSES—continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
RESEARCH REACTORS—continued			
Delaware, University of, Newark, Del.	AGN-201 100-milliwatt research reactor, serial 113 (purchased from AGN).	Mar. 21, 1958	Notice of intent to issue facility license published June 18, 1958.
General Dynamics Corp., Torrey Pines Mesa, San Diego, Calif.	10-kilowatt tank-type isotope-production reactor.	Nov. 19, 1957	Construction permit issued May 2, 1958; license issued May 3, 1958.
Massachusetts Institute of Technology, Cambridge, Mass.	1,000-kilowatt heavy water moderated research reactor.	Feb. 20, 1956	Construction permit issued May 7, 1956; license issued June 9, 1958.
North American Aviation, Inc., Canoga Park, Calif.	5-watt solution-type laboratory reactor (Model L–47).	Jan. 24, 1957	Construction permit issued Aug. 2, 1957; license issued Aug. 5, 1957; license terminated June 30, 1958.[6]
North American Aviation, Inc., Atomics International Division, Canoga, Calif.	10-watt solution-type laboratory reactor (Model L–77).	Jan. 20, 1958	Construction permit issued May 17, 1958; license issued May 17, 1958.
Nuclear Development Corp. of America, Pawling, N. Y. (prototype of reactors to be sold to licensees).	5-watt heavy water moderated and reflected research reactor.	Apr. 7, 1958	Pending.
Oregon State College, Corvallis, Oreg.	AGN-201 100-milliwatt research reactor, serial 114 (to be purchased from AGN).	May 5, 1958	Pending.
Vanderbilt University, Nashville, Tenn.	AGN-201 100-milliwatt research reactor, serial 116 (to be purchased from AGN).	Jan. 30, 1958	Pending.
CRITICAL EXPERIMENT FACILITIES			
Allis-Chalmers Manufacturing Co., Greendale, Wis.	Critical experiments for Northern States Power Co.	June 16, 1958	Pending.
The Babcock & Wilcox Co., Lynchburg, Va.	Consolidated Edison experiments.	Oct. 27, 1955	Construction permit issued Dec. 9, 1955; license issued Mar. 20, 1957; amended license to perform second Con-Ed experiment issued Jan. 24, 1958.
The Babcock & Wilcox Co., Lynchburg, Va.	Nuclear Merchant Ship Reactor experiment.	Feb. 1, 1957	Construction permit issued Oct. 2, 1957; license issued Jan. 22, 1958.
Battelle Memorial Institute, West Jefferson, Ohio.	----------	Oct. 28, 1955	Construction permit issued Dec. 28, 1955; license to possess facility issued Jan. 16, 1958.
General Dynamics Corp., Torrey Pines Mesa, San Diego, Calif.	Experiments relating to General Dynamics research reactor.	Oct. 25, 1956	Construction permit issued June 18, 1957; license issued Aug. 13, 1957; amended license to perform additional experiment issued Feb. 3, 1958 and June 26, 1958.
Lockheed Aircraft Corp., Palo Alto, Calif.	----------	June 20, 1956	Construction permit issued Mar. 14, 1957; permit expired Oct. 1, 1957.[7]
The Martin Co., Middle River, Md.	Engineering Research & Development Laboratories experiment.	Mar. 4, 1957	Construction permit issued May 13, 1957; license issued June 12, 1958.

[6] In letter dated May 26, 1958, the licensee advised that the L–47 reactor had been dismantled and requested that its license to operate the reactor be terminated.

[7] In letter dated Feb. 11, 1958, the applicant advised that Lockheed does not intend to proceed with construction of the facility as originally designed.

FACILITY LICENSES—continued

APPLICANT AND LOCATION OF FACILITY	DESCRIPTION OF FACILITY	DATE FILED	STATUS
CRITICAL EXPERIMENT FACILITIES—continued			
National Advisory Committee for Aeronautics, Cleveland, Ohio.	Zero Power Reactor	July 8, 1957	Construction permit issued Jan. 22, 1958.
Nuclear Development Corp. of America, Pawling, N. Y.		Mar. 14, 1956	Construction permit issued June 11, 1956; license to possess facility issued Jan. 22, 1958.
Westinghouse Electric Corp., Waltz Mill, Pa.	Yankee critical experiments	Sept. 21, 1956	Construction permit issued Oct. 17, 1957; license issued Nov. 25, 1957; amended license for additional experiments issued June 30, 1958.
Westinghouse Electric Corp., Waltz Mill, Pa.	Critical Experiment Station (CES) for the WTR critical experiments.	Oct. 24, 1957	Construction permit issued June 14, 1958; license issued June 17, 1958.
EXPORT LICENSES			
ACF Industries, Inc., New York, N. Y.	20,000-kilowatt tank-type materials testing reactor for export to Reactor Centrum Nederland, Pettin, Netherlands.	Apr. 23, 1957	License issued Jan. 17, 1958.
ACF Industries, Inc., New York, N. Y.	1-watt, pool-type, light water cooled and moderated research reactor for export to Tecnicas Hispano Americanas, S. A., Madrid, Spain.	Feb. 4, 1958	Pending.
ACF Industries, Inc., New York, N. Y.	30,000-kilowatt tank-type test reactor for export to Aktiebolaget Atomenergi of Sweden, Tystberga, Sweden.	June 18, 1957	License issued May 14, 1958.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor or AGN-211 1-watt pool-type research reactor for export to Government of Belgium for exhibit at International Science Hall, 1958 World's Fair, Brussels.	Dec. 9, 1958	Application withdrawn by letter dated Mar. 14, 1958.[8]
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor for export to Laboratoires R. Derveaux, Boulogne, France.	July 9, 1957	Application withdrawn by letter dated Mar. 14, 1958.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor for export to Instituto di Fisica, Facolta D'Ingegneria, University of Palermo, Palermo, Sicily, Italy.	Apr. 21, 1958	Pending.
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor for export to the Universite of Geneva, Geneva, Switzerland.	April 24, 1958	Application withdrawn by letter dated June 25, 1958.[8]
Aerojet-General Nucleonics, San Ramon, Calif.	100-milliwatt AGN-201 research reactor for export to the University of Palermo, Palermo, Sicily, Italy.	April 21, 1958	Pending.
American Machine & Foundry Co., Greenwich, Conn.	1,000-kilowatt pool-type research reactor for export to Commissariat a L'Energie Atomique, Tel Aviv, Israel.	Apr. 11, 1958	License issued June 12, 1958.
American Machine & Foundry Co., Greenwich, Conn.	5,000-kilowatt tank-type research reactor for export to the Osterreichische Studiengesellschaft fur Atomenergie Gesellschaft m. b. h., Vienna, Austria.	June 19, 1958	Pending.

[8] These reactors were exported by AGN under AEC contract, one for exhibit at the 1958 World's Fair at Brussels, Belgium, the other for exhibit at the Fifth International Electronics and Nuclear Congress and Exposition at Rome, Italy, and the Second International Exhibition of the Peaceful Uses of Atomic Energy at Geneva, Switzerland.

FACILITY LICENSES—continued

Applicant and Location of Facility	Description of Facility	Date Filed	Status
EXPORT LICENSES—continued			
General Electric Co., New York, N. Y.	3,000-kilowatt pool-type research reactor for export to Instituto Venezolano de Neurologia e Investigaciones Cerebrales, Caracas, Venezuela.	Oct. 3, 1957	License issued Jan. 16, 1958.
General Electric Co., New York, N. Y.	1,000-kilowatt pool-type research reactor for export to National Tsing-Hua University, Taipei, Republic of China.	Apr. 4, 1958	License issued June 5, 1958.
S. A. Innocente Mangili Adriatica, Inc., New York, N. Y.	50-kilowatt solution-type research reactor (Atomics International Model L-54) for export to Politecnico Di Milano, Milan, Italy.	June 2, 1958	Pending.

ACCESS PERMITS

Business or Occupation of Access Permit Holders

	June 30, 1957	Dec. 31, 1957	June 30, 1958
Aircraft and/or components	21	28	32
Beverage industry		1	1
Chemical—general	72	80	79
Chemical—pharmaceutical	5	5	4
Chemical—processing equipment	5	9	10
Coal industry	4	6	4
Communications	1	1	1
Consultants	83	93	77
Educational institutions	22	23	26
Electronic industry	24	31	41
Engineering—construction	51	52	49
Engineering—consulting	70	79	94
Engineering—design	25	42	49
Federal, State, and city governments or departments	53	56	46
Financial organizations	22	18	17
Food companies	4	4	3
Information services	16	23	22
Instrument manufacture	64	66	65
Insurance companies	79	89	88
Lawyers and public accountants	30	39	39
Machinery—general	35	39	43
Machinery—special	10	11	17
Metal products manufacture	158	164	157
Mining and refining	71	70	61
Motor vehicles and/or components	6	6	8
Paper and pulp companies	6	6	6
Petroleum and petroleum products	20	20	19
Printing and publishing	10	12	10
Professors, teachers, and scientists	65	69	67
Railroads and railway equipment	9	12	10
Research—general	44	51	52
Research—medical	4	4	3
Rubber and rubber products	6	6	5
Scrap and waste disposal	7	7	7
Shipbuilding and/or components	20	21	20
Special carriers and warehousing	4	4	2
Stone, clay, and glass products	16	13	18
Tobacco and tobacco products	1	1	1
Unions, trade associations, chambers of commerce, and manufacturers' representatives	16	15	19
Utilities	153	169	170
Weapons, explosives, and propellants	10	10	6
Others (not elsewhere classifiable)	5	6	8
Total [1]	1,327	1,464	1,455

[1] Some permittees have been classified in more than 1 category.

Access Permit Holders by Principal Fields of Interest

	JUNE 30, 1957	DEC. 31, 1957	JUNE 30, 1958
Batteries (nuclear)		1	1
Chemical processing and equipment	64	74	50
Components (except reactor components)		171	101
Consultants	215	248	209
Controlled thermonuclear field		15	21
Design and construction of atomic energy facilities	98	103	84
Electronic systems		1	10
Fuel element fabrication		34	32
General nuclear research and development	66	73	52
Information services		27	36
Instruments		97	92
Insurance evaluation	82	91	86
Investment and banking	23	19	18
Isotope production and utilization	64	65	89
Legal assistance and accounting		25	36
Machinery		11	13
Ore refining and production of feed materials	80	83	84
Radiation hazards and effects		39	57
Radioactive waste		42	48
Reactor—central station	162	196	193
Reactor—components	287	2	35
Reactor—heating		4	5
Reactor—other	149	99	31
Reactor—propulsion		33	48
Reactor—research		8	9
Shield materials		17	18
Special materials	149	141	100
Surveys for potential use or need		1	8
Training and education		8	12
Transportation and storage		3	4
Weapons and components		1	1
Others (not elsewhere classifiable)	65	10	4
Total	1,504	1,742	1,587

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

Access Permit Holders by Geographic Areas [2]

	JUNE 30, 1957	DEC. 31, 1957	JUNE 30, 1958
New England	119	131	127
Middle Atlantic	467	477	470
East North Central	281	298	309
West North Central	79	70	75
South Atlantic	132	140	148
East South Central	34	40	36
West South Central	49	55	57
Mountain	43	45	45
Pacific	118	142	144
Hawaii, Alaska, and Puerto Rico	5	6	6
Total	1,327	1,404	1,417

[2] Standard Department of Commerce areas.

Number of Permittees Having Access to Secret Restricted Data by Categories

	JUNE 30, 1957	DEC. 31, 1957	JUNE 30, 1958
Chemistry—general	397	453	471
Chemistry—radiation and radiochemistry	447	503	525
Chemistry—separation processes for plutonium and uranium	356	376	386
Chemistry—transuranic elements	226	227	253
Controlled thermonuclear processes	91	100	119
Criticality hazards	369	388	84
Hanford—fuel element technology	1	1	592
Hanford—reactor technology	1	1	243
Hanford—separations process technology	4	4	175
Health and safety	481	515	488
Instrumentation	440	464	512
Isotope separation	64	78	544
Metallurgy and ceramics	506	246	565
Metallurgy—raw materials	296	320	369
Particle accelerators and high voltage machines	130	158	416
Physics and mathematics	418	445	292
Radiation effects on reactor materials	476	505	274
Radioactive waste	470	502	55
Reactors—power	515	573	1
Reactors—production	291	295	1
Reactors—research and testing	454	503	4
Savannah River—fuel element technology	1	1	539
Savannah River—reactor technology	1	0	1
Savannah River—separations process technology	4	4	0
Technology—feed materials	278	286	4
Technology—plutonium	236	246	519
Technology—tritium	52	60	586

NOTE.—"Experimental Biology and Medicine" and "Geology and Mineralogy" were removed from Appendix "A" of 10 CFR Part 25 when it was published on Feb. 4, 1956, because the information in these categories, available under the civilian application program, is now unclassified. As of June 30, 1958, there were 820 Secret permits in effect. Most permit holders have access to more than one category of information.

As of June 30, 1958, 814 permittees had 500 employees or less, while 603 had over 500 employees. Six months ago permittees with 500 or less employees numbered 793, while 611 had over 500 employees.

Personnel Security Clearances Granted For Access to Secret and Confidential Restricted Data

	Total as of June 30, 1957	Total as of Dec. 31, 1957	6 months Jan.–June 1958	Total as of June 30, 1958
QX CLEARANCE ACTIONS:				
New clearances granted	6,345	7,682	811	8,493
Clearances reinstated	1,465	1,709	204	1,913
Clearances extended	5,029	5,515	263	5,778
Total	12,839	14,906	1,278	16,184
Clearances terminated	843	1,521	825	2,346
Active clearances	11,996	13,385	453	13,838

For Access to Confidential Restricted Data

LX CLEARANCE ACTIONS:				
New clearances granted	6,927	7,872	549	8,421
Clearances reinstated	518	589	62	651
Clearances extended	1,467	1,551	75	1,626
Total	8,912	10,012	686	10,698
Clearances terminated	843	1,045	522	1,567
Active clearances	8,274	8,967	164	9,131

APPENDIX 9

Nuclear Reactors Built, Building or Planned in the United States, as of June 30, 1958

The following tabulation is a compilation as issued by the Commission for June 30, 1958, of facilities built, building, or planned in the United States which are capable of sustaining a nuclear chain reaction, with the exception of weapons research experiments being conducted at Commission laboratories. Certain experiments relating to military propulsion systems are included in the statistical summary but are not listed in the tabulation because of their classified nature.

Where cells within critical experiment facilities have housed two or more experiments, only the most recent experiment is listed. Where two or more cells operate from a single control panel, experiments in both cells may be listed, but only one count is made in the statistical summary.

Listings in the "principal contractor" column refer to the technical organization assigned primary responsibility for completion of the reactor project. Contractors' names, abbreviated in the column listing, are given in full in the listing that follows. Also listed are the names of designers, shipbuilders, and facility operators; these are abbreviated in the column listings.

Startup dates refer to the year of first criticality. Startup dates shown for projects not yet in service are estimates based on the best available information. The dates for non-Commission projects are estimates announced by the sponsoring organizations.

The generalized test reactor category is arbitrarily defined to include only reactors with a thermal output of 10,000 kilowatts or more.

Reactors are listed as being "operable" under the following circumstances:

a) Federal Government reactors—when criticality is achieved.

b) Non-Federal Government reactors in the United States—when an operating license is issued by the Commission.

c) Reactors for foreign locations—when criticality is achieved.

Reactors are listed as "being built" under the following circumstances:

a) Federal Government reactors—when ground is broken, components ordered, or contract awarded, whichever is first.

b) Non-Federal Government reactors in the United States—when construction permit is issued by the Commission.

c) Reactors for foreign locations—when an export license is issued by the Commission.

Reactors are listed in the "planned" category under the following circumstances:

a) Federal Government reactors—when publicly announced or when development work is started.

b) Non-Federal Government reactors in the United States—when license application is received by the Commission, or a public announcement which includes principal contractor and reactor type is made, whichever is first.

c) Reactors for foreign locations—when public announcement is made.

LIST OF CONTRACTORS, DESIGNERS, SHIPBUILDERS, AND FACILITY OPERATORS FOR WHICH ABBREVIATIONS APPEAR IN TABLES

Abbreviation	*Name of Organization*
AC	Allis-Chalmers Manufacturing Co.
ACF	ACF Industries, Inc.
AG	Aerojet-General Corp.
AGN	Aerojet-General Nucleonics, Subsidiary of Aerojet-General Corp.
Alco	Alco Products, Inc.
AMF	AMF Atomics, a Division of American Machine & Foundry Co.
ANL	Argonne National Laboratory, operated by the University of Chicago.
ARSS	American Radiator and Standard Sanitary Corp.
B&W	Babcock & Wilcox Co., The.
BAC	Bendix Aviation Corp.
Bethlehem	Bethlehem Shipbuilding Corp., Quincy, Mass.
BNL	Brookhaven National Laboratory, operated by Associated Universities, Inc.
CE	Combustion Engineering, Inc.
CL	Clinton Laboratory of Manhattan Engineer District.
Convair	Convair Division of General Dynamics Corp.
Daystrom	Daystrom, Inc.
DuPont	E. I. DuPont de Nemours & Co.
FW	Foster Wheeler Corp.
Fluor	Fluor Corp., Limited.
GDC	General Atomic Division of General Dynamics Corp.
GE	General Electric Co.
GNE	General Nuclear Engineering Co.
Elec. Boat	Electric Boat Division of General Dynamics Corp.
HKF	H. K. Ferguson Co., The.
Ingalls	Ingalls Shipbuilding Corp.
KE	Kaiser Engineers, Division of Henry J. Kaiser Co.
LASL	Los Alamos Scientific Laboratory, operated by University of California.
Lockheed	Lockheed Aircraft Corp.
MA	Maritime Administration, Department of Commerce.
Mare Island	Mare Island Naval Shipyard.
Martin	Martin Co., The.
Met. Lab	Metallurgical Laboratory of Manhattan Engineer District.
NAA	Atomics International, a Division of North American Aviation, Inc.
NACA	National Advisory Committee for Aeronautics.
Newport News	Newport News Shipbuilding and Dry Dock Co.
NRL	Naval Research Laboratory.
NDA	Nuclear Development Corp. of America.
ORNL	Oak Ridge National Laboratory, operated by Union Carbide Nuclear Co., a Division of Union Carbide Corp.
Portsmouth	Portsmouth Naval Shipyard.
PPC	Phillips Petroleum Co.
P&W	Pratt and Whitney Aircraft Division, United Aircraft Corp.
West	Westinghouse Electric Corp.
Vitro	Vitro Engineering Co., a Subsidiary of Vitro Corp.

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 1958

Statistical Summary

	Operated, later dismantled	Operable	Being built	Planned	Total
A. *High-temperature reactors (suitable for power production):*					
A.1. Prototype civilian power reactors, United States locations		1	4	10	15
A.2. Prototype civilian power reactors, foreign locations			1	1	2
A.3. Civilian power reactor experiments	3	7	2	2	14
A.4. Maritime propulsion reactors, ship or land based prototypes			1	2	3
A.5. Full-scale military power reactors		3	31		34
A.6. Military prototypes and experiments, unclassified	3	2	6	2	13
A.7. Military prototypes and experiments, classified (not listed)		1	2	3	6
Total, high temperature reactors	6	14	47	20	87
B. *Low-temperature reactors (not suitable for power production):*					
B.1. Research and training reactors, United States locations	5	35	32	20	92
B.2. Research, training and testing reactors, foreign locations		10	16	2	28
B.3. General testing reactors		3	2	2	7
B.4. Specialized testing reactors		13	8	2	23
B.5. Production reactors		13		1	14
Total, low temperature reactors	5	74	58	27	164
C. *Critical assembly facilities:*					
C.1. Critical assembly facilities, unclassified	7	46	3	4	60
C.2. Critical assembly facilities, classified (not listed)	1	4	1	1	7
Total, critical assembly facilities	8	50	4	5	67
Grand total	19	138	109	52	318

NUCLEAR REACTORS BUILT, BUILDING, OR PLANNED IN THE UNITED STATES AS OF JUNE 30, 1958

A. High Temperature Reactors (Suitable for Power Production)

A.1. *Prototype Civilian Power Reactors, U. S. Locations*

Name and/or owner	Location	Principal contractor	Type	Power (kilowatts)[1]		Startup
				Electrical (net)	Thermal	
Operable:						
Shippingport Atomic Power Station (AEC & Duquesne Light Co.).[2]	Shippingport, Pa.	West	Pressurized water	60,000	231,000	1957
Being Built:						
Dresden Nuclear Power Station (Commonwealth Edison Co.).	Morris, Ill.	GE	Boiling water	180,000	626,000	1959
Consolidated Edison Thorium Reactor [3]	Indian Point, N. Y.	B&W	Pressurized water	255,000	500,000	1960
Enrico Fermi Atomic Power Plant (Power Reactor Development Co.)[4 5]	Lagoona Beach, Mich.	Owner	Fast breeder	90,000	300,000	1960
Yankee Atomic Electric Co.[4 6]	Rowe, Mass.	West	Pressurized water	110,000	392,000	1960
Planned:						
AEC & Rural Cooperative Power Association [7 8]	Elk River, Minn.	ACF	Boiling water	22,000	73,000	1960
AEC & City of Piqua, Ohio [7]	Piqua, Ohio	NAA	Organic moderated	11,400	45,500	1961
Hallam Nuclear Power Facility (AEC & Consumers Public Power District).[4]	Hallam, Nebr.	NAA	Sodium graphite	75,000	245,000	1962
Northern States Power Co.[4 9]	Sioux Falls, S. Dak.	AC	Boiling water	62,000	203,000	1962
Carolinas-Virginia Nuclear Power Associates, Inc.[7]	Parr Shoals, S. C.	West	Pressurized heavy water	16,950	60,500	1962
AEC & Chugach Electric Association, Inc.[7 10]	Anchorage, Alaska	NDA	Sodium heavy water	10,000	40,000	1962
Pacific Gas and Electric Co.	Humboldt Bay, Calif.	GE	Boiling water	50,000–60,000	171,000	1962
East Central and Florida West Coast Nuclear Power Groups.[7]	Florida	GNE	Gas cooled, heavy water moderated.	46,000	173,000	1963
Pennsylvania Power & Light Co.[7 11]	Allentown, Pa.	West	Aqueous homogeneous	70,000–150,000	550,000	1963
Gas Cooled Power Reactor (AEC) [12]			Gas cooled, graphite moderated.	30,000–40,000		

A.2. *Prototype Civilian Power Reactors, Foreign Locations*

Name and/or owner	Location	Principal contractor	Type	Power (kilowatts)[1]		Startup
				Electrical (net)	Thermal	
Being Built:						
Belgium (Syndicate for the study of Nuclear Energy-SEEN).	Mol	West	Pressurized water	11,500	43,000	1959
Planned:						
Italy (Project Enrico Fermi of SELNI) [13]	Milan	West	Pressurized water	134,000	492,000	1961

See footnotes at end of table.

A. High Temperature Reactors (Suitable for Power Production)—Continued

A.3. *Civilian Power Reactor Experiments*

Name (all owned by AEC except as noted)	Designation	Location	Principal contractor	Type	Power (kilowatts) [1]		Start-up	Dismantled
					electrical (net)	Thermal		
Operated, later dismantled:								
Boiling Reactor Experiment No. 1	BORAX-1	NRTS, Idaho	ANL	Boiling water	No electricity	1,400	1953	1954
Homogeneous Reactor Experiment No. 1	HRE-1	Oak Ridge, Tenn.	ORNL	Aqueous homogeneous solution. (UO_2SO_4)	140	1,000	1952	1954
Los Alamos Power Reactor Experiment No. 1.[14]	LAPRE-1	Los Alamos, N. Mex.	LASL	Aqueous homogeneous (phosphoric acid).	No electricity	2,000	1956	1957
Operable:								
Experimental Breeder Reactor No. 1 [15]	EBR-1	NRTS, Idaho	ANL	Fast breeder	150	1,400	1951	
Boiling Reactor Experiments [16]	BORAX-2,3,4	NRTS, Idaho	ANL	Boiling water	2,000	15,500	1954	
Experimental Boiling Water Reactor [17]	EBWR	Lemont, Ill.	ANL	Boiling water	4,500	20,000	1956	
Vallecitos Boiling Water Reactor (General Electric Co. and Pacific Gas and Electric Co.).[18]	VBWR	Pleasanton, Calif.	GE	Boiling water	5,000	20,000	1957	
Sodium Reactor Experiment (AEC & Southern Calif. Edison Co.).	SRE	Santa Susana, Calif.	NAA	Sodium graphite	6,000	20,000	1957	
Organic Moderated Reactor Experiment	OMRE	NRTS, Idaho	NAA	Organic Moderated	No electricity	5,000 to 15,000	1957	
Homogeneous Reactor Experiment No. 2.[19]	HRE-2	Oak Ridge, Tenn.	ORNL	Aqueous homogeneous solution. (UO_2SO_4)	Negligible	5,220	1957	
Being built:								
Los Alamos Power Reactor Experiment No. 2.[20]	LAPRE-2	Los Alamos, N. Mex.	LASL	Aqueous homogeneous	No electricity	1,000	1958	
Experimental Breeder Reactor No. 2	EBR-2	NRTS, Idaho	ANL	Fast breeder	16,500	62,500	1960	
Planned:								
Los Alamos Molten Plutonium Reactor Experiment No. 1.[21]	LAMPRE-1	Los Alamos, N. Mex.	LASL	Fast molten plutonium	No electricity	1,000		
Liquid Metal Fuel Reactor Experiment No. 1.	LMFRE-1		B&W	Liquid metal	No electricity	5,000		

A.4. *Maritime Propulsion Reactors, Ship or Land Based Prototypes*

Name and/or owner	Designer	Shipbuilder	Type	Shaft horsepower [1]	Thermal power (kilowatts)	Startup
Being Built:						
Nuclear Ship Savannah (AEC and Maritime Adm.)	B&W	New York Shipbuilding Corp.	Pressurized water	20,000	74,000	1960
Planned:						
Tanker (Maritime Adm.)	GE		Boiling water	20,000		
Maritime Gas Cooled Reactor (AEC)	GDC		Gas cooled			

A.5. *Full-Scale Military Power Reactors*

Name and/or owner	Designation	Designer	Shipbuilder	Type	Startup
Operable:					
Submarine USS Nautilus (USN)	SSN571	West	Elec. Boat	Pressurized water (S2W)	1955
Submarine USS Seawolf (USN)	SSN575	GE	Elec. Boat	Sodium (S2G)	1956
Submarine USS Skate (USN)	SSN578	West	Elec. Boat	Pressurized water (S3W)	1957
Being Built:					
Submarine Swordfish (USN)	SSN579	West	Portsmouth	Pressurized water (S4W)	
Submarine Sargo (USN)	SSN583	West	Mare Island	Pressurized water (S3W)	
Submarine Seadragon (USN)	SSN584	West	Portsmouth	Pressurized water (S4W)	
Submarine Skipjack (USN)	SSN585	West	Elec. Boat	Pressurized water (S5W)	
Submarine Triton, 2 reactors (USN)	SS(R)N586	GE	Elec. Boat	Pressurized water (S3G)	
Submarine Halibut (USN)	SS(G)N587	West	Mare Island	Pressurized water (S5W)	
Submarine Scamp (USN)	SSN588	West	Mare Island	Pressurized water (S5W)	
Submarine Scorpion (USN)	SSN589	West	Elec. Boat	Pressurized water (S5W)	
Submarine Sculpin (USN)	SSN590	West	Ingalls	Pressurized water (S5W)	
Submarine Shark (USN)	SSN591	West	Newport News	Pressurized water (S5W)	
Submarine Snook (USN)	SSN592	West	Ingalls	Pressurized water (S5W)	
Submarine Thresher (USN)	SSN593	West	Portsmouth	Pressurized water (S5W)	
Submarine Permit (USN)	SS(G)N594	West	Mare Island	Pressurized water (S5W)	
Submarine Pollack (USN)	SS(G)N595	West	Not assigned	Pressurized water (S5W)	
Submarine Plunger (USN)	SS(G)N596	West	Not assigned	Pressurized water (S5W)	
Submarine Tullibee (USN)	SSN597	CE	Elec. Boat	Pressurized water (S1C)	
Fleet Ballistic Missile Submarine (USN)	SS(G)N598	West	Elec. Boat	Pressurized water (S5W)	
Fleet Ballistic Missile Submarine (USN)	SS(G)N599	West	Elec. Boat	Pressurized water (S5W)	
Fleet Ballistic Missile Submarine (USN)	SS(G)N600	West	Mare Island	Pressurized water (S5W)	
Guided Missile Cruiser, Long Beach (2 reactors) (USN).	CG(N)160	West	Bethlehem	Pressurized water (C1W)	
Aircraft Carrier Enterprise (8 reactors) (USN)	CVA(N)65	West	Newport News	Pressurized water (A1W)	
Army Package Power Reactor No. 1a (USA) [22]	APPR-1a	Alco		Pressurized water	1960

See footnotes at end of table.

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A. High Temperature Reactors (Suitable for Power Production)—Continued

A.6. *Military Prototypes and Experiments*

Name (all owned by AEC)	Designation	Location	Principal contractor	Type	Power (net electric kilowatts)[1]	Startup	Dismantled
Operated, later dismantled:							
Aircraft Reactor Experiment	ARE	Oak Ridge, Tenn	ORNL	Molten salt		1954	1954
Submarine Intermediate Reactor Mark A.	S1G	West Milton, N. Y	GE	Sodium		1955	1957
Heat Transfer Reactor Experiment No. 1.	HTRE-1	NRTS, Idaho	GE	Direct air cycle		1956	1957
Operable:							
Naval Reactor Facility	S1W	NRTS, Idaho	West	Pressurized water		1953	
Army Package Power Reactor No. 1	APPR-1	Ft. Belvoir, Va	Alco	Pressurized water	1,855	1957	
Being Built:							
Large Ship Reactor Prototype, 2 reactors.	A1W	NRTS, Idaho	West	Pressurized water		1958	
Submarine Advanced Reactor Prototype.	S3G	West Milton, N. Y	GE	Pressurized water		1958	
Small Submarine Reactor Prototype	S1C	Windsor, Conn	CE	Pressurized water		1959	
Argonne Low Power Reactor	ALPR	NRTS, Idaho	ANL	Boiling water	200	1958	
Gas-Cooled Reactor Experiment	GCRE	NRTS, Idaho	AG	Gas cooled	No elec	1959	
Planned:							
Destroyer Reactor Prototype	D1G	Schenectady, N. Y	GE	Pressurized water		1960	
Army Package Power Reactor No. 2 [23]	APPR-2			Pressurized water			

B. Low Temperature Reactors (Not Suitable for Power Production)

B.1. *Research and Training Reactors, U. S. Locations*

Name and/or owner	Designation	Location	Principal contractor	Type	Thermal power (kilowatts)	Startup	Dismantled
Operated, later dismantled:							
Chicago Pile 1, rebuilt as CP-2 (MED-AEC) [24]	CP-1	Chicago, Ill	Met. Lab	Graphite	0.2	1942	1954
Los Alamos Water Boiler	HYPO	Los Alamos, N. Mex	LASL	Homogeneous	5.5	1944	1950
Argonne CP-3, rebuilt as CP-3 [1] (MED-AEC).	CP-3	Palos Park, Ill	Met. Lab	Heavy water	300	1944	1955
Los Alamos Fast Reactor (AEC)	Clementine	Los Alamos, N. Mex	LASL	Fast, plutonium fuel	25	1946	1953
Atomics International [25]	L-47	Canoga Park, Calif	NAA	Homogeneous	Negligible	1957	1958
Operable:							
Oak Ridge Graphite Reactor (AEC)	X-10	Oak Ridge, Tenn	CL	Graphite	3,800	1943	
Los Alamos Water Boiler (AEC)	SUPO	Los Alamos, N. Mex	LASL	Homogeneous	45	1950	
Brookhaven Research Reactor (AEC)		Upton, N. Y	HKF	Graphite	30,000	1950	
Low Intensity Test Reactor (AEC)	LITR	Oak Ridge, Tenn	ORNL	Tank	3,000	1950	
North American Aviation Water Boiler Neutron Source (AEC). [8 25 26]	WBNS	Santa Susana, Calif	NAA	Homogeneous	Negligible	1952	
Livermore Water Boiler (AEC)	LIWB	Livermore, Calif	NAA	Homogeneous	0.5	1953	
North Carolina State College (Raleigh Research Reactor). [27]	RRR	Raleigh, N. C	Owner	Homogeneous	0.5	1957	
Argonne Research Reactor (AEC)	CP-5	Lemont, Ill	ANL	Heavy water	2,000	1954	
Pennsylvania State University		Univ. Park, Pa	Owner	Pool	100	1955	
Armour Research Foundation	APR	Chicago, Ill	NAA	Homogeneous	50	1956	
Battelle Memorial Institute	BRR	West Jefferson, Ohio	AMF	Pool	1,000	1956	
Naval Research Reactor (USN)	NRR	Washington, D. C	NRL	Pool	100	1956	
Omega West Reactor (AEC)	OWR	Los Alamos, N. Mex	LASL	Tank	1,000	1956	
Argonne Naught Power Reactor (AEC)	Argonaut (CP-11)	Lemont, Ill	ANL	Graphite/water	10	1957	
University of Michigan (Ford Nuclear Reactor).		Ann Arbor, Mich	B&W	Pool	1,000	1957	
Livermore Pool Type Reactor (AEC)	LPTR	Livermore, Calif	FW	Tank	1,000	1957	
U. S. Naval Post Graduate School [25]	AGN-201-100	Monterey, Calif	AGN	Homog. solid	Negligible	1956	
Catholic University of America [25]	AGN-201-101	Washington, D. C	AGN	Homog. solid	Negligible	1957	
Oklahoma State University of Agri. & Appl. Science. [25]	AGN-201-102	Stillwater, Okla	AGN	Homog. solid	Negligible	1957	
Aerojet-General Nucleonics [25]	AGN-201M-103	San Ramon, Calif	AGN	Homog. solid	Negligible	1957	
University of Akron [25]	AGN-201-104	Akron, Ohio	AGN	Homog. solid	Negligible	1957	
National Naval Medical Center (USN) [25]	AGN-201M-105	Bethesda, Md	AGN	Homog. solid	Negligible	1957	
Texas A&M College [25]	AGN-201-106	College Station, Tex	AGN	Homog. solid	Negligible	1957	
University of Utah [25]	AGN-201-107	Salt Lake City, Utah	AGN	Homog. solid	Negligible	1957	
Aerojet-General Nucleonics [25]	AGN-201-108	Lemont, Ill	AGN	Homog. solid	Negligible	1957	
Colorado State University [25]	AGN-201-109	Ft. Collins, Colo	AGN	Homog. solid	Negligible	1957	
University of California [25]	AGN-201-112	Berkeley, Calif	AGN	Homog. solid	Negligible	1957	

See footnotes at end of table.

B. Low Temperature Reactors (Not Suitable for Power Production)—Continued

B.1. *Research and Training Reactors, U. S. Locations*—Continued

Name and/or owner	Designation	Location	Principal contractor	Type	Thermal power (kilowatts)	Startup	Dismantled
Operable—Continued							
University of Delaware [25]	AGN-201-113	Newark, Del.	AGN	Homog. solid	Negligible	1958	
Oregon State College [25]	AGN-201-114	Corvallis, Oreg.	AGN	Homog. solid	Negligible	1958	
Curtiss-Wright Corp.		Quehanna, Pa.	Owner	Pool	1,000	1958	
General Dynamics Corp. [26]	TRIGA	Lajolla, Calif.	GDC	Homog. solid	10	1958	
Neutron Source Reactor (AEC)		Upton, N. Y.	BNL	Tank	100	1958	
Atomics International [25]	L-77	Canoga Park, Calif.	NAA	Homogeneous	Negligible	1958	
American Radiator & Standard Sanitary Corp. [25]	UTR-1	Mountain View, Calif.	Owner	Graphite/water	Negligible	1958	
Massachusetts Institute of Technology	MITR	Cambridge, Mass.	ACF	Heavy water	1,000	1958	
Being Built:							
Brookhaven Medical Reactor (AEC)	MRR	Upton, N. Y.	Daystrom	Tank	1,000	1958	
Industrial Reactor Laboratories, Inc.		Plainsboro, N. J.	AMF	Pool	5,000	1958	
University of Virginia		Charlottesville, Va.	Owner	Pool	1,000	1958	
Union Carbide Nuclear Co.		Sterling Forest, N. Y.	AMF	Pool	5,000	1958	
University of Florida		Gainesville, Fla.	GNE	Graphite/water	10	1958	
Vanderbilt University [25]	AGN-201-116	Nashville, Tenn.	AGN	Homog. solid	Negligible	1958	
Aerojet-General Nucleonics (25 reactors) [25]	AGN-201 (115, 117-120, 126-140) AGN-201M (121-125)	San Ramon, Calif.	AGN	Homog. solid	Negligible	1958-59	
Ordnance Materials Research Office (USA)		Watertown, Mass.	Owner	Pool	1,000	1959	
Planned:							
State College of Washington		Pullman, Wash.	GE	Pool	100	1958	
University of Buffalo		Buffalo, N. Y.	AMF	Pool	1,000	1958	
Rice Institute [25]	AGN-211-101	Houston, Tex.	AGN	Homog. solid	Negligible	1958	
General Atomic Division of General Dynamics.	IRGA	San Diego, Calif.	GDC	Heterog. solid	10	1958	
Babcock & Wilcox Atomic Energy Division.		Lynchburg, Va.	Owner	Pool	10	1958	
University of Arizona	TRIGA	Tucson, Ariz.	GDC	Heterog. tank	10	1958	
Cornell University		Ithaca, N. Y.	Vitro	Pool	10	1959	
Aerojet-General Nucleonics (9 reactors) [25]	AGN-211 (102-110)	San Ramon, Calif.	AGN	Homog. solid pool	Negligible	1959	
Puerto Rico Nuclear Center		Mayaquez, West Puerto Rico.		Pool	1,000	1960	
University of California at Los Angeles, Medical Reactor. [29]		Los Angeles, Calif.	NAA	Homogeneous	50		
Sandia Engineering Reactor Facility (AEC).	SERF	Sandia Base, N. Mex.	Sandia Corp.	Tank	5,000	1960	
Pawling Research Reactor (NDA)	PRR	Pawling, N. Y.	NDA	Heavy water	Negligible		

B. 2. *Research, Training and Testing Reactors, Foreign Locations*

Owner	Location	Principal contractor	Type	Thermal power (Kilowatts)	Startup
Operable:					
Brazil, Government of (University of Sao Paulo)	Sao Paulo	B&W	Pool	5,000	1957
Denmark, Government of (Atomic Energy Commission)[25]	Risoe	NAA	Homog. (L-54)	Negligible	1957
Germany, Federal Republic of (Munich Technical Univ.)	Munich	AMF	Pool	1,000	1957
Germany, Federal Republic of (Hoechst Dyeworks, Inc.)	Frankfurt	NAA	Homog. (L-54)	50	1958
Japan, Government of (Atomic Energy Research Institute)	Tokai-mura	NAA	Homog. (L-54)	50	1957
Netherlands, Government of (Delft Technical Univ.)[31]	Delft	AMF	Pool	10	1957
Switzerland, Government of (Reactor, Inc.)[32]	Wuerenlingen	ORNL	Pool	100	1955
Switzerland (University of Geneva)[25 30]	Geneva	AG	AGN-201-111	Negligible	1958
AEC (Belgium Worlds Fair Reactor)[25 33]	Brussels	AG	AGN-211-100	Negligible	1958
Italy (University of Palermo)[25 30]	Palermo	AG	AGN-201-110	Negligible	1958
Being Built:					
Canada (McMaster University)	Hamilton, Ont	AMF	Pool	1,000	1958
Denmark, Government of (Atomic Energy Commission)	Risoe	FW	Tank	5,000	1958
Germany, Federal Republic of (Society for the Utilization of Nuclear Energy in Shipbuilding and Navigation, Inc.)	Hamburg	B&W	Pool	5,000	1958
Greece, Government of (Atomic Energy Commission)	Near Athens	AMF	Pool	1,000	1958
Israel, Government of (Atomic Energy Commission)	Tel-Aviv	AMF	Pool	1,000	1959
Italy, Government of (National Committee for Nuclear Research)	Ispra	ACF	Heavy water, tank	5,000	1958
Italy (SORIN Nuclear Center)	Chivasso	AMF	Pool	1,000	1958
Japan, Government of (Atomic Energy Research Institute)	Tokai-mura	AMF	Heavy water	10,000	1959
Netherlands, Government of (Reactor Center)	Petten	ACF	Tank (MTR)	20,000	1959
Portugal, Government of (Nuclear Energy Board)	Near Lisbon	AMF	Pool	1,000	1959
Republic of China (National Tsing-Hua University)	Hsinchu	GE	Pool	1,000	1959
Spain, Government of (Nuclear Energy Board)	Near Madrid	GE	Pool	3,000	1958
Sweden (Atomic Energy Company)	Studsvik	ACF	Tank (MTR)	30,000	1958
Venezuela, Government of (Institute of Neurology and Brain Research)	Near Caracas	GE	Pool	3,000	1958
West Berlin, City of (Institute for Nuclear Research)	West Berlin	NAA	Homog. (L-54)	50	1958
AEC (1958 International Conference Reactor)	Geneva	ANL	Graphite water	10	1958
Planned:					
Austria, Government of (Austrian Study Co. for Atomic Energy)	Vienna	AMF	Pool	5,000	1959
Italy (Milan Technical University)	Milan	NAA	Homog. (L-54)	50	1958

See footnotes at end of table.

B. Low Temperature Reactors (Not Suitable for Power Production)—Continued

B. 3. *General Testing Reactors*

Name and/or owner	Designation	Location	Principal contractor	Type	Thermal power (kilowatts)	Startup
Operable:						
Materials Testing Reactor (AEC)	MTR	NRTS, Idaho	Fluor	Tank	40,000	1952
Engineering Test Reactor (AEC)	ETR	NRTS, Idaho	KE	Tank	175,000	1957
Oak Ridge Research Reactor (AEC) [34]	ORR	Oak Ridge, Tenn	ORNL	Tank	20,000	1958
Being Built:						
General Electric Co. Materials Testing Reactor	GETR	Pleasanton, Calif	Owner	Tank	30,000	1958
Westinghouse Testing Reactor	WTR	Waltz Mill, Pa	Owner	Tank	20,000	1959
Planned:						
National Advisory Committee for Aeronautics	NACA-TR	Sandusky, Ohio	NACA	Tank	60,000	1959
Industrial Testing Reactors, Inc	ITR	Wadesboro, N. C	GE	Tank	50,000	1960

B. 4. *Specialized Testing Reactors*

Name and/or owner	Designation	Location	Principal contractor	Type	Thermal power (kilowatts)	Startup
Operable:						
Hanford 305 Test Reactor (AEC)	HEW-305	Hanford, Wash	DuPont	Graphite	0.01	1944
Bulk Shielding Reactor No. 1 (AEC)	BSR-1	Oak Ridge, Tenn	ORNL	Pool	500	1950
Thermal Test Reactor No. 1 (AEC)	TTR-1	Schenectady, N. Y	GE	Graphite	10	1951
Savannah River Test Pile 305 (AEC)	SR-305	Savannah River, S. C	DuPont	Graphite	1	1953
Process Development Pile (AEC)	PDP	Savannah River, S. C	DuPont	Heavy water	1	1953
Thermal Test Reactor (AEC)	SP	Savannah River, S. C	DuPont	Graphite	1	1953
Ground Test Reactor (USAF)	GTR	Ft. Worth, Tex	Convair	Pool	500	1953
Tower Shielding Reactor No. 1 (AEC)	TSR-1	Oak Ridge, Tenn	ORNL	Tank	500	1954
Aircraft Shield Test Reactor (USAF)	ASTR	Oak Ridge, Tenn	Convair	Light water	1,000	1954
Thermal Test Reactor No. 2 (AEC)	TTR-2	Hanford, Wash	GE	Graphite	10	1955
Special Power Excursion Reactor Test No. 1 (AEC) [35]	SPERT-1	NRTS, Idaho	PPC	Tank		1955
Kinetic Experiment on Water Boilers No. 1 (AEC)	KEWB-1	Santa Susana, Calif	NAA	Homogeneous	50	1956
General Electric Research Reactor	NTR	Pleasanton, Calif	GE	Light water	30	1957
Being Built:						
Special Power Excursion Reactor Test No. 2 (AEC) [35]	SPERT-2	NRTS, Idaho	PPC	Pressurized water		1958
Special Power Excursion Reactor Test No. 3 (AEC) [35]	SPERT-3	NRTS, Idaho	PPC	Pressurized water	60,000	1958
Radiation Effects Reactor (USAF)	RER	Dawsonville, Ga	Lockheed	Pressurized water	10,000	1958
Transient Reactor Test (AEC)	TREAT	NRTS, Idaho	ANL	Graphite	100	1959
Nuclear Engineering Test Reactor (USAF) [36]	NETR	Dayton, Ohio	ACF	Pool	10,000	1959
Plutonium Recycle Test Reactor (AEC)	PRTR	Hanford, Wash	GE	Heavy water	70,000	1960
Shield Test Pool Reactor (AEC)	STPR	NRTS, Idaho	GE	Pool	100	1958
Tower Shielding Reactor No. 2 (AEC)	TSR-2	Oak Ridge, Tenn	ORNL	Light water	5,000	1959
Planned:						
Heavy Water Components Test Reactor (AEC)	HWCTR	Savannah River, S. C	DuPont	Pressurized heavy water.	62,000	1961
Advanced Engineering Test Reactor (AEC) [37]	AETR					

B. 5. *Production Reactors*

Designation	Designer	Type	Location
Operable:			
B Reactor	DuPont	Graphite	Hanford, Wash.
D Reactor	DuPont	Graphite	Hanford, Wash.
F Reactor	DuPont	Graphite	Hanford, Wash
C Reactor	GE	Graphite	Hanford, Wash.
DR Reactor	GE	Graphite	Hanford, Wash.
H Reactor	GE	Graphite	Hanford, Wash.
KE Reactor	GE	Graphite	Hanford, Wash.
KW Reactor	GE	Graphite	Hanford, Wash.
R Reactor	DuPont	Heavy water	Savannah River, S. C.
P Reactor	DuPont	Heavy water	Savannah River, S. C.
K Reactor	DuPont	Heavy water	Savannah River, C. S.
L Reactor	DuPont	Heavy water	Savannah River, S. C.
C Reactor	DuPont	Heavy water	Savannah River, S. C.
Planned:			
New Production Reactor [38]	GE		

See footnotes at end of table.

C. List of Critical Assembly Facilities Abbreviated in Table C.1

Abbreviation	Name and location of facility	Operator	Number of cells	Number of control panels
AC	Allis-Chalmers Critical Experiment Facility, Greendale, Wis	Owner	1	1
Alco	Alco Products, Inc., Schenectady, N. Y	Owner	1	1
ANL	Argonne National Laboratory (AEC), Lemont, Ill	ANL	3	3
ANL-ID	Argonne National Laboratory, Idaho Div., (AEC), NRTS, Idaho	ANL	1	1
Bettis	Bettis Plant (AEC), Pittsburgh, Pa	West	8	8
B&W	The Babcock & Wilcox Co., Lynchburg, Va	Owner	3	2
BMI	Battelle Memorial Institute, West Jefferson, Ohio	Owner	1	1
BNL	Brookhaven National Laboratory (AEC), Upton, N. Y	BNL	2	2
CANEL	Connecticut Aircraft Nuclear Engine Laboratory (AEC), Middletown, Conn	P&W	2	2
CE	Nuclear Engine Laboratory of Combustion Engineering, Inc., Windsor, Conn	Owner	3	3
ETRC	Engineering Test Reactor Critical Facility (AEC), NRTS, Idaho	PPC	1	1
GE	General Electric Co., Vallecitos Laboratory Experimental Physics Facility, Pleasanton, Calif	Owner	2	2
CEANP	Evendale Critical Experiment Facility (AEC), Evendale, Ohio	GE	2	2
GDC	General Dynamics Corp., San Diego, Calif	Owner	1	1
KAPL	Knolls Atomic Power Laboratory (AEC), Schenectady, N. Y	GE	7	6
LAC	Lockheed Aircraft Corp., Dawsonville, Ga. (USAF)	Owner	1	1
LASL	Los Alamos Scientific Laboratory, Los Alamos, N. Mex	LASL		
LPTF	Low Power Test Facility (AEC), NRTS, Idaho	GE	2	2
Martin	The Martin Co., Middle River, Md	Owner	2	2
NACA	Lewis Flight Propulsion Laboratory, Sandusky, Ohio	Owner	1	1
NDA	Nuclear Development Corporation of America, Pawling, N. Y	Owner	1	1
ORNL-CF	Oak Ridge National Laboratory Critical Facility (AEC), Oak Ridge, Tenn	ORNL	3	5
ORNL-PCA	Pool Critical Assembly, BSR Pool (AEC), Oak Ridge, Tenn	ORNL	1	1
PCTR	Physical Constants Test Reactor Facility (AEC), Hanford, Wash	GE	1	1
RMF	Reactivity Measurements Facility, MTR Canal (AEC), NRTS, Idaho	PPC	1	1
West	Westinghouse Reactor Evaluation Center Critical Experiment Station (CES) and Yankee Critical Facility (YCF), Waltz Mill, Pa.	Owner	2	2

C. 1. *Critical Assembly Facilities* [39]

Abbreviation of facility and location within facility	Subject of experiment or study	Designation of experiment	Startup of experiment	Experiment dismantled
Operated, later dismantled:				
LASL	Los Alamos Water Boiler Critical Experiment	LOPO	1943	1944
ORNL, Bldg. 205	Nuclear safety and reactor design studies	X-10-200	1945	1948
ORNL, Bldg. K-25	Nuclear physics and nuclear safety with uranium solutions	K-25	1946	1950
ORNL-MTR	Materials test reactor mockup		1950	1950
ORNL-Y12 area	Test reactor assembly No. 1	TRA-1	1954	1954
Bettis	Spare Plate Critical Assembly	SPCA	1952	1955
Bettis	Danger Coefficient Test Facility	DCTF	1953	1957
Operable:				
Alco	APPR core design	APPR-s	1956	
ANL-ID	Fast critical mass determinations	ZPR-3	1955	
ANL—Bldg. 316, Cell A [40]	Nuclear constants with fast exponential source	ZPR-4'	1957	
ANL—Bldg. 316, Cell B [40]	Interactions between two basic systems	ZPR-5	1956	
ANL—Bldg. 316, Cell C [40]	Boiling water concept	ZPR-7	1957	
Bettis	Two region physics	TRX	1953	
Bettis	Reactivity physics measurements	RPF	1956	
Bettis	S5W core design	S5W-FA	1956	
Bettis	A1W core 1 physics and mockup [41]	A1W-FA-1&M-1	1956	
Bettis	A1W core 2 physics and mockup [41]	A1W-FA-2&M-2	1957	
Bettis	PWR core 1 physics	PWR-FA-1	1954	
Bettis	PWR core 2 physics	PWR-FA-2	1957	
Bettis	S3W/S4W mockup and clean critical physics [41]	SFR-FA and FC	1954	
B&W—Cell 1	Consolidated Edison reactor		1957	
B&W—Cell 2	NS Savannah Fuel Assembly and Core		1958	
BMI—Cell 1	Reflector control critical [42]	BMI-CX	1957	
BNL—Bldg. T-526	Exponential and critical assembly		1956	
CE—Bldg. 1, Cell 1, Pot 1	S1C physics and mockup	S1C-FC	1956	
CE—Bldg. 2, Cell 1, Pot 1	Vacant [43]			
CE—Bldg. 2, Cell 2, Pot 1	S1C advanced mockup	S1C-AC	1956	
Canel—Physics Bldg., Cell 1	Propulsion reactor experiments		1958	
Canel—Physics Bldg., Cell 2	Vacant [43]			
ETRC—ETR-MTR Area	ETR physics, core loading, and core design		1957	
GDC—Cell 1	Zirconium—uranium hydride fuel for TRIGA		1957	
GE—Cell 1	Commonwealth Edison reactor		1957	
GE—Cell 2	Checkout test for Spanish swimming pool reactor [44]		1957	
GEANP-1 [45]	Aircraft propulsion		1955	
GEANP-2 [45]	Aircraft propulsion		1956	
PCTR—Bldg. 305-A	Physical constants not directly connected with power generation		1955	
KAPL [46]	Physical data [46]	PPA	1948	
KAPL	Reactor physics studies with plastic moderator and mockup [47]	PMA	1954	
KAPL	Submarine advanced reactor mockup	ATR	1954	
KAPL	D1G cold water mockup	CWA	1957	
KAPL [48]	SAR physics and mockup	FPR	1956	

See footnotes at end of table, p. 347.

C. 1. *Critical Assembly Facilities* [39]—Continued

Abbreviation of facility and location within facility	Subject of experiment or study	Designation of experiment	Startup of experiment	Experiment dismantled
Operable—Continued				
KAPL	SAR high temperature and pressure physics and mockup	PTR	1958	
LAC	RER core configurations	CERF	1958	
LPTF—Cell 1	Air cooled reactor		1958	
LPTF—Cell 2	Air cooled reactor		1958	
Martin—Cell 1	Martin power reactor experiments		1957	
Martin—Cell 2	Engineer Research & Development Laboratory experiments		1958	
RMF—MTR Canel	Reactor physics constants and reactivity changes caused by test reactor irradiation.		1954	
West—YCF	Yankee power reactor		1957	
West—CES	Westinghouse Test Reactor critical experiments		1958	
NDA—Cell 1 [49]	Development of research reactor	NDA-CX	1957	
ORNL-CF—Bldg. 9213, Cell E	Uranium-paraffin experiments related to physics and safety of homogeneous reactors.	CA-28	1956	
ORNL-CF—Bldg. 9213, Cell W	Reactor physics and nuclear safety studies with homogeneous uranium solutions.		1950	
ORNL-CF—Bldg. 9213, Cell S	Comparison of nuclear properties of U-235 and U-233			
ORNL-PCA—Bldg. 3010	ORR control system and safety studies		1958	
Being Built:				
B&W—Cell 3 [50]	LMFRE physics data		1958	
BNL—Bldg. T-525	LMFRE physics data		1958	
NACA—Materials & Stresses Bldg.	NACA Test Reactor critical experiments		1958	
Bettis	High temperature physics and mockup	HTTF	1959	
Planned:				
ANL—Bldg. 316 addition	Fast nuclear and core mockup	ZPR-6		
ANL—Bldg. 316 addition	Fast neutron instrumentation and physics studies	FNS-1		
ANL—Bldg. 316 addition	Thermal reactor core tests	CTF		
AC	Northern States power reactor experiments	CRBR-CX	1959	

[1] Capacity figures for power reactors are based on the best available information. In some cases future modification in plans may cause changes.

[2] The Shippingport station is provided with a turbogenerator rated at 100,000 EKW and may reach this gross output with later cores.

[3] Of total net output shown for the Consolidated Edison plant, 151,000 KW will be nuclear and 104,000 KW oil-fired superheat.

[4] Contract awarded by Commission under Power Demonstration Reactor Program.

[5] The Enrico Fermi plant is to be provided with a turbogenerator rated at 150,000 EKW and may reach this gross output with later cores.

[6] The net EKW for Yankee's second core is expected to be 134,000.

[7] Approved as a basis for Commission contract negotiations under Power Demonstration Reactor Program.

[8] Net output of Elk River plant includes about 7,000 EKW conventional superheat.

[9] Capacity of Northern States plant includes about 16,000 EKW superheat, which may be either nuclear or conventional.

[10] Contract signed with Nuclear Development Corp. of America for research and development under Power Demonstration Reactor Program. Contract under negotiation with Chugach and NDA for later phases of the project.

[11] Specific Congressional authorization will be required prior to the award of a Commission contract for the Pennsylvania Power and Light Co. project.

[12] Design study only, as authorized by Public Law 85-162. Specific plans for carrying out the project have not yet been formulated.

[13] Construction contract is subject to the following conditions: (a) obtaining favorable long-term arrangements with AEC regarding fuel cycle, and (b) obtaining favorable long-term loan from Export-Import Bank covering capital costs.

[14] LAPRE-1 was designed as a small reactor experiment which was to produce 2,000 kilowatts of heat power. It operated only very briefly and never succeeded in reaching full power.

[15] Gross EKW is shown for EBR-1 in the tabulation. In a trial run on December 21 and 22, 1951, EBR-1 generated the world's first electric power from nuclear energy. Criticality with the third core was achieved in November 1957.

[16] Originally built and operated in 1954 as Boiling Reactor Experiment No. 2 (BORAX-2). With the addition of a turbogenerator, it operated during 1955 as BORAX-3. BORAX-4 is a further modification and has been operating since 1956.

[17] EBWR was successfully operated at a power level of 62,000 kilowatts of heat in experiments on March 20, 1958. Its electrical output is limited by turbogenerator capacity.

[18] In January 1958, VBWR operated at a power level of 30,000 kilowatts of heat. Its electrical output is limited by turbogenerator capacity.

[19] Since it is provided with a very small turbogenerator, the HRE-2 will produce only token amounts of electricity (about 300 kilowatts gross) as compared to a thermal output of 5,000 kilowatts, most of which will be dumped to the atmosphere.

[20] LAPRE-2 fabrication is nearing completion. The project is to be terminated after the completion of fabrication and initial operation and testing.

[21] It is now believed that considerably more technical investigation, development, and evaluation are required before a power reactor embodying the fast molten plutonium concept can be built and successfully operated. For this reason the project has an indefinite schedule.

[22] APPR-1a is being built at Fort Greely, Alaska. This plant will produce 42 million BTU per hour of steam for space heating and about 1,700 KW of electricity.

[23] APPR-2 is to be constructed at an undetermined site. In addition to electricity, the plant will produce 7 million BTU per hour of steam for space heating.

[24] In 1943, the Manhattan Engineer District disassembled Chicago Pile 1 and rebuilt it at Palos Park, Ill., as Chicago Pile 2. CP 2 had a thermal power level of 10 KW. It was dismantled by the AEC in 1954.

[25] Reactors whose thermal power output is less than 50 watts are shown as having negligible power output. The thermal power of these reactors is as follows: AGN 201's, 100 milliwatt; AGN 201 M's, 5 watts; AGN 211's, 15 watt; AI's L-47, 5 watts; AI's L-77, 10 watts; ARSS; UTR-1, 1 watt; NDA's PRR, 5 watts; Hanford 305 Test Pile, 10 watts.

[26] WBNS was built and first operated at Downey, Calif. It was moved to Santa Susana in 1957.

[27] Original 10 KW research reactor at Raleigh, N. C., was started up in 1953 and dismantled in 1955. Reactor was reactivated with a 500-watt core in March 1957.

[28] This reactor (TRIGA) will be shipped to and operated at the 1958 International Conference in Geneva, Switzerland.

[29] Plans for the construction of the UCLA medical reactor have been deferred pending a decision on financing.

[30] Has operated under license to AGN. Transfer to listed owner is expected shortly.

[31] The Netherlands research reactor originally operated at the Amsterdam International Exhibition in June 1957. It is now operating at Delft.

[32] This is the 1955 Geneva Conference Reactor rebuilt with increased power and now operating at Wuerenlingen, Switzerland.

[33] This reactor is being operated in the International Science Section of the Brussels International Exhibition, April 15–October 1, 1958.

[34] ORR detailed design was completed and construction was well under way (1955) before the Commission on Nov. 8, 1956 announced its policy of constructing test reactors only to develop new and improved reactors of advanced design or if its needs for irradiation space could not be met by private industry.

[35] Operated for reactor transient experiments only.

[36] NETR was originally scheduled for operation in 1960. Present schedule is indefinite.

[37] Authority to construct the AETR has not been requested.

[38] Public Law 85–162 authorized a design study for a new production reactor. No plans for construction have been formulated.

[39] Critical experiments at Los Alamos and other weapons sites not included.

[40] Zero power experiments of historical interest previously conducted in ANL facility. Cells include the *Nautilus* Core design (ZPR-1), the Savannah River reactor design (ZPR-2), and a series of fast neutron studies (ZPR-4).

[41] Cell has one control panel. Experiment may be operated in either part of cell but not simultaneously. Only a single count is made in statistical summary.

[42] Experiment transferred from Battelle Memorial Institute to Connecticut Aircraft Nuclear Engine Laboratory.

[43] Vacant critical facility cells at CE and CANEL not counted in statistical summary.

[44] Experiment in GE cell 2 is dismantled.

[45] Test Reactor Assembly No. 1 and No. 2 were previously conducted in GEANP facility.

[46] PPA physics data experiment was formerly located at Sacondago Site, West Glenville, N. Y.

[47] PMA at KAPL was modified from SIR Proof Test Reactor (PTR).

[48] The PPA and FPR are in the same cell but each has a separate control panel. Interlocks prevent reactors from being operated simultaneously.

[49] The NDA facility is designed to accommodate two experiments but has a present capability of one.

[50] B&W cells 2 and 3 will share a control panel with only one cell capable of being operated at any one time. Cell 3 is not counted in the statistical summary.

APPENDIX 10

Health and Safety Precautions for Eniwetok Proving Ground Tests

Protection of health and safety is a primary consideration in the conduct of the Hardtack series of nuclear weapons tests at the Eniwetok Proving Ground in the Pacific.

As announced previously, the test series will advance the development of weapons for defense against aggressive whether airborne, missile-borne or otherwise mounted. Information on the effects of weapons will be obtained for military and civilian defense use. As in the past, test operations will be conducted in a manner designed to keep to as low as possible the public exposure to radiation arising from the detonation of nuclear weapons.

An important objective of the tests is the further development of nuclear weapons with greatly reduced radioactive fallout so that the area of radiation hazard may be kept as small as possible. This principle was first proved in the Eniwetok test series of 1956.

Various precautions have been taken to keep significant radioactive fallout within the confines of the danger area in the Pacific which was announced on February 14, 1958. With the exception of Joint Task Force facilities, there are no inhabited places within the danger area.

Extensive systems have been established to detect and measure radioactivity in the vicinity of the Proving Ground, in the United States, and in other parts of the world. Radiological monitoring and sampling will be conducted by several networks of stations extending from the Proving Ground to locations around the world. In addition marine surveys will be conducted to measure radioactivity in sea water and marine organisms.

More detailed information on health and safety measures relating to the test series follows:

FALLOUT PREDICTIONS

Tests will be conducted only when the forecast pattern of significant fallout is entirely within the danger area. In forecasting fallout patterns, scientists will make use of improved methods of collecting and evaluating data which have been developed as a result of intensive study of the problem of predicting fallout in the vicinity of the Proving Ground.

Fallout predictions are dependent upon weather information. Experience has shown that weather data normally available in the Pacific Ocean area are inadequate for the needs of testing. Therefore for nuclear tests in the Pacific special arrangements are made to obtain additional data. For the 1958 tests thirteen special United States weather stations, located within several hundred miles of the Proving Ground, will participate in a weather network reporting to a central station. These stations will be staffed by military and civilian meteorologists. Weather reconnaissance will be carried on employing aircraft, ships, balloons and rockets.

Research has been conducted in the special field of tropical meteorology, and weather observers and forecasters have been instructed in the latest methods of forecasting which have been developed as a result of these studies.

Trained personnel have been organized into a fallout prediction unit. To assist in predicting fallout patterns they will utilize fallout computers which mechanize most of the mathematical procedures involved. Use of the computers will make possible rapid forecasts. Models of the clouds produced by previous large-scale nuclear detonations have been developed, and these also are expected to improve fallout predictions.

DANGER AREA

The danger area is generally rectangular in shape and comprises roughly 390,000 square nautical miles. It is approximately the same size as the area used in the 1956 test series, but its east and west boundaries have been shifted approximately 120 nautical miles to the west. Except for the test personnel, there are no inhabitants within the area.

All ships, aircraft and personnel have been cautioned to remain clear of the area which is bounded by a line joining the following geographic coordinates:

18°30′ N.,	156°00′ E.
18°30′ N.,	170°00′ E.
11°30′ N.,	170°00′ E.
11°30′ N.,	166°16′ E.
10°15′ N.,	166°16′ E.
10°15′ N.,	156°00′ E.

Notices have been given the widest possible distribution through marine, aviation and international organizations.

Regular air and sea searches of the area will be conducted in advance of the start of operations. Before each shot, the patrol of the danger area will be intensified, particularly in the area where fallout is forecast.

The Atomic Energy Commission has issued regulations which prohibit entry into the danger area of U. S. citizens and all other persons subject to the jurisdiction of the United States, its territories and possessions.

The regulations effective from April 11, 1958 until the Hardtack test series is completed prohibit entry, attempted entry or conspiracy to enter the danger area.

RADIATION MONITORING IN PROVING GROUND REGION

Radiological safety personnel, equipped with radiation detection and measuring instruments and two-way radios to enable them to communicate with the central Task Force Radiological Safety Office, will be stationed on nearby inhabited atolls, and at weather stations of the weather reporting network. In the unlikely event of significant fallout in an inhabited area, the monitors would warn the inhabitants and advise and assist them in taking safety measures. The monitors also have trained Marshallese medical practitioners and health aides in basic emergency measures.

RADIATION SURVEYS OF SEA AND MARINE LIFE

Outside of the testing area, the detonations are not expected to add enough radioactive material to natural levels of radioactivity in the ocean to be harmful to marine life. Experience shows that outside the testing area, resulting quantities of radioactivity in edible sea foods will result in exposures which will be very small compared with the limits for public exposure recommended by the United States National Committee for Radiation Protection and Measurement.

As in the past there will be a program of study to explore the ultimate destination and behavior of radioactivity in the sea water and in marine organisms. Sweeps by U. S. Navy Vessels both during and after the test series will include such measures as taking continuous readings of radioactivity in surface water, sampling of water at various depths, making tows to gather plankton—the tiny marine organisms which tend to concentrate radioactive materials in their tissues—and catching of fish for analysis for radioactivity.

In addition to these investigations, land and marine biological surveys again will be conducted at Eniwetok and Bikini and other atolls nearby. Samples of water and of plants and animals living in the lagoons and on the reefs and islands of the atolls will be collected and analyzed for radioactivity.

FALLOUT MONITORING IN UNITED STATES

The heavier particles fall out of the radioactive cloud at early times after a detonation, while their radioactivity is still high. Therefore, the highest levels of radioactivity occur over a local area downwind from the point of detonation. The area of significant fallout is expected to occur entirely within the uninhabited danger area surrounding the Eniwetok Proving Ground.

As the radioactive cloud is transported away from the point of detonation, it is widely dispersed by air currents and diluted by normal air. Its radioactivity also decreases rapidly because of the normal process of radioactive decay.[1] By the time the cloud from a detonation in the Eniwetok Proving Ground has traveled across a vast expanse of ocean, it will have become thoroughly dispersed into the air and will have lost most of its original radioactivity.

As a result, the exposures to radioactivity in the United States from the Eniwetok tests are expected to be low. Although levels of many times the normal background may be reached in some localities, these increases will be temporary and will not greatly increase the total exposure to radiation. Average exposures of residents of the United States to radiation from weapons tests during the past five years has been much less than the average exposure to radiation from natural sources during the same period.

Outside of the Pacific area monitoring and sampling activities will be conducted in cooperation with the U. S. Weather Bureau, the U. S. Public Health Service, and at Atomic Energy Commission installations. These operations will not be conducted in the expectation of possible hazard, but for scientific purposes and to keep the public informed on levels of radioactivity.

Information will be provided by two monitoring networks, one consisting of 42 stations established by the U. S. Public Health Service and the other consisting of monitors at 11 Commission installations. The locations of these monitoring stations are in Tables I and II.

The Public Health Service established its country-wide monitoring system in 1956 in connection with the Redwing series of tests at the Commission's Eniwetok Proving Ground. Under a contract between the Public Health Service and the Commission the monitoring system will operate throughout the year.

The Public Health Service monitoring stations will take daily radiation readings and collect filter samples of radioactivity and will forward these to a central collection office in Washington. The stations also will report data to the health officers of the States or territories in which the stations are located. They will

[1] Radioactive fallout consists of a mixture of radioisotopes, with varying half-lives. The mixture as a whole decreases in radioactivity in such a way that for every seven-fold increase in age, the total radioactivity is decreased ten-fold. Thus, the radioactivity at seven hours after H+1 hour is only one-tenth that at H+1 hour, and in 49 hours is one-hundredth, etc.

be manned by trained technicians from State health departments, local universities and scientific institutions.

Still another network in the United States gathers data which is used in a long range scientific study of the behavior of radioactive materials in the environment and their effect on man. This network consists of 46 U. S. Weather Bureau and 8 Atomic Energy Commission stations which collect fallout samples at selected locations throughout the nation and its territories.

MEASUREMENTS OF RADIOACTIVITY OUTSIDE THE U. S.

Samples of airborne dust will be taken at approximately 70 localities throughout the world, in addition to the 46 U. S. stations.

Soils also will be sampled on a worldwide basis, and samples of other materials such as milk and cheese, field crops and human and animal bones will be taken for analysis of their strontium 90 content. This program is part of the Commission's Project Sunshine, a study of the worldwide distribution and uptake of radioactive fission products, particularly strontium 90.

TABLE I.—U. S. PUBLIC HEALTH SERVICE MONITORING STATIONS DURING OPERATION HARDTACK

Albany, N. Y.	Honolulu, T. H.	Oklahoma City, Okla.
Anchorage, Alaska	Indianapolis, Ind.	Pascagoula, Miss.
Atlanta, Ga.	Iowa City, Iowa	Phoenix, Ariz.
Austin, Tex.	Jacksonville, Fla.	Pierre, S. Dak.
Baltimore, Md.	Jefferson City, Mo.	Ponca City, Okla.
Berkeley, Calif.	Juneau, Alaska	Portland, Oreg.
Boise, Idaho	Klamath Falls, Oreg.	Richmond, Va.
Cheyenne, Wyo.	Lansing, Mich.	Salt Lake City, Utah
Cincinnati, Ohio	Las Vegas, Nev.	Santa Fe, N. Mex.
Denver, Colo.	Lawrence, Mass.	Seattle, Wash.
El Paso, Tex.	Little Rock, Ark.	Springfield, Ill.
Gastonia, N. C.	Los Angeles, Calif.	Topeka, Kans.
Harrisburg, Pa.	Minneapolis, Minn.	Trenton, N. J.
Hartford, Conn.	New Orleans, La.	Washington, D. C.

TABLE II.—AEC MONITORING STATIONS DURING OPERATION HARDTACK

Location	*Agency*
Albuquerque, N. Mex	Sandia Corp.
Berkeley, Calif	Radiation Laboratory, University of California
Cincinnati, Ohio	General Electric Co.—Aircraft Nuclear Propulsion Department
Idaho Falls, Idaho	Idaho Operations Office
Lemont, Ill	Argonne National Laboratory
Los Alamos, N. Mex	Los Alamos Scientific Laboratory
New York, N. Y	New York Operations Office
Richland, Wash	Hanford Operations Office
Oak Ridge, Tenn	Oak Ridge National Laboratory
Rochester, N. Y	The Atomic Energy Project, University of Rochester
West Los Angeles, Calif	Atomic Energy Project, UC-Los Angeles

APPENDIX 11

A Report on the Domestic Mining and Milling Problems Resulting From Limitation on Additional Milling Capacity

BY THE DIVISION OF RAW MATERIALS

1. The Commission on October 28, 1957, announced a policy of limiting its contracts prior to 1962 for additional domestic uranium concentrate. Its Grand Junction Operations Office was instructed to negotiate no new contracts involving additional milling facilities.

2. This action was taken to keep the Commission's annual uranium purchases in reasonable balance with its currently estimated requirements. Recent rapid expansion of domestic production, and the prospects of continued rapid expansion under an unlimited procurement program, posed a threat of overproduction that in the end might have serious adverse effects on the uranium industry, as well as result in excessive purchases by the Commission.

3. A review of the background of the domestic uranium program will indicate the basis upon which the uranium industry was developed and the reasons for the problems resulting from the limitation announcement.

I. BACKGROUND

4. Private uranium exploration and development have been based largely upon the procedures followed for nearly ten years under the Commission's domestic uranium program.

5. The objective of the Commission had been to purchase the uranium concentrate it requires from privately financed and operated mills. In addition to providing the Commission with the type of material required for its production chain, this procedure had the advantage of promoting the development of private uranium mining and milling along the established pattern of the mining industry.

6. Under the procedures followed during the period of uranium shortage, any area having developed sufficient commercial ore to support a milling operation was eligible for a concentrate contract. The prospective milling company had to negotiate a concentrate contract with the Atomic Energy Commission and had to provide reasonable evidence of being able to finance the mill construction and operation and carry out the terms of the contract. The independent miners were protected by provisions in the contracts requiring the milling companies to purchase a minimum quantity of custom ore, if offered, and to pay prices for ore not less favorable than those contained in the Commission's published ore buying circular. Because of discoveries after execution of contracts the mill capacity allocated to custom ore has in some cases proved inadequate, and in the past this situation was generally corrected by providing new mills or expansion of existing facilities.

7. It was largely on the basis of these procedures that prospectors, independent miners, and milling organizations engaged in prospecting, exploration, and mine development. Usually the major expenditures for development have been by the prospective milling companies because adequate ore reserves had to be available in order to finance the proposed milling operations and to qualify for an AEC

contract. In most areas the prospectors and small miners were the pioneers making the initial discoveries. Many of them transferred their properties to mining or milling companies for cash or stock, or retained royalty rights or a working interest. Others developed and operated their mines and sold their ore to the mills. Many, including some who as yet have no developed reserves, have continuing expenditures in order to hold their properties because of purchase or lease requirements, or the annual assessment work required under the U. S. mining laws.

II. SCOPE OF THE STUDY

8. Following the October 1957 announcement, the Grand Junction Operations Office was asked to study the effects of the limitation policy upon the uranium industry, with special reference to those who had spent money prior to the announcement for exploration, acquisition of property, development of ore reserves, mine preparation, or for metallurgical and engineering work in connection with proposed milling operations.

9. The survey concentrated on the areas and on the individual cases which have or may have ore marketing problems. All available information on ore reserves was taken into consideration. In addition, more than 150 individual mining properties were studied in detail to determine operating data. From this study minimum economic mining rates were calculated for individual properties. In the case of some of the smaller deposits, the minimum economic mining rate could exhaust the deposit in a year or two or even in less time. For some properties with large ore reserves, the minimum rate would result in an operating life well beyond 1966.

10. These estimates of ore production rates, taking into consideration the available market at mills now operating or under construction, were the basis of the estimates, by areas, of the additional mill facilities required to provide a minimum economic market for presently developed ore reserves. No detailed studies were made of the mines in areas having no marketing problems although the areas as a whole were studied to determine the relationship between existing mill capacity and total ore reserves, and the possibility of future problems.

11. Industry has cooperated in supplying, on a business confidential basis, much of the basic data, such as drilling results and cost information. Much of the detailed information had been gathered earlier in connection with preliminary discussions on new milling proposals. Furthermore, the Grand Junction geological and mining staffs have maintained a continuing study of the various mining districts and most of the deposits since the initial discovery and development. Consequently, the Commission has reasonably complete information on the grade, and tonnage and mining characteristics of developed ore reserves. On the basis of this information we have estimated the rate of ore production required for an economic mining operation for the various types of deposits.

12. It should be emphasized that most of the approximately 700 mines now in operation, together with those being developed to supply mills under construction, are faced with no difficulties in marketing ore. In 1957, 3,676,000 tons of ore were mined and delivered to mills or buying stations. Mill requirements for 1958 are estimated at 5,500,000 tons of ore, and for 1959 at 7,200,000 tons. Thus the problems stemming from the limitation policy affect only a limited part of the domestic uranium industry but for the areas and the individuals affected, the problems are serious.

13. In this study, the availability of mill capacity has been used in considering the market for ore. This is the type of market which has been provided in the past

under the domestic uranium program. During the period of uranium shortage, the Commission established a number of ore buying stations to assist and speed up development of new areas. These stations usually offered only a limited market for ore pending construction of private mills and most of them now have been closed. At present, more than 95 percent of all ore produced is delivered directly to the private mills.

14. Government stockpiling of crude ore is an alternate method of providing a market for mine production. The purchase of crude ore, instead of concentrate, has the advantage of lower initial cost to the Government, but the final cost of the concentrate may be much higher. Eventually the ore will have to be milled to obtain a usable product and mills will have to be available or constructed near the stockpile sites because crude ore cannot stand high shipping costs. A considerable lead time might be required to convert the ore into concentrate. Stockpiles are subject to wind and erosion losses which are substantial, and for some ores soluble losses may be important.

III. DISCUSSION OF THE PROBLEMS

A. *Current Ore Marketing Problems*

15. Most seriously affected by the limitation policy are the individuals and organizations who have developed or acquired ore reserves and now find that they do not have a market. If measured by the effort and money expended prior to the announcement, this group probably would sustain by far the greater part of any losses which could be attributed to the limitation. Consequently, the study by the Grand Junction Operations Office was directed primarily toward determining the extent to which currently planned mill capacity would be inadequate to provide a reasonable market for developed ore.

16. This study shows that in certain uranium areas there are no mills, or that milling capacity at present is inadequate to provide an economic market for all mine operators having developed ore reserves; that in other areas existing mill capacity would be adequate if arrangements could be worked out for prorating mill capacity to the mining properties now producing or in position to produce; and that in some uranium areas there are no ore marketing problems and none are anticipated. A brief review of each of the individual areas is included in this Appendix.

a. The areas listed below have either no market or an inadequate market to process presently developed ores at a minimum economic mining rate. These reserves include ores controlled by milling companies and by independent mine operators. Estimated minimum requirements for additional mill capacities to provide such a market are:

	New mill capacity tons/day
(a) Southeast Texas	600
(b) North Dakota—South Dakota (Lignites)	600
(c) Wyoming	1,700
(d) Colorado Front Range	200
(e) Nevada (Austin)	200
Total	3,300

Based on the average grade of ore in the several districts, 3,300 tons of new mill capacity would produce an additional 5,300,000 pounds of U_3O_8 per year.

Presently authorized milling capacity taken in conjunction with proposed additional mills should provide a minimum market for the independent mine operators and for the mines controlled by the milling companies, provided all existing mines are given a proportion of the market.

b. Six areas have adequate milling capacity in relation to total developed ore reserves, but the portion available for ore from independent miners is or may be insufficient because the ore reserves controlled by independent miners have been increased since the milling contracts were negotiated.

These areas are:

(a) White Canyon—Monument Valley, Utah-Arizona
(b) Eastern Wyoming—Black Hills, South Dakota
(c) Salt Lake City, Utah (Area tributary to the Salt Lake City mill)
(d) Moab (Big Indian Wash), Utah
(e) Grants, New Mexico
(f) Spokane, Washington

In the case of these areas a reasonable market for all mines with developed ore reserves might be provided without additional mill construction. The problem is one of making equitable provision for production from the various mines. If adequate provision cannot be made, some additional capacity may be required.

c. The following areas have an adequate market for ore produced from the known mines:

(a) Uravan Mineral Belt, Colorado
(b) Cameron District, Arizona
(c) Shiprock District, New Mexico
(d) Lakeview, Oregon
(e) Baggs—Maybell, Wyoming—Colorado

d. In addition to those listed above, there are several areas in which uranium occurrences have been discovered but which do not have sufficient ore reserves to support an economic milling operation. For example, the known deposits in California are generally small and widely scattered. Total reserves, particularly those which might be economic to mine, contain but a small fraction of the quantity needed for even a five-year milling operation. At present, there is no basis for predicting that sufficient commercial ore could be developed to support an economic milling operation. It may pay the miner to ship selected higher grade ore from some of the deposits to one of the existing mills.

e. Special Problems. Although every effort has been made to obtain full information and arrive at accurate estimates, additional information and discussions with mine operators may indicate revisions are desirable. Also, there may be special cases which do not fall in the categories as discussed above.

B. *The Small Mine Operator*

17. Many of the problems of the small mine operator have been discussed under "A" above. In this report the term "independent miner" has been used to designate the mine operator, large or small, who has no financial interest in a mill or whose mining operation is not controlled by a milling company through an operating arrangement or lease.

18. The size of a mining operation usually is determined by the size of the deposit. The small operator who develops a large deposit becomes a large operator unless he sells or leases his property, which he often does. Many of the large uranium deposits cannot be operated at a low production rate because of the large capital expenditure required. This is particularly true in the Ambrosia

Lake District, New Mexico, and the Gas Hills District, Wyoming. In some districts the deposits generally are small and small operations predominate.

19. Since most small mine operators work small deposits, and many of these deposits are marginal or submarginal, many small operators have economic problems because of the type of the deposits they work. Problems of this type are not the result of the limitation on procurement.

20. The Domestic Uranium Program has been designed to help in opening up new deposits. The Initial Production Bonus, Circular 6, provides additional payments, which may total $35,000, on the first 10,000 pounds of U_3O_8 contained in ore from any new property that is sold to a mill or buying station. The bonus has helped the small miner in bringing mines into production. Also, small deposits that have proved marginal have been tested by mining with a minimum of loss or even a profit. This is evident by the large number of deposits which have been abandoned when bonus payments were completed.

21. The problems of the small miners will receive continuing attention.

C. *Current Provision for Milling Capacity to Cover Future Ore Discoveries*

22. Some industry representatives have proposed that assurances should be given that milling contracts would be negotiated to provide a market for additional ore discoveries.

23. The most difficult problems under this category relate to those who have invested money in geological studies and land acquisition but as yet have no developed ore. In some cases substantial commitments already have been made and the lease arrangements require heavy continuing expenditures and active mining if commercial ore is found. Failure to proceed may mean loss of investments already made. Those in this position contend that further expenditures would not be justified without assurance of a market for the ore that may be found. Some have requested assurances of a concentrate contract if sufficient ore is developed to support a milling operation.

24. If assurance is given that concentrate contracts will be negotiated to provide additional milling capacity for ore that may be found, there can be no effective limitation on procurement. There is no way of predicting with certainty how much ore will be found and what economic mining rate will be required. Our latest estimate of domestic ore reserves is 78,000,000 tons. Geological evidence is favorable for finding additional reserves of similar magnitude by active exploration. If, instead of providing new milling capacity, future ore discoveries share the mill capacity which has been provided for ore reserves already developed, the result might be an unsatisfactory and uneconomic market both for those who already have developed ore at substantial expense and those who find and develop new deposits. For the immediate future at least, the market for newly discovered ore should depend primarily upon the capacity that may be available, without displacing presently developed ore, at mills now in operation or under construction, plus any additional capacity that may be provided for those who already have developed reserves. That there will be a substantial market in many areas for ore to be developed between now and the end of 1966, or even prior to 1962, is indicated by the following discussion on future exploration.

D. *Incentive for Future Exploration and Development*

25. Concern has been expressed that a limitation on Government purchases will eliminate the incentive for exploration and that ore reserves will be seriously depleted during the period of the AEC program.

26. In some districts additional ore must be developed to provide for the operation of existing mills prior to 1962, and in all districts additional ore development may be required prior to 1966. Although estimated domestic ore reserves theoretically would support a milling rate of approximately eight million tons of ore a year for about nine years, in practice this would not be the case. Mining operations in general are not capable of sustaining a given rate of production but experience a declining output as the mines approach exhaustion. This means that there is need for continuing exploration and development on the basis of the present Government market. However, rate of exploration and development can be expected to decline sharply for a time if there is no longer an expanding uranium market.

27. Maintenance of adequate ore reserves by private industry for the industrial market in the post-1966 period will be based largely upon industry's appraisal of that market. At present industry in general has confidence that there will be a substantial future industrial market but has little firm data upon which to estimate the size and timing of that market. As long as this uncertainty exists, exploration and development for the future market will proceed cautiously and on a limited scale.

28. A sizable market for nuclear fuel now seems to be developing in Europe and other power-short parts of the world. The domestic uranium industry desires to compete for that market as soon as possible. Although the opportunity for private sales may be limited at present, industry could better assess the future market if it were in a position to undertake negotiations for sales with prospective industrial users.

29. The question of licensing such sales subject to appropriate safeguards on end use is under active study by the AEC.

30. There should be a continuing study of ore reserves in relation to future requirements, taking into consideration the anticipated needs of the nuclear power industry. A periodic appraisal should provide the information needed to determine what action, if any, should be taken by the Government if at any time reserves appear inadequate in relation to national requirements.

Summary

31. The study made by the Division of Raw Materials indicates that 3,300 tons of ore per day is the additional milling capacity required to provide a minimum economic market for developed ore reserves in those areas which can support economic milling operations. It is recognized that in order to prevent possible inequities, this estimated milling capacity may have to be increased by a moderate amount. In terms of concentrate procurement, 3,300 tons of ore per day of new milling capacity would yield in excess of 2,650 tons of U_3O_8 annually. Production under existing domestic contracts for F. Y. 1961 is estimated at 17,500 tons of U_3O_8 and if the additional milling capacity is provided, production for that year would be in excess of 20,000 tons of U_3O_8.

32. Government stockpiling of crude ore is an alternative to concentrate procurement.

33. The problems of those who have made investment in the acquisition of land preparatory to undertaking exploration programs are recognized, but no estimate can be made of the additional milling capacity which might be required for future discoveries, because the magnitude of such discoveries cannot be predicted. If action is taken which would commit the Commission to provide through purchase contracts or additional milling facilities, a market for all ore reserves of commercial

size and grade that may be discovered in the future, there could be no effective limitation policy.

34. The study indicates a need for a continuing review of the ore reserves in order to provide the information needed to determine what action should be taken if reserves at any stage appear inadequate in relation to national requirements.

ANALYSIS OF MARKETING PROBLEMS BY DISTRICT

Every district having substantial ore reserves has been evaluated during the course of this survey. A brief summary of the results of the survey is given in the following pages by individual district.

All available information on ore reserves and ore grades was taken into consideration in evaluating each situation. Much of the information used in calculating the tonnage and grade of ore reserves is based upon drilling by private operators. We believe that our over-all information is reasonably complete and accurate and that any possible omissions will have but minor effect upon the estimated total reserves as of November 1, 1957.

More than 150 individual mining properties were studied in detail in arriving at estimated minimum economic mining rates. These are all located in areas where marketing problems are reported.

The term, "captive ore," refers to ore owned or controlled by companies operating the mills. The terms, "independent ore," or, "custom ore," refer to ores owned or controlled by others. Estimates of the grade of ore used in discussions of the individual districts relates to the grade mined and takes into consideration normal dilution in course of mining.

BAGGS-MAYBELL AREA

(WYOMING-COLORADO)

Situation

Indicated and inferred ore reserves in the district as of November 1, 1957 are estimated at 564,000 tons with an average grade of approximately 0.16 percent U_3O_8. Of this total, 85,000 tons are controlled by two independent operators in the Baggs area. Several other operators have been carrying on development work but no substantial reserves of commercial grade ore had been developed prior to November 1, 1957. Mill capacity is 300 tons per day, of which 75 tons is reserved for custom ore.

Analysis of Situation

There appears to be an adequate market for all ores of the district. Based on ore developed by November 1957, and the rated mill capacity, the ores could be treated by the end of 1962.

CALIFORNIA

Situation

Only small, scattered ore deposits have been developed in the State. Indicated and inferred reserves of commercial grade ore totaled 27,000 tons as of November 1, 1957, having an average grade of 0.29 percent U_3O_8.

Analysis of Situation

Ore reserves developed to date contain only a small fraction of the tonnage necessary to support a commercial milling operation. A market may be available at one of the existing mills in nearby states for selected high grade ores of the area.

COLORADO FRONT RANGE

Situation

A large number of uranium occurrences have been found in the Colorado Front Range but few have been developed sufficiently to provide the data needed to establish developed ore reserves. Our estimate of the total indicated and inferred ore reserves for the district as of November 1, 1957, was approximately 140,000 tons, ranging in grade from 0.20 percent to 0.70 percent U_3O_8 and averaging approximately 0.40 percent U_3O_8. Because there are a number of potential sources a considerably larger tonnage might be available if there should be a local market for all of the various types of ore that have been found.

Two new mills just starting operations, one at Gunnison, Colo., and the other at Rifle, Colo., are offering a limited market for the more amenable ores of satisfactory grade.

Analysis of Situation

Numerous small size deposits have been found along 250 miles of the Front Range in Colorado. Ore types vary from primary minerals associated with sulfided and secondary minerals in fissure type vein deposits (some of it quite rich in uranium) to the usual mineralization in sandstones and other sedimentaries (much of it low grade). Such wide variation in minerals and mineral association results in a wide variety of metallurgical characteristics. Further testing of the available ores may be required before the most effective milling method can be established. While it is possible that a single treatment method would be satisfactory, auxiliary circuits for ores having unusual characteristics might be necessary.

Sufficient ore of any one metallurgical type is not currently proven to justify an economical size mill in the area with the possible exception of the highest grade vein type ores. Any mill constructed in the area would be required to supply a market for a major portion of the ores developed. The minimum size for an economic milling operation is generally considered to be about 200 tons of ore per day.

EASTERN WYOMING—BLACK HILLS, SOUTH DAKOTA

Situation

The present mill capacity of approximately 400 tons per day at the Edgemont, S. Dak. mill is sufficient to supply a market for all indicated and inferred ore reserves developed on November 1, 1957. The mill is a custom mill, having no captive ores.

Indicated and inferred ore reserves in the tributary area are estimated at 499,000 tons on November 1, 1957, including 105,000 tons in stockpiles at the mill. The grade of the ore is approximately 0.23 percent U_3O_8.

Analysis of Situation

While the mill capacity in the area is sufficient to permit the treatment of all ores developed as of November 1, 1957, before March 31, 1962, there exists a current marketing problem. The combined mining capacity exceeds the amount the mill can treat. Operators of the Edgemont mill have instituted a system of allocation for the various independent producers.

GRANTS, NEW MEXICO AND GALLUP, NEW MEXICO AREAS

Situation

Indicated and inferred ore reserves in these districts as of November 1, 1957 are estimated at 52,775,000 tons, of which 49,775,000 tons are calculated as captive ore and 3,000,000 tons as independent ore. The average grade of the ore is expected to be 0.24 percent U_3O_8.

When mills now under construction are completed, total mill capacity in the area will be 11,683 tons per day, of which 1,169 tons per day will be available for custom ores.

Analysis of Situation

A market appears available for independent ores developed prior to November 1, 1957, which should permit mining at economic rates over the next eight years.

Development of mines in the Ambrosia Lake area is currently behind schedule due to the mining problems being encountered. With mill construction on schedule, this slow mine development should assure independent operators of a market in excess of the minimum provided in AEC contracts. As captive mines are brought into full production, the market for independent ores will probably be held to that provided by contract. The possibility exists that a temporary shortage of mill capacity may occur if all independent mines reach peak production at the same time. Some adjustment may be possible if this situation occurs.

The largest reserves controlled by independent operators in this area are in the Ambrosia Lake District and most of them are subject to the same mining problems now being encountered in the captive mines.

Earliest dates by which the November 1957 ore reserves could be milled with presently planned milling capacity is shown in the following tabulation:

	Reserves plus stockpiles	Mill capacity (tons/day)	Indicated life of reserves
Captive	49,775,000	10,514	August 1971.
Independent	3,000,000	1,169	August 1965.
Total	52,775,000	11,683	

Independent operators control 5.6 percent of the estimated ore reserves in the district and have 10 percent of the total mill capacity.

LITTLE COLORADO, NORTHERN ARIZONA

Situation

Indicated and inferred ore reserves in the district as of November 1, 1957 are estimated at 309,000 tons, with an average grade of 0.20 percent U_3O_8. The

capacity of the Tuba City mill is approximately 300 tons per day. Many of the deposits in the area are proving submarginal and the mill is faced with a possible ore shortage within three or four years.

Analysis of Situation

Present mill capacity is sufficient to provide a market for all mining operations in the district.

MOAB (BIG INDIAN WASH), UTAH

Situation

Present mill capacity in this area is sufficient to allow processing of all indicated and inferred ore reserves prior to 1967.

Tributary indicated and inferred ore reserves plus stockpiles in the area as of November 1957 are estimated at 4,179,000 tons, having an average assay of 0.37 percent U_3O_8.

Analysis of Situation

If satisfactory arrangements can be made for allocating mill capacity to the various mines in the district, it should be possible for the mines to operate at a rate consistent with good mining practice for economical extraction of the ores.

Based on a mill throughput of 1,500 tons per day the estimated dates by which the November 1, 1957, ore reserves plus stockpiles would be milled are shown below:

	Reserves	Mill capacity (tons/day)	Estimated dates
Captive Stockpiles	2,541,000	980	February 1965
Independent	1,638,000	520	August 1965.
Total	4,179,000	1,500	

NEVADA (AUSTIN)

Situation

Indicated and inferred ores in the area on November 1957 totaled 215,000 tons assaying 0.18 percent U_3O_8.

There is no nearby outlet for the production from central Nevada.

Analysis of Situation

The area of known reserves is located some distance from rail facilities. The truck haulage coupled with rail freight charges to the nearest mill make shipment uneconomical except for a small tonnage of high-grade ores. Unless a mill is built locally much of the ores in the area will have no market.

The minimum size for an economic milling operation is generally considered to be about 200 tons of ore per day.

SALT LAKE DISTRICT, UTAH

Situation

Indicated and inferred ore reserves in the central part of the Salt Lake district are estimated at 397,000 tons, assaying 0.20 percent U_3O_8, as of November 1, 1957. The majority of these reserves are controlled by three companies.

Indicated and inferred reserves in the Green River district on November 1, 1957, are estimated at 328,000 tons. Of this total 299,000 tons are in deposits owned by two companies whose entire production is now processed at the Salt Lake City mill, which has an approximate capacity of 600 tons of ore per day.

Analysis of Situation

The Salt Lake City mill is primarily a custom mill. Because of its advantageous location with respect to transportation, it is the logical outlet not only for the reserves mentioned above, but also for ores from the Reno, California, Montana, and Colorado districts. In addition, the mill treats ore from a large producer in the Moab, Utah, district.

An adequate market should be available to all of the mines tributary to Salt Lake if the milling capacity is properly distributed to the various producers.

The recent completion of a 300-tons-per-day concentrator at Green River, Utah, to process vanadium-uranium ores from the San Rafael district provides an additional outlet for mines in the Salt Lake and Green River districts.

SHIPROCK, NEW MEXICO

Situation

The present mill is operated at a rate of 300 tons per day which is sufficient to provide a market for all mines in this district.

Indicated and inferred reserves as of November 1957, are estimated at 187,000 tons and including stockpiles totaled 30,000 tons. Grade of ore is expected to average 0.27 percent U_3O_8.

Analysis of Situation

The Shiprock mill has in the past operated at 500 tons per day but mill capacity has only been maintained by purchases of ore from the Commission and from other areas such as the Gallup, N. Mex. and Grants, N. Mex. areas.

It is indicated that all developed reserves in this district can be mined and treated before expiration of the Commission's ore purchase program on March 31, 1962. Because of their vanadium content, any remaining ores in the district should find a market in the vanadium mills to the north.

The milling capacity is adequate for known ores of the area.

SOUTHEAST TEXAS

Situation

No market is available for the ore reserves as of November 1, 1957, in Karnes and Duval Counties. The nearest market is at Grants, N. Mex. and freight rates make shipment to the mills there uneconomical.

Indicated and inferred reserves in the two counties are estimated at 1,713,000 tons of a 0.25 percent U_3O_8 grade.

Analysis of Situation

The shallow deposits in Karnes County can be easily and quickly mined but the total present developed reserves will not support a mill. The majority of the reserves are in Duval County and must be mined by underground methods. The logical site for a mill is Duval County with the ores from Karnes County transported for processing, a distance of some ninety miles.

Based upon the total ore reserves and mining conditions a mill having a capacity of about 600 tons of ore per day is indicated.

SPOKANE DISTRICT, WASHINGTON

Situation

Indicated and inferred ore reserves in the district on November 1, 1957, are estimated at 1,038,000 tons assaying 0.19 percent U_3O_8.

Present mill capacity is approximately 400 tons per day, of which 100 tons per day is available for custom ores.

Analysis of Situation

The mill capacity at the plant near Ford, Wash., should be adequate to process all presently indicated and inferred ores in the district by early 1965.

The only large reserve of independent ore developed on November 1, 1957, is held by one company, with small reserves held by a second company. Based upon information available to the Atomic Energy Commission, exploration by other operators has not been successful in developing any significant tonnage of commercial grade ore. Heavy surface cover has made prospecting and exploration difficult in this area.

Twenty-five percent (25%) of the milling capacity is available to independent producers who control only 18 percent of the existing ore reserves.

URANIFEROUS LIGNITES

(NORTH DAKOTA—SOUTH DAKOTA)

Situation

The uraniferous lignites have no market at present since they cannot be processed in any mill currently operating or under construction. Special milling methods have had to be developed.

Although our data on private drilling is incomplete, information that has been presented indicates that the developed and partially developed ore reserves may approximate 500,000 tons having a grade of approximately 0.20 percent U_3O_8 with a potential, based upon present geological studies, of an additional 500,000 to 1,000,000 tons. Because there have been no commercial mining or milling operations, estimates of the economic reserves—material that can be mined and milled profitably—are not as firm as the estimates of the ore reserves in other areas where cost information on mining and milling is available.

A firm milling proposal has been submitted to the Commission offering concentrate at a competitive price. The proposed mill would have a capacity to process 600 tons of lignite per day and this appears to be the minimum size for economic operation.

URAVAN MINERAL BELT, COLORADO

Situation

Total milling capacity at the Uravan, Rifle, Durango and Grand Junction mills is 2,580 tons per day. Of this capacity approximately 2,300 tons per day is available for processing the Uravan Mineral Belt ores. Some of the uranium-vanadium ore processed by these mills comes from mines outside of the area.

Available indicated and inferred ore reserves in the district comprising the Uravan Mineral Belt are estimated to be 3,256,000 tons as of November 1, 1957, having a grade of approximately 0.30 percent U_3O_8.

Because of the nature of the deposits opportunity for development of ore reserves in advance of mining is limited. Much of the ore is discovered in connection with mining of known deposits. While the November 1957 ore reserves might appear to be sufficient to supply the mills only until April 1961, ultimate ore reserves are expected to meet requirements of existing mills for a much longer period.

This area has the largest number of small uranium producers of any area. Of the 555 independent uranium mines which produced less than 1,000 tons per year in F. Y. 1957, 207 are in the Uravan Mineral Belt.

Analysis of Situation

Mills are purchasing all amenable ores offered for sale and should continue to do so. This ready purchase is necessary because of the erratic nature of the deposits requiring a slow mining rate and a resultant uncertain daily production from any one mine.

The milling companies in this area adjust production from captive mines to allow purchase of independent ores.

The four mills in the area are designed to recover vanadium as well as uranium from the carnotite ores found in the district. The quantities of uranium that might be produced after March 31, 1962, may be affected by the industrial requirements for vanadium since the Commission has no commitment to purchase V_2O_5 after that date.

WHITE CANYON—MONUMENT VALLEY

(SOUTHEASTERN UTAH AND NORTHERN ARIZONA)

Situation

Indicated and inferred reserves are estimated at 1,869,000 tons as of November 1, 1957 assaying 0.28 percent U_3O_8. Reserves of the Monument No. 2 Mine of Vanadium Corporation of America, which contains high vanadium ores, are not included in this total. Monument No. 2 ore is being processed at the Durango mill.

The present mill capacity is 775 tons per day of which 155 tons is available for custom ores.

Analysis of Situation

At the time the Mexican Hat mill contract was negotiated, the milling company controlled the only large ore reserve blocks on which a milling operation could be

based. Two large deposits and numerous small deposits have been developed since then by other companies. At present independent mining companies control more than half of the known reserves.

Milling capacity is sufficient to permit the treatment by mid-1964 of all ores developed prior to November 1, 1957 at an economic mining rate if arrangements can be made to provide a larger percentage of the mill capacity for custom ores. Purchase of independent ores at a higher rate would extend the life of captive mines into the post-1962 period.

WYOMING

Situation

Present mill capacity is inadequate to process the indicated and inferred ore reserves of central and northern Wyoming at a rate that will allow many of the mining companies to mine their ores economically. When mills now under construction are in operation milling capacity for the area will be approximately 1,845 tons per day, of which 654 tons per day is reserved for custom ore.

Indicated and inferred reserves in this district as of November 1, 1957 are estimated at 8,722,000 tons of which 4,777,000 tons are controlled by independent producers. The grade is approximately 0.24 percent U_3O_8.

Analysis of Situation

A large part of the November 1957 reserves are comparatively low grade and shallow. Most of these deposits will be mined by open pit methods that require the use of large excavating equipment. The pits must be operated at a large daily tonnage rate to achieve reasonable costs.

Several of the operators control more than one deposit. By scheduling mining operations from a limited number of pits, an even flow of ore to the mills could be maintained, and the deposits could be mined out in an orderly manner.

The earliest dates by which the November 1957 ore reserves could be milled with the present milling capacity is shown in the following tabulation:

	Reserves	Present contracted mill capacity (tons/day)	Earliest date
Captive	3,945,000	1,191	March 1967.
Independent	4,777,000	654	August 1978.
Total	8,722,000	1,845	

An additional 1,700 tons per day milling capacity is needed to allow mining operations in the district to be maintained at a reasonably economic rate and to provide for moderate adjustment in the scheduling of mine operations. Such addition would provide a market before December 1966 for the greater part of the reserves of November 1957.

APPENDIX 12

Remarks Prepared by Dr. Willard F. Libby, Commissioner, for Delivery Before the Swiss Academy of Medical Sciences Symposium on Radioactive Fallout, Lausanne, Switzerland, March 27

RADIOACTIVE FALLOUT

I. Introduction

The whole world is concerned over the question of radioactive fallout, particularly that from the testing of nuclear weapons. This has focused worldwide attention on the problem of the effects of radiation, whether it be from atomic fallout or medical X-rays, and a field of knowledge formerly known to only a limited group of scientists is becoming a matter of general concern, thought about and discussed by millions of people. The widespread concern may be due to the general fear of the unknown which has always been a basic human instinct. If the knowledge of the effects of radiation and the magnitude of the doses from fallout were more widely known, this would considerably allay the apprehension. So the first problem is the dissemination of the knowledge of fallout and radiation effects which has been gained over the last several years, and it is for this reason that this paper is presented. Last June the Congress of the United States held extensive hearings on radioactive fallout and radiation, and the minutes of these hearings are one of the best sources of information about the whole subject. In addition, a considerable number of articles have been published since last June which present more recent data and considerations. I hope to refer to some of these in the present paper.

Since there is every reason for the information on radioactive fallout and radiation to be known to any interested person, the United States Atomic Energy Commission has the policy of publishing promptly and completely on this subject, and this paper serves this function also. Before beginning a main subject of "Radioactive Fallout," I would like to mention a new development which though related is not entirely germane.

During the recent test operations of the U. S. Atomic Energy Commission and the U. S. Department of Defense, in Nevada, Operation Plumbbob, a bomb was fired underground which had no radioactive fallout because its fireball was sealed in molten rock. The fireball consisted largely of vaporized rock which congealed and totally contained the radioactivity. Essentially no radioactivity, even that belonging to such a volatile material as radioactive krypton, escaped to any considerable degree.

The entirety of the radioactive material was found in some 700 tons of rock which had been fused and then cooled and crushed. Apparently the bomb, which had the power of 1,700 tons of ordinary chemical explosive, blew itself a bubble of vaporized rock about 55 feet in radius, which had a skin about 3 or 4 inches thick. The shock wave crushed rock out to about 130 feet so the weight of the crushed rock overhead crushed the thin eggshell when it cooled and broke it into fragments. These fragments contain the bomb debris essentially in its entirety. This means it is possible at least in the small yield range, to contain

and eliminate radioactive fallout in certain types of weapons tests. Of course, effects tests where such materials as structures and military equipment are being checked against atomic blast cannot be conducted in this manner, but these tests could conceivably be done with the special type of bomb with reduced radioactivity. Thus, it is likely that a technique has been developed which will make possible test operations which contribute much less fallout.

In addition, the non-military applications of atomic explosives, which the underground shot on September 19 last year disclosed, appear to be so promising that for them alone we must continue certain tests in order that these benefits may be available to the human race. For example, in the underground shot, just mentioned, we produced an earth shock which was very revealing to the seismologists in its clarity and sharpness within a considerable distance from the Nevada test site and it is certain now that from atomic detonations we will be able to determine the internal structure and character of the earth with a clarity and detail never possible with earthquake shocks because of their diffuseness in both time and location.

A second possibility is the applicability of nuclear explosions to moving earth, if the fallout hazard can be controlled. Craters produced in the Pacific Islands are convincing testimony of the possibility of making harbors in regions where the local fallout hazard is tolerable. Perhaps with the devices of reduced fallout which are now being developed such applications will be possible in more populated regions.

A third most intriguing possibility is that of shaking and breaking subterranean structures by nuclear shock. The underground detonation, despite its small 1.7 kiloton yield, is estimated to have crushed about 0.4 million tons of rock. It happened that the mountain selected consisted of rather soft rock, but nevertheless it was consolidated and supported its own weight. After the explosion, a sphere 260 feet in radius was crushed so it could easily be mined. It was not rendered radioactive because the radioactivity was contained in a thin rock shell mentioned earlier, which weighed only 700 tons and which was visually distinguishable from the ordinary rock and thus can be separated easily. It is clear that this type of application has great promise. A fourth example is the containment of the heat generated from large atomic explosions in rock structures which are dry and therefore free of the pervasive thermal conductive characteristics of steam and water. This affords a definite possibility for generating atomic power; if detonations, which are large enough to make such power economical, are practical and if the subsequent drilling and removal of the heat by injection of water to produce steam prove to be practical. A fifth example is the possibility of making radioactive isotopes by surrounding the explosive devices with appropriate materials so that the neutrons which always escape in atomic explosions can be utilized at least in part. A sixth example is the potential utilization of the radiation and heat of the bomb to cause chemical reactions. These six possible non-military applications show that nuclear explosions may have peaceful applications of real importance and that the understanding of the phenomena of radioactive fallout is useful not only in conducting a weapons test, but in the promotion of important peaceful applications.

The radioactivity produced by the detonation of nuclear weapons has been extensively studied and reported upon. (1–17) From this work we have learned about the amount of radioactive fallout which occurs, and the mechanisms for its dissemination in a broad and general way. Let us consider a few of these general points.

(1) The stratosphere plays an extremely important role for the fallout from megaton yield weapons, and the troposphere is the medium which disseminates

the fallout from kiloton detonations; thus, speaking broadly, stratospheric debris is from megaton yield detonations and the tropospheric fallout is from those of lower yield. It is not that the yield of the detonation is determinative, but rather that the altitude to which the fireball arises before its average density is equalized with that of the surrounding air determines the fallout rates. The megaton yield fireballs are so enormous that they stabilize at levels only above the tropopause—the imaginary boundary layer dividing the upper part of the atmosphere, the stratosphere, from the lower part, the troposphere—while the kiloton yield fireballs stabilize below the tropopause. The tropopause normally occurs at something like 40 to 50 thousand feet altitude, although it depends on season and location. In other words, low-yield bombs fired in the stratosphere would be expected to give the same slow fallout rates as high-yield weapons do when fired in the troposphere—or on the surface if attention is focused on the part of the fallout which does not come down locally to form the oval shape pattern pointed in the downwind direction.

(2) The stratospheric debris descends very slowly, unless, of course, it is so large as to fall in the first few hours. This paper is concerned only with the worldwide fallout—that is, the fallout which does not occur in the first few hours, and excludes the local fallout which constitutes the famous elliptical pattern which is so hazardous because of its radiation intensity, but which in test operations is carefully restricted to test areas. It is worth mentioning in passing that the local fallout may be the principal hazard in the case of nuclear war. Most serious attention should be paid to it in civilian defense programs.

The worldwide fallout from the stratosphere is literally worldwide in that the rate of descent of the tiny particles produced by the detonations is so small that something like ten years or somewhat less probably is the average time they spend before descending to the ground, corresponding to an average annual rate of about ten percent of the amount in the stratosphere at any given time. It is not clear as to just how they do finally descend. It seems probable that general mixing of the stratospheric air with the tropospheric air which occurs as the tropopause shifts with season and as is brought about by the jet streams constitutes the main mechanism, and that the descent of the stratospheric fallout is never mainly due to gravity; but rather the bulk mixing of stratospheric air with tropospheric air brings the radioactive fallout particles down from the stratosphere into the troposphere where tropospheric weather finally takes over. This mechanism makes the percentage fallout rate the same for all particles too small to fall of their own weight—and the same as would be expected for gases providing some means of rapidly removing the gases from the troposphere exists, so the reverse process of troposphere to stratosphere transfer does not confuse the issue.

(3) Worldwide radioactive fallout in the troposphere is restricted to the general latitude of the detonations for the reason that the residence time in the troposphere is about thirty days. (18) (19) (20) (21). The lifetime of fine particulates in the troposphere appears to be determined by the cleansing action of the water droplets in the clouds. For those particulates which are below one micron in diameter, Greenfield (20) calculates that the mean residence time of a one micron particle in a typical cloud of water droplets of 20 microns diameter may vary between 50 and 300 hours, but that a particle of .04 micron diameter will last only 30 to 60 hours, and that a particle of .01 micron diameter will last only 15 to 20 hours. The theory calculates the diffusion due to Brownian motion and says that it is just this motion induced by the collisions with the air molecules which makes possible the contact between the fallout particles and the cloud drops. Since this theory is based on first principles with the single assumption that the fallout particle sticks to the water droplet on impact—an assumption so plausible as to

be almost beyond doubt—it is no surprise to learn experimentally that the Greenfield theory appears to be correct.

There is essentially no worldwide fallout in the absence of rainfall; i. e., in desert regions—except for a little that sticks to tree leaves, blades of grass, and general surfaces, by the same type of mechanism Greenfield describes in the case of clouds. Thus we see that it is the moisture in the troposphere which assures the short lifetime of the worldwide fallout particles, and that when the stratospheric air which contains essentially no moisture and therefore has no cleansing mechanism descends into the troposphere, the tropospheric moisture proceeds to clean it up. On this model, we see that for submicron fallout particles, weather phenomena are controlling, and that the bombs which have insufficient energy to push their fireballs above the troposphere will have their worldwide fallout brought down in raindrops in a matter of about a month, in extreme contrast with the stratospheric material which apparently stays aloft for something like ten years on the average. The contrast between these two lifetimes means that the concentration of radioactive fallout in the stratospheric air in terms of equal densities of air is always much higher than in tropospheric air. This has been experimentally observed to be true. (22) In fact, the stratospheric content is about one hundredfold higher than that of the troposphere corresponding to the much longer stratospheric residence time. Later in this paper new data on the fallout content of the stratosphere are given.

It is inherent in the Greenfield mechanism that the total worldwide fallout will be proportional to rainfall if other factors are not allowed to vary. Thus we find that the Mediterranean basin affords a good example of the truth of this principle. Other regions are the Northeastern United States, the Southeastern United States, the Northwest United States and the Southwest United States. (23) It is now well established that desert areas have very little fallout.

(4) After falling to the gound in the form of rain or being picked up on the surface of the leaves of grass or trees by the same type of Brownian motion accretion mechanism causing cloud drop pick up, the radioactive fallout may enter the biosphere by normal biological processes. Radioactive strontium 90 and radioactive cesium 137 are the two principal isotopes which have this facility and are produced in high yield by the fission reaction and are of long enough lifetimes to be disseminated worldwide particularly by the stratospheric mechanism—about 28 years half-life for each. Strontium 90 is produced at a level equivalent to about 1 millicurie of strontium 90 per square mile of the earth's surface for every two megatons of fission energy, and radiocesium is produced at about 50 percent higher yield. Of the two isotopes, strontium 90, because of its chemical similarity to calcium, collects in human bone, where it is held for years and where its radiations might then cause deleterious effects to the health of the individual, such as leukemia or bone cancer. It is interesting that strontium 90 constitutes a relatively less important genetic hazard because of the short range of its radioactive radiation and the fact that it is not held in the reproductive organs. Radiocesium stays in the human body only six or eight months on the average, because it has no permanent structure like the bone for which it has a natural affinity. As a result, the amount of radiation occurring from internally ingested radiocesium is much less and most likely is subject to palliative measures calculated to reduce its time in the body. Strontium 90 taken into the bone, however, appears to be stored for many years, the exact time not being known very well. (24)

Radiostrontium is taken into the body because of its similarity to calcium, but there is a definite difference in chemical behavior which causes animal organisms to prefer calcium. Thus the radiostrontium content of newly deposited bone calcium is less than that for food calcium. In many countries, the principal

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source of calcium is milk products, so the fact that cow's milk has only one-seventh the strontium in it per gram of calcium that the cow's food has, and that milk taken into the human body similarly deposits calcium in the bones with only half the strontium 90 content of the milk itself means that human beings naturally have a lower strontium 90 to calcium ratio for new bone than for the food source by something like a factor of 15 for dairy products. On the other hand, vegetation containing strontium 90 also deposits its strontium relatively inefficiently with a factor of something like 4 less strontium in the bone from these sources than is carried in the vegetable food itself—all relative to calcium. In some countries where calcium in the human diet comes principally from vegetables other sources of calcium contribute, some of which contain essentially no strontium 90—namely sea food. Because fallout is diluted so quickly by the action of the waves in the ocean, the concentration of the radioactive strontium in the sea calcium is very much lower that it is in the soil of the land in which the grass and vegetable crops grow. This difference becomes even larger when the effects of direct leaf and stem base pick up are considered. This perhaps accounts for the high values reported by Ogawa (25) for rice in Japan. So, fish from the sea are naturally at the lowest level in radiostrontium and sea food should be the lowest source of calcium among ordinary human foods. With all of these factors taken together, the world populations assimilate calcium at a much lower radiostrontium content than is exhibited by land plants to a very considerable degree. Eckelmann, Kulp and Schulert have given a detailed sample calculation recently, based on their extensive measurements on human bone.

(5) The biological hazard from the radioactive fallout from weapons testing is not well known, and like many biological problems the determination of the hazard in any exact way seems to be almost impossibly difficult. Fortunately, however, it is possible to compare the radiation from radioactive fallout with the intensities of natural radiation to which we are always exposed. For example, it is clear that the present level of the radiostrontium in the bones of young children which are, of course, closest to being in equilibrium with the fallout, since adults have had their bones some time even before there was any radioactive fallout, is about 2 milliroentgens per year as compared to an average natural dosage of 150 to 200 milliroentgens per year, about one to two percent of the dosage from natural sources to the bones depending upon location. Natural radioactivity present in the ground, building materials and even in our own bodies gives us an average total dose at sea level of about 150 milliroentgens per year, and medical X-rays add something like another 150 milliroentgens. The radiocesium taken into the body and the penetrating radiations from non-assimilable radioactive fallout contribute perhaps another three or four percent to the whole body dosage. Thus the total dosage to freshly formed human bone is at most five percent of the natural dosage. Furthermore, we do know that the variations in natural background dosages from place to place are enormous in magnitude as compared to the average value, and of course as compared to the fallout dosage. For example, it has been found (26) that exposure rates from external radiation rise from a value of about 110 milliroentgens per year at sea level to something like 230 milliroentgens per year at five to six thousand feet altitude in the United States. These numbers are considerably larger than those expected on the basis of earlier calculations and measurements, (27), (28) the increase apparently being due to the cosmic rays and their increase with altitudes. (29) In addition, the effects of radioactivity in the soil and in building materials made of stone or soil are considerable, amounting in some instances to fifty or one hundred percent of the average natural background dose at sea level, and the magnitude of the

medical exposures to X-rays approximates on the average those due to all natural sources. (30)

We see, therefore, that whatever the extent of our ignorance of the biological effects of radiation, we do know that these effects are not unexperienced by the human species, even from the genetic point of view, since it is clear now that persons living at high altitudes on granitic rocks always have received extra radiation many times greater than is contained in the radioactive fallout from the testing of nuclear weapons, and that even those living on certain sedimentary rocks at sea level always have received about ten to twenty times the present fallout dose.

Of course, this does not mean that any of the effects from radioactive fallout are in any way negligible and it does not mean that certain numbers of people will not be injured by radioactive fallout radiations, even though these numbers be very small relative to the total population of the world. However, the problem is bounded, and common sense and good judgment can be brought to bear on the extent of the biological hazards even though they are not now known exactly, and probably will not be well understood for many years. Researches to increase this understanding are being done, especially in the United States and United Kingdom and other countries. Information on radioactive fallout and all of its aspects, both physical and biological, is collected and collated by the United Nations' Scientific Committee on the Effects of Atomic Radiation, which is drafting its first report at the present time.

(6) From our study of radioactive fallout from testing, we have learned much of value about the circulation of the atmosphere of the world, and we have much more to learn as the study continues, particularly in the stratosphere by balloon and aircraft sampling techniques being carried out principally in the United States at the present time. As we undertake the problem of locating the fallout in the oceans, we undoubtedly will learn much of interest to oceanographers about the circulation of the water in the seas.

(7) From our understanding of radioactive fallout from tests, we are the better able to devise methods of civilian defense against fallout in the case of nuclear war, and widespread popular interest in the potential possible hazards from radioactive fallout from nuclear tests has led to a considerable understanding on the part of the general public of these strange phenomena. From this debate and study may come the protection for millions in the case nuclear war should occur.

Understanding of the nature of the mechanism by which radioactive fallout is disseminated has led to the reduction of the offsite fallout from testing. We know now that bombs placed upon the ground produce relatively more local fallout and therefore less worldwide fallout. It seems likely that firing on the surface of the sea has a similar, though probably considerably less marked effect.

II. Recent Data and Their Implications

Figures 1, 2, 3, 4 and 5 and Tables I, II and III, which are up-to-date versions of earlier publications, give the most recent results for the fallout observed for rainfall collections, for the strontium 90 content of milk (fresh and dry), for human bone, and for animal bone. It is particularly interesting to note that the data continue to show the principal features noted previously and that little new in principle has appeared.

TABLE I.—HEALTH AND SAFETY LABORATORY PASTURE PROGRAM

Strontium 90 in Hay					Strontium 90 in Bone			
Location	Site	Sampling date	Percent Ca ash	μμc/g Ca	Location	Animal	Sampling date	μμc/g Ca
Tifton, Ga.	Unimproved	September 1954	3.8	30±2	Tifton, Ga.	Calves	Fall 1953	3.8
	Improved	September 1954	5.2	3.9±0.8		Calves	September 1954	7.0±0.3
	Improved	June 1955	7.5	34±2		Calves	September 1954	2.7±0.2
	Improved	September 1955	6.9	21±1		Calves	October 1955	12±0.3
	Improved	May 1956	5.6	89.9±2.3 90.8±2.3		Calves	Oct. 24, 1956	19.45±0.47 18.36±0.44
	Improved	September 1956	5.8	109.9±1.7 129.5±2.7				9.95±0.35 9.53±0.34
New Brunswick, N. J.		Sept. 19, 1954	6.0	9.1±0.4	New Brunswick, N. J.	Sheep	Fall 1953	1.1
		July 4, 1955	7.1	85±2		Sheep	Sept. 9, 1954	2.7±0.2
		October 1955	6.9	77±2		Sheep	Oct. 14, 1955	4.1±0.2
		July 3, 1956	6.3	88.8±2.1 86.9±2.1		Sheep	Oct. 11, 1956	5.63±0.05 5.5±0.3
		Oct. 13, 1956	9.0	56.8±1.4 55.0±1.4		Sheep	Oct. 11, 1956	7.5±0.3
Raleigh, N. C.		Sept. 16, 1954	8.4	26±0.5	Raleigh, N. C.	Sheep	September 1954	2.1±0.2
		Sept. 1, 1955	3.5	69±3		Sheep	Dec. 14, 1955	8.6±0.4
	Pig pasture	July 20, 1956	12.5	38.6±0.3		Sheep	Sept. 19, 1956	26.2±0.1
	Pig pasture	Aug. 4, 1956	10.3	24.8±0.3		Pig	Sept. 24, 1956	1.87±0.03
						Pig	Sept. 24, 1956	1.61±0.04
Ithaca, N. Y.		Sept. 10, 1954	33	0.15±0.07	Ithaca, N. Y.	Sheep	Fall 1953	1.1
		June 15, 1955	13	19±0.8		Sheep	Sept. 20, 1954	2.6±0.2
		Sept. 14, 1955	12	20±1		Sheep	Sept. 20, 1955	5.4±0.3
		June 7, 1956	8.1	38.15±0.24		Lamb	Oct. 20, 1956	8.8±0.4
		Aug. 25, 1956	10.3	15.08±0.27		Lamb	Oct. 20, 1956	7.8±0.3
						Lamb	Oct. 20, 1956	10.6±0.4
						Hog	Oct. 20, 1956	2.66±0.10
						Hog	Oct. 20, 1956	2.18±0.10
						Hog	Oct. 20, 1956	2.56±0.12
Logan, Utah	Robinson Farm	Sept. 18, 1954	7.0	10±0.8	Logan, Utah	Sheep	Fall 1953	1.2
	College Farm	Sept. 18, 1954	8.2	6.3±0.7		Sheep	Fall 1953	0.6
	College Farm	July 18, 1955	7.5	19±1		Sheep	September 1954	4.4±0.2
	College Farm	June 10, 1956	16.2	8.27±0.50 7.89±0.53		Sheep Sheep Sheep	September 1954 October 1955 May 1956	1.7±0.2 8.2±0.4 8.4±0.4
						Sheep	Nov. 13, 1956	5.10±0.05 5.5±0.3
Mandan, N. Dak.		June 1956 (sileage).	15 3.7	39±1 27±3	Mandan, N. Dak.	Sheep Calf Sheep	Mar. 27, 1956 May 1957	23±0.6 24±0.6 26.8±0.5

TABLE II.—Sr^{90} IN FALLOUT AT MONITORING SITES OUTSIDE CONTINENTAL UNITED STATES

(High-walled Stainless Steel Pot Collections)

Month	Precipitation in inches	Observed mc Sr^{90}/mi^2	mc Sr^{90}/mi^2 calculated from theory
Bangkok, Thailand (14° N):			
March 1957	1.95	0.05	0.085
April 1957	5.85	.13	.25
May 1957	1.56	.037	.068
June 1957	9.36	.016	.41
July 1957	6.63	.022	.29
August 1957	11.70	.039	.051
Nagasaki, Japan (35° N):			
August 1956	17.43	.34	.76
September 1956	16.1	.17	.71
October 1956	3.59	.2	.16
November 1956	1.44	.08	.063
December 1956	1.37	.22	.069
January 1957	3.94	1.01	.172
February 1957	3.28	.17	.143
March 1957	1.40	.38	.061
April 1957	11.27	1.98	2.4
May 1957	6.44	.72	1.3
June 1957	10.18	.27	2.1
July 1957	28.67	1.07	6.0
August 1957	11.35	.457	2.4
September 1957	14.74	.260	3.1
Hiroshima, Japan (35° N):			
August 1956	11.93	.50	.52
September 1956	9.83	----------	----------
October 1956	3.51	.27	.15
November 1956	1.64	.11	.072
December 1956	.23	.06	.010
January 1957	2.15	.29	.097
February 1957	2.26	.53	.098
March 1957	1.29	.23	.056
April 1957	11.00	1.12	2.3
May 1957	6.44	.567	1.35
June 1957	10.22	.493	2.2
July 1957	21.10	.817	4.4
August 1957	4.48	.047	.94
September 1957	10.92	.277	2.3
Rio de Janeiro, Brazil (23° S):			
September 1956	1.95	.12	.085
October 1956	3.12	.21	.135
November 1956	3.51	.06	.155
December 1956	3.51	.02	.155
January 1957	2.73	.04	.12
February 1957	5.07	.05	.22

TABLE II.—Sr^{90} IN FALLOUT AT MONITORING SITES OUTSIDE CONTINENTAL UNITED STATES—Continued

Month	Precipitation in inches	Observed mc Sr^{90}/mi^2	mc Sr^{90}/mi^2 calculated from theory
Salisbury, South Rhodesia (20° S):			
November 1956	7. 41	0. 18	0. 32
December 1956	7. 80	. 12	. 34
January 1957	5. 85	. 11	. 26
February 1957	8. 97	. 08	. 04
March 1957	5. 46	. 05	. 24
April 1957	1. 17	. 04	. 05
Kikuyu, Kenya (0°):			
January 1957	9. 75	. 14	. 43
February 1957	2. 34	. 26	. 10
March 1957	3. 12	. 03	. 13
April 1957	7. 02	. 03	. 31
May 1957	14. 82	. 138	. 64
June 1957	1. 56	. 187	. 068
July 1957	. 08	. 148	. 0035
August 1957	. 20	. 020	. 0087
September 1957	2. 34	. 038	. 10
Dakar, French West Africa (14° N):			
August 1957	5. 2	. 532	. 23
September 1957	10. 44	. 244	. 45
Durban, Union of South Africa (30° S):			
June 1957	. 39	. 080	. 017
July 1957	. 39	. 012	. 017
August 1957	. 78	. 096	. 034
September 1957	4. 64	. 230	. 21
Pretoria, Union of South Africa (30° S):			
July 1957	4. 29	. 061	. 187
August 1957	1. 56	. 074	. 068
Vienna, Austria (47° N):			
June 1957	. 78	. 45	. 29
July 1957	5. 07	1. 95	1. 85
August 1957	2. 73	. 79	1. 0
Klagenfurt, Austria (47° N):			
August 1957	3. 51	1. 17	1. 3

Oahu, Hawaii (20° N):

Month	Precipitation in inches	Observed mc Sr^{90}/mi^2		Precipitation in inches	Observed mc Sr^{90}/mi^2 University of Hawaii	mc Sr^{90}/mi^2 calculated from theory
		AEC Laboratory	Weather station			
June 1957	0. 32	0. 72	----------	0. 83	0. 58	0. 036
July 1957	2. 10	1. 36	. 477	1. 62	. 42	. 071
August 1957	1. 57	. 303	. 156	3. 09	. 306	. 134
September 1957	1. 54	. 274	. 188	. 62	. 159	. 027

TABLE II.—Sr^{90} IN FALLOUT AT MONITORING SITES OUTSIDE CONTINENTAL UNITED STATES—Continued

Month	Precipitation in inches	Observed mc Sr^{90}/mi^2	mc Sr^{90}/mi^2 calculated from theory	
			With Russian component	Without Russian component
Lemont, Ill. (44° N):				
December 1956	1. 26	0. 14	0. 51	0. 053
January 1957	2. 06	. 30	. 38	. 088
February 1957	1. 77	. 27	. 72	. 076
March 1957	1. 98	. 47	. 80	. 085
April 1957	6. 09	1. 15	2. 5	1. 3
May 1957	3. 21	. 27	1. 5	. 68
June 1957	5. 94	. 48	1. 95	1. 0
July 1957	8. 98	1. 57	3. 6	1. 9
August 1957	5. 36	. 69	2. 1	1. 1
September 1957	1. 08	. 12	. 41	. 21
			With U. S. component	Without U. S. component
Birmingham, Ala. (33° N):				
April 1957	5. 41	. 83	1. 1	0. 23
May 1957	2. 96	. 39	. 62	. 13
June 1957	7. 70	. 95	1. 6	. 33
July 1957	2. 62	. 80	. 55	. 11
August 1957	4. 19	1. 10	. 87	. 37
September 1957	9. 59	. 42	2. 0	. 41
			With Russian component	Without Russian component
Salt Lake City, Utah (38° N):				
December 1956	1. 67	. 31	0. 66	0. 071
January 1957	1. 37	. 8	. 54	. 058
February 1957	. 72	. 83	. 29	. 031
March 1957	2. 18	2. 39	. 87	. 093
April 1957	3. 24	2. 30	1. 4	. 65
May 1957	3. 37	. 81	1. 5	. 70
June 1957	1. 47	1. 61	. 66	. 31
July 1957	. 31	. 94	. 13	. 06

TABLE II.—Sr^{90} IN FALLOUT AT MONITORING SITES OUTSIDE CONTINENTAL UNITED STATES—Continued

Month	Precipitation in inches	Observed* mc Sr^{90}/mi^2	mc Sr^{90}/mi^2 calculated from theory
West Los Angeles, Calif. (34° N):			
December 1956	0. 49	0. 15	0. 02
January 1957	3. 88	. 99	. 16
February 1957	1. 94	. 76	. 08
March 1957	. 95	. 09	. 041
April 1957	1. 33	. 84	. 28
May 1957	. 27	. 24	. 056
June 1957	. 06	. 12	. 012
July 1957	. 03	. 92	. 006

*Some local fallout from Nevada.

Month	Precipitation in inches	Observed mc Sr^{90}/mi^2	mc Sr $^{90}/mi^2$ calculated from theory	
			With U. S. component	Without U. S. component
South Miami, Fla. (26° N):				
April 1957	5. 04	. 53	1. 07	. 22
May 1957	10. 11	. 50	2. 10	. 44
June 1957	5. 82	. 56	1. 28	. 27
July 1957	8. 5	1. 51	1. 7	. 35
August 1957	13. 6	. 75	2. 8	. 58
September 1957	6. 27	. 52	1. 3	. 27

TABLE III.—AVERAGE STRONTIUM 90 CONTENT IN MAN—JULY 1, 1956 TO JUNE 30, 1957

(Values are in uuc Sr/g of Ca, normalized to the whole skeleton. Figures in parentheses give the number of samples in the category)

Location	Age at death (year)								
	0–4	5–9	10–19	20–29	30–39	40–49	50–59	60–80	20–80 (Average)
North America	0.67(30)	0.69(17)	0.38(15)	0.07(14)	0.06(9)	0.08(16)	0.05(5)	0.07(18)	0.070(62)
South America	.16(3)	.20(1)	.19(5)	.03(5)	.02(2)	.03(2)	.06(3)	.01(1)	.034(13)
Europe	.65(2)	.34(4)	.34(9)	.06(20)	.07(4)	.04(6)	.06(1)	.08(2)	.059(33)
Africa			.06(2)	.03(2)	.03(3)	.04(4)			.035(9)
Asia	.93(1)	.12(2)	.32(2)	.06(8)	.04(6)	.12(8)	.06(5)	.05(5)	.070(32)
Australia	.75(3)	.60(2)			.03(3)	.03(4)	.03(3)		.030(10)
Entire World	.64(39)	.57(26)	.30(33)	.059(49)	.047(27)	.070(40)	.052(17)	.065(26)	.060(159)

Figure 6 shows preliminary data on the stratospheric content of strontium 90. The data are preliminary for the reason that the air filter efficiencies are unknown at the present, although estimated to be something like 25 percent. The samples are taken by pumping stratospheric air through filters which are then analyzed. It is clear that even though an enormous scatter is present for reasons of time and experiment, it also is clear that there is no large variation in the stratospheric content of strontium 90 between the latitude of 30° S and the Northern Hemisphere. Since most of the megaton yield explosions have occurred in the northern latitudes, though the Pacific Testing Grounds are only 11° north of the equator, it appears that this evidence argues for rapid north and south mixing in the stratosphere. As we shall see later, other evidence in the dissemination of nonradioactive carbon dioxide derived from the combustion of fossil fuels (31), (32), (33), (34), (35) and of the dissemination of bomb derived radioactive carbon 14 seems to confirm this (36), (37), (38). It is interesting to note also that the actual content of the stratosphere is not in disagreement with the estimates given earlier, although the value of the filter efficiencies remains to be settled, and it is estimated at the efficiency of about 25 percent on evidence assuming homogeneity of the particle size. Experiments are now underway to settle the point.

In the model previously advanced, it is proposed that material introduced into the stratosphere is mixed immediately horizontally to a uniform concentration and has a residence time of ten years. Further, it is assumed that the latitudinal spread of tropospheric bomb clouds is only 10° with a sharp step function rather than a normal error curve distribution. The bomb debris is arbitrarily assigned to the stratosphere except for 1 percent tropospheric in the case of megaton yields. Local fallout is assumed to be 80 percent for land surface shots, 20 percent for surface water shots, and 10 percent for air shots. All kilo yield shots are assigned to the troposphere. On these very simple bases we are then, from classified data about the magnitudes and nature of the explosions, able to estimate the total fallout for any place on earth if the deposition from the troposphere is assumed to be proportional to the rain content at a given location. Figure 7 gives such a theoretical latitudinal fallout profile for worldwide fallout as of December 1957, neglecting rainfall variation, and Figure 8 is the corresponding world map. Figure 9 gives the corresponding timewise variations in the northern latitudes and compares them with the rainfall fallout curves for Milford Haven in England (39). Figure 10 gives a similar comparison for Chicago and Pittsburgh. Curves for other latitudes are given in Figures 11 and 12. Figure 13 gives the estimated stratospheric reservoir and the expected composition in strontium 89 versus time. If a further assumption is made, namely that the proportion of the fallout in a given location is given by the ratio of the rainfall to the world-wide average, 0.77 meters, (40) it is possible to compare the detailed fallout observed by the pot collection programs in various localities with the theoretical predicted values, and these are given in Table II.

On the basis of these comparisons and in the absence of conclusive evidence as to the age of radioactive fallout, it appears that the simple theory outlined explains the known information within the experimental error. It may develop when more reliable data are available on the age of fallout through the use of short-lived, 12.8 day half-life barium 140 fission product, that a mechanism by which a sort of concentrated leaking from the stratosphere occurs at a latitude of about 40° more may be proved or disproved. At the present time the observed extreme concentration may be explained as being due to coincidence of the tropospheric fallout from the U. S. and Russian tests. If this theory be correct, the

barium 140 content in periods of high fallout will show that the fallout is young. It is to be hoped that these data will be forthcoming soon.

Machta, (1), (41) and Stewart, Osmond, Crooks and Fisher (39) have stated that meteorological considerations and likely stratospheric wind patterns, together with evidence that the Sr^{89}/Sr^{90} ratio of the fallout shows the fallout to be old, have led them to the conclusion that the heavier fallout observed in the 40° to 50° N. latitude band is stratospheric and not tropospheric in origin as proposed here. The issue still seems to be unsettled since the radiochemical difficulties of the determination of the Sr^{89}/Sr^{90} ratio are large and may well have introduced sizeable errors into some of the reported values for this number and since it apparently is possible to account reasonably well for the observed fallout distribution on the present uniform stratospheric fallout theory as shown in the present paper. The critical difference between the two theories is in the matter of the age of the fallout. Better and more significant results probably will be available soon using the Ba^{140}/Sr^{90} ratio which for both radiochemical and lifetime reasons is more suitable than Sr^{89}/Sr^{90}. Ba^{140} has a half-life of 12.8 days which is more appropriate to distinguishing between an expected fallout age of perhaps 30 days on the one hand and of about 1 to 2 years on the other, than is the Sr^{89} half-life of 51 days. The radiochemical procedure for Ba^{140} is very similar to that for Sr^{90} and both are more sensitive and reliable than the Sr^{89} procedure which is particularly susceptible to errors from radioactive impurities such as other fission products which may have been imperfectly separated. Both Ba^{140} and Sr^{90} are measured by short-lived radioactive daughters of characteristic half-life and which can be repeatedly removed and measured since a new supply is grown into equilibrium each time a separation has been made.

The importance of settling this point is obviously considerable for both meteorology and geophysics and certainly for the understanding of the mechanism of radioactive fallout. Perhaps the Ba^{140} data will show the truth to lie somewhere between the two mechanisms.

Bomb Carbon 14

Rafter (37) and Rafter and Fergusson (36) have shown carbon 14 increases in surface air at Makara in New Zealand and in New Zealand woods and ocean carbonate as shown in Figure 14. This additional carbon 14 is due to bomb generated neutrons which react with air nitrogen to produce it. They find about 2.1 percent increase per year.

Williams (38) of Humble Oil and Refining Company, finds 3.0 ± 9.5 percent per year in Texas tree rings, Figure 14, and de Vries (42) in Holland, and Munnich (43), in Heidelberg, Germany, both report increases. The carbon 14 increase in the flesh of the land snail, helix pomatia, amounted to 4.3 percent between November 1953 and June 1957 in Holland, while an increase of about 10 percent during 1955 and 1956 occurred in Heidelberg in various biosphere samples.

At a rate of 2.5 neutrons per 200 Mev of energy release, one megaton would generate 3.2×10^{26} carbon 14 atoms. The best estimate, keeping in mind that a substantial amount falls back as calcium carbonate, would be that about 10^{28} carbon 14 atoms have been introduced into the atmosphere, mostly into the stratosphere. The estimate of 2.5 neutrons per 200 Mev energy released is higher than an earlier estimate based on an assumed 15 percent escape efficiency (44), the later value being based on firmer information. It also attempts to weigh fusion and fission as they have actually occurred.

About 9.4×10^{27} carbon 14 atoms are normally present in the stratosphere due to cosmic ray production (45). This figure assumes 22 percent of the atmosphere

to be in the stratosphere. Therefore, with worldwide stratospheric circulation, the rise in the stratosphere should be about 100 percent as was found in a few measurements made on samples collected in October 1956. Further measurements are in progress.

In the troposphere in the three years since the 1954 Castle test at the 10 percent per year figure used for fallout, about 3×10^{27} carbon 14 atoms should have descended, or about 1×10^{27} carbon 14 atoms per year. The average carbon 14 inventory in the troposphere is 3.3×10^{28} without including the ocean or biosphere, so the observed carbon 14 rise might be as high as 3 percent per year as appears to have been observed.

If mixing with the biosphere and top ocean above the thermocline occurred immediately, according to Arnold and Anderson (35) who gave $0.2 g/cm^2$ in the top 100 meters of the ocean, the total tropospheric reservoir would be 7.5×10^{28} giving an expected rate of increase due to the bombs of 1.3 percent per year which is in fair agreement with the observations if we assume the mixing with the ocean and the biosphere, particularly the former, is not quite instantaneous.

The main points are that the ratio of the Northern to Southern Hemisphere effect here is not enormous and fits fairly well with the notion that stratospheric gases have a residence time not too different from that of the ultra fine worldwide fallout particles.

In addition, Fergusson (31) has recently found in studying fossil CO_2 and its effect on reducing the carbon 14 content of the biosphere that the mean life of a CO_2 molecule before being absorbed from the tropospheric air into the oceans and biospheres is perhaps two years and that north to south mixing of the fossil CO_2 occurs in less than two years.

Consequently, it seems clear that the ten year residence time for stratospheric gases before descent into the troposphere seems to fit data for carbon 14 from bombs as well as the strontium 90 and cesium 137 fallout data.

Figure 15 gives up-to-date data on the occurrence of tritium in rainwater in the Chicago area (21), (46), (47). It is clear that whereas strontium 90 and probably carbon 14 remain in the stratosphere for years, the tritium from high yield thermonuclear detonations does not, but descends in a matter of one or two months. This most probably is due to the enormous mass of water carried into the stratosphere by the fireballs of detonations in the moist tropospheric air. The characteristic white mushroom cloud is evidence of the formation of ice crystals in the cold stratospheric air, which if large enough to be seen in this way must certainly be large enough to fall into the troposphere where they melt and join in the ordinary phenomena; i. e. fall out as rain or snow. Thus a large fractionation relative to fission products and radioactive carbon dioxide occurs. Of course, there probably is some entrainment of fission products on the surfaces of the falling ice crystals by the Greenfield Brownian motion accretion mechanism. In fact, it is known that about 1 percent of megaton yield off-site fallout occurs in the early banded tropospheric manner. This may be due to this entrainment and thus one would expect that the latitudinal distributions of early tropospheric fallout of both fission products and tritium water from megaton yield bombs fired in the troposphere (11) should be identical. No satisfactory data are now available to check this point. In the calculations in this paper the figure of 1 percent for tropospheric contribution from megaton yields has been used.

III. Conclusion

The more recent data, particularly on bomb carbon 14, when taken together with the earlier data on bomb fission products and tritium, give us some confi-

dence in our present understanding of the fallout mechanism. All of these observations and considerations afford unprecedented opportunities for the study of meteorology and geophysics, particularly in an international cooperative effort such as the International Geophysical Year.

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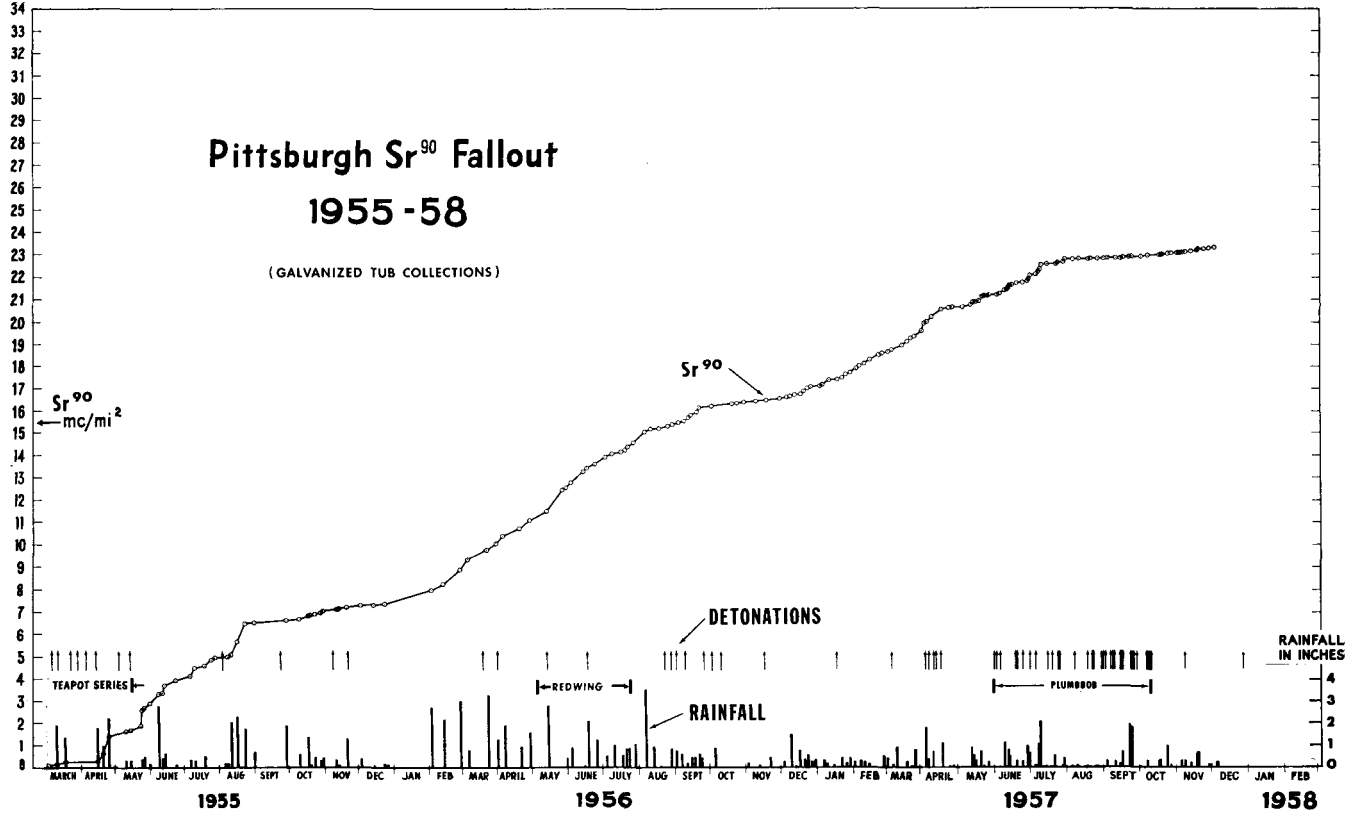

Pittsburgh Sr90 Fallout
1955-58
(GALVANIZED TUB COLLECTIONS)
Sr90
←mc/mi2
Sr90
DETONATIONS
RAINFALL
IN INCHES
TEAPOT SERIES
REDWING
PLUMBBOB
RAINFALL
MARCH APRIL MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APRIL MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APRIL MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB
1955
1956
1957
1958

Figure 1.

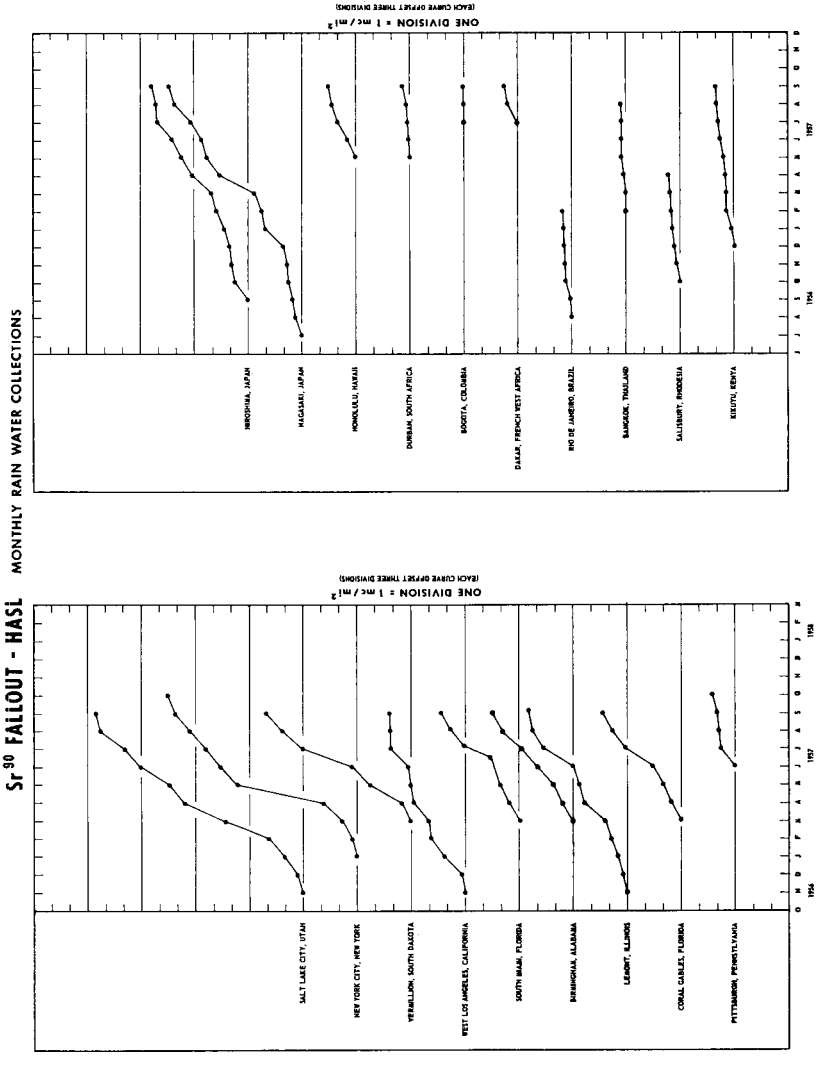

Sr 90 FALLOUT - HASL
MONTHLY RAIN WATER COLLECTIONS
ONE DIVISION = 1 mc / mi²
(EACH CURVE OFFSET THREE DIVISIONS)
SALT LAKE CITY, UTAH
NEW YORK CITY, NEW YORK
VERMILLION, SOUTH DAKOTA
WEST LOS ANGELES, CALIFORNIA
SOUTH MIAMI, FLORIDA
BIRMINGHAM, ALABAMA
LEMONT, ILLINOIS
CORAL GABLES, FLORIDA
PITTSBURGH, PENNSYLVANIA
HIROSHIMA, JAPAN
NAGASAKI, JAPAN
HONOLULU, HAWAII
DURBAN, SOUTH AFRICA
BOGOTA, COLOMBIA
DAKAR, FRENCH WEST AFRICA
RIO DE JANEIRO, BRAZIL
BANGKOK, THAILAND
SALISBURY, RHODESIA
KIKUYU, KENYA
O N D J F M A M J J A S O N D J F M
1956
1957
1958

Figure 2.

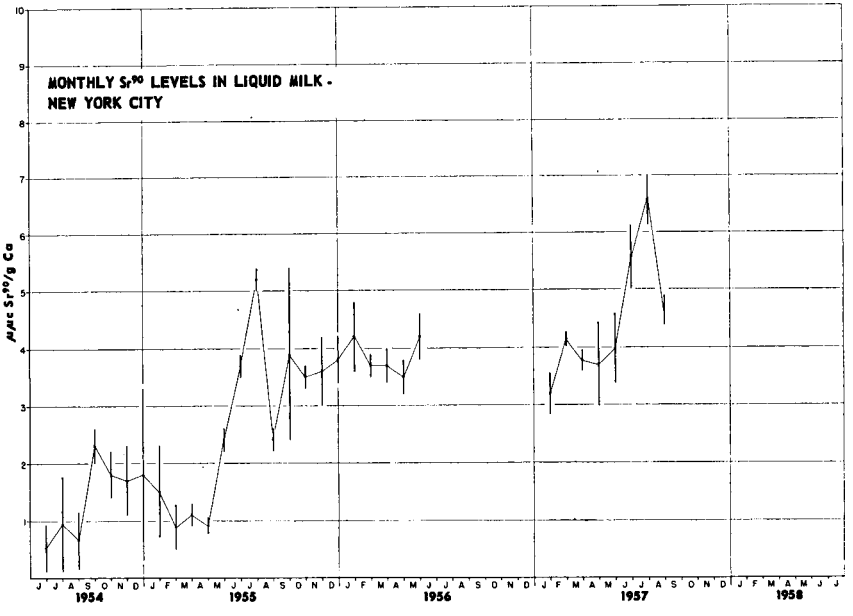


Figure 3.

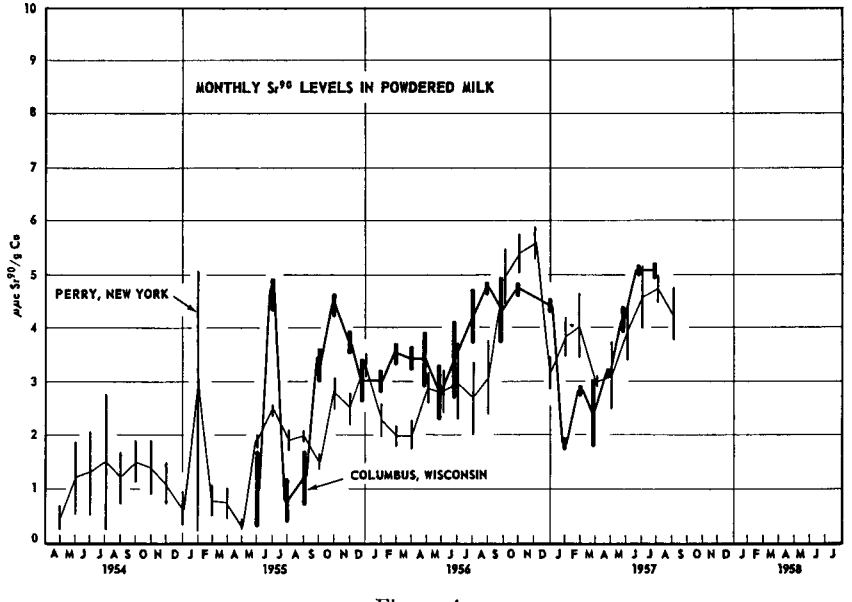


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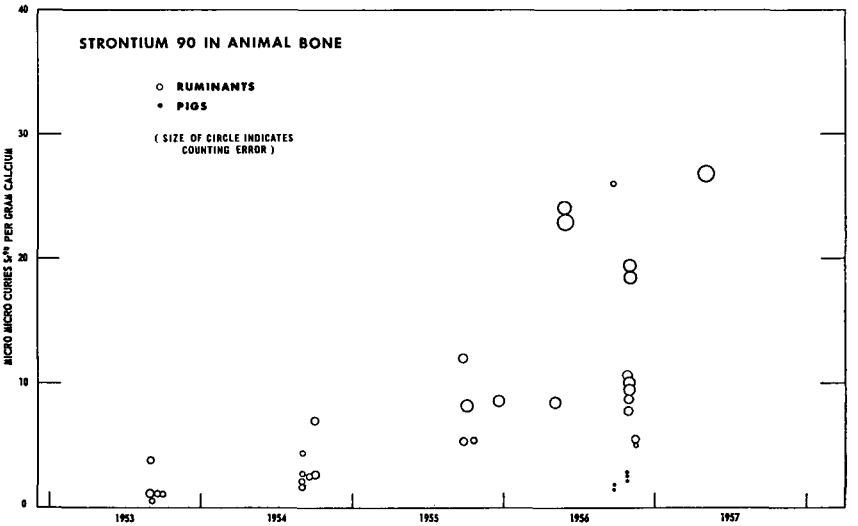


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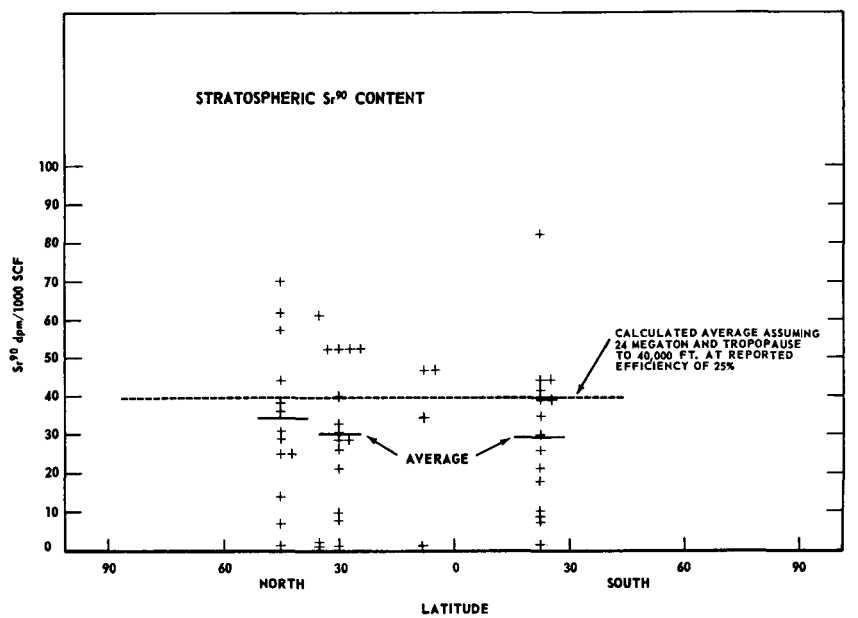


Figure 6.

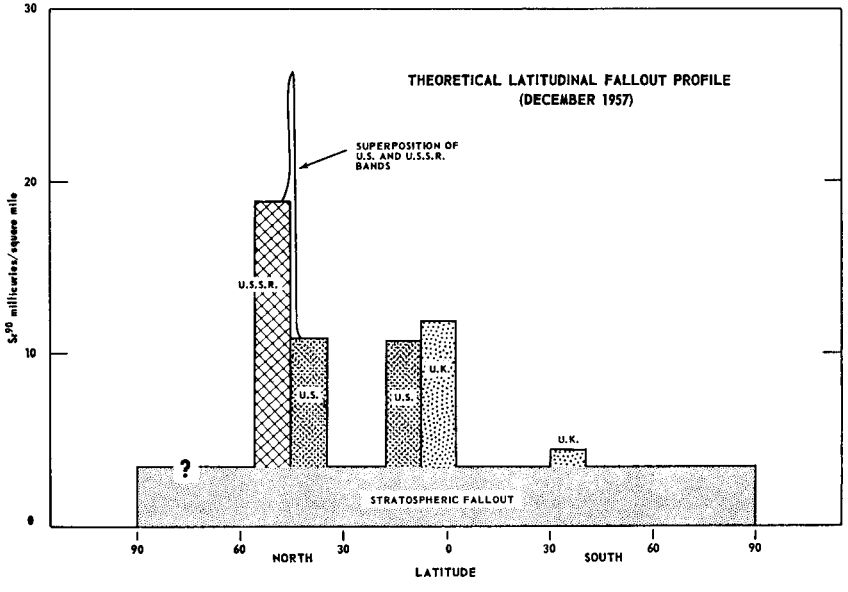

THEORETICAL LATITUDINAL FALLOUT PROFILE
(DECEMBER 1957)
SUPERPOSITION OF U.S. AND U.S.S.R. BANDS
U.S.S.R.
U.S.
U.K.
U.S.
U.K.
?
STRATOSPHERIC FALLOUT
30
20
10
0
S_r^{90} millicuries/square mile
90
60
30
0
30
60
90
NORTH
SOUTH
LATITUDE

Figure 7.

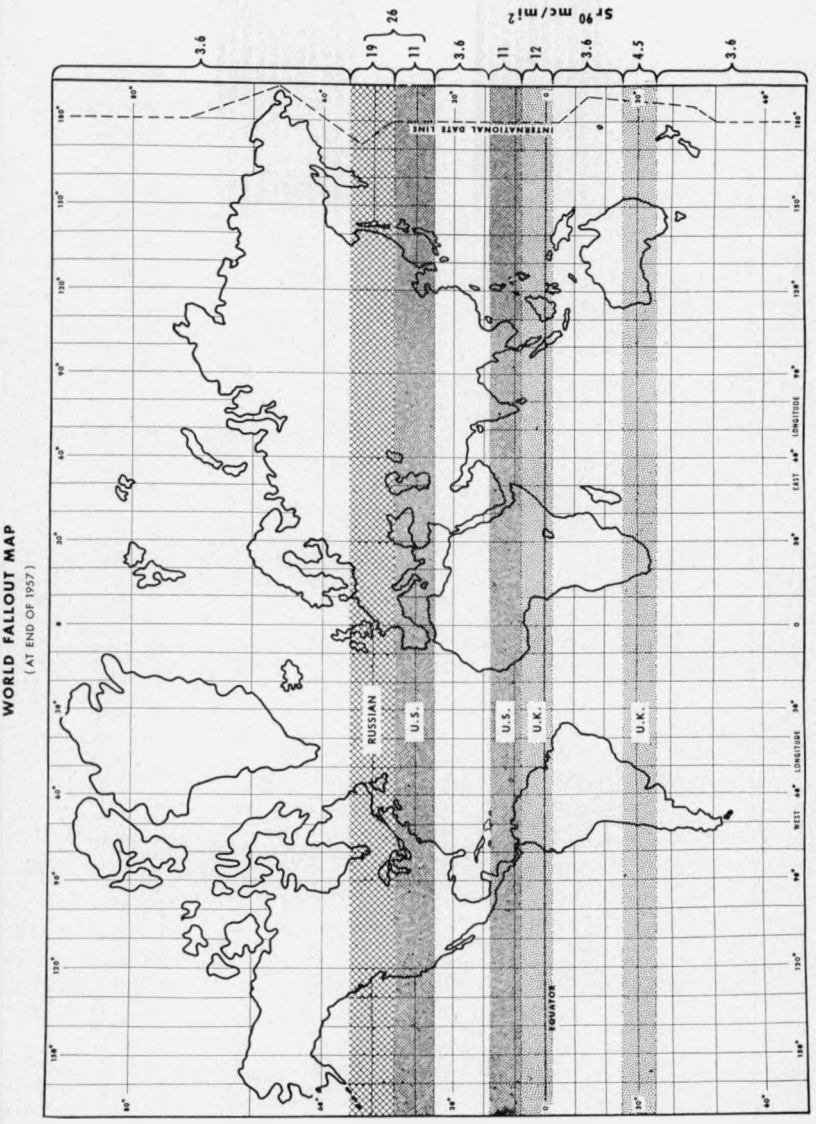

WORLD FALLOUT MAP
(AT END OF 1957)
Sr^{90} mc/mi²
3.6
19
26
11
3.6
11
12
3.6
4.5
3.6
INTERNATIONAL DATE LINE
RUSSIAN
U.S.
U.S.
U.K.
U.K.
EQUATOR
WEST LONGITUDE
EAST LONGITUDE

Figure 8.

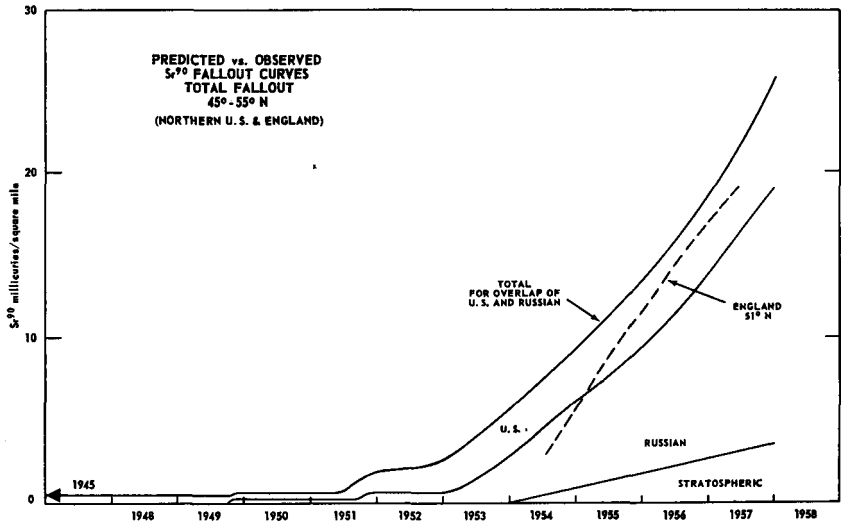


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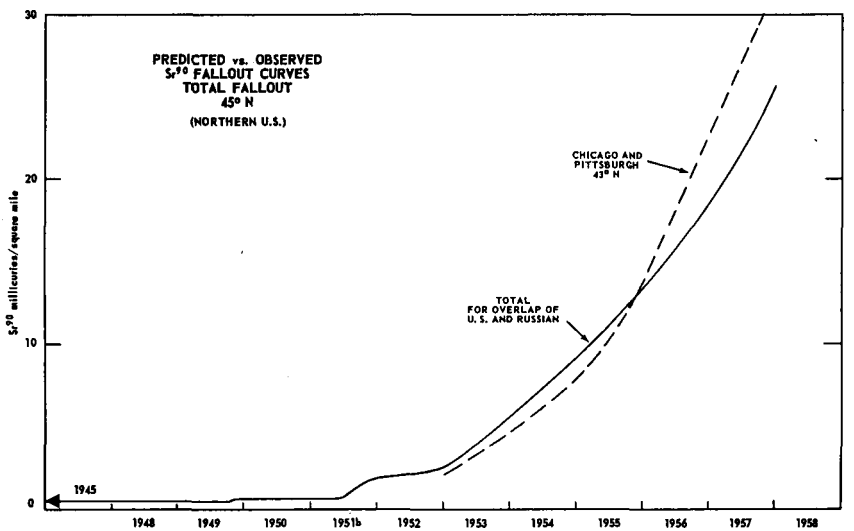


Figure 10.

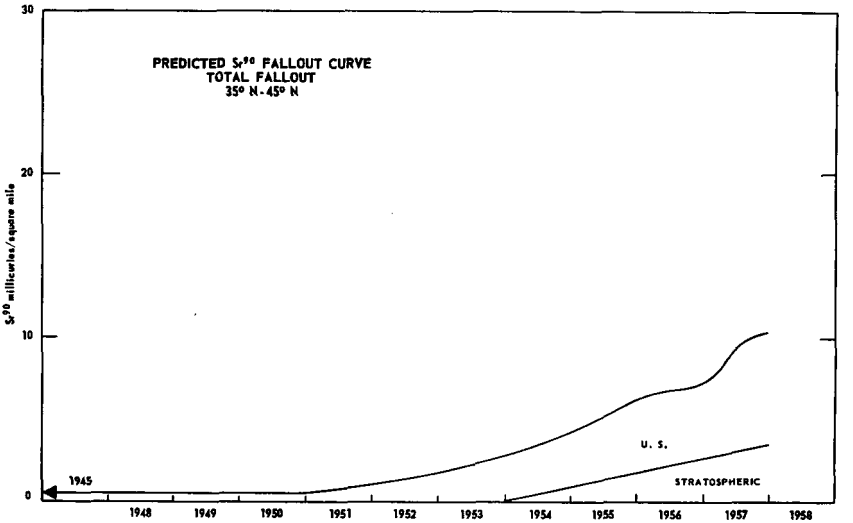


Figure 11.

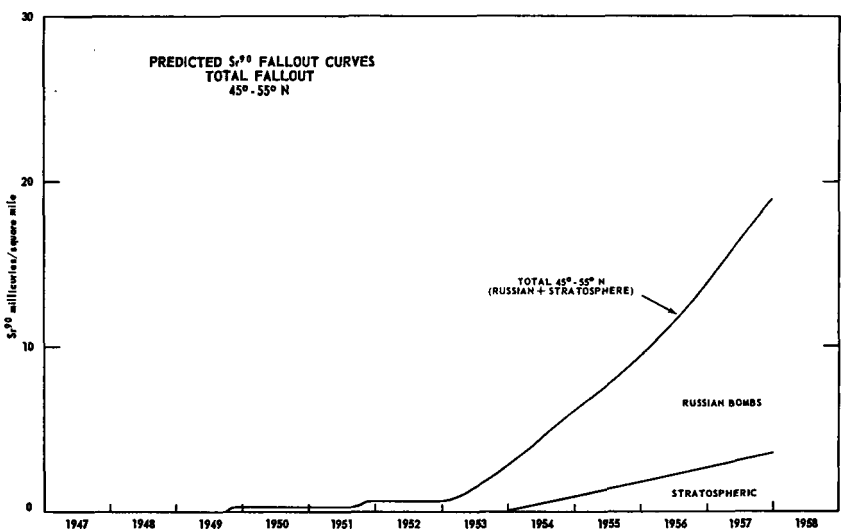


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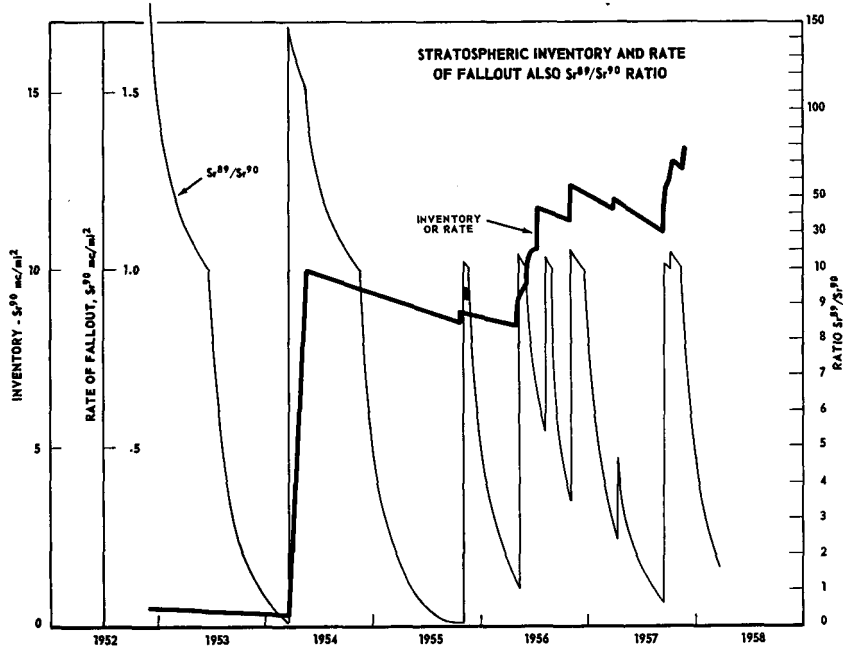


Figure 13.

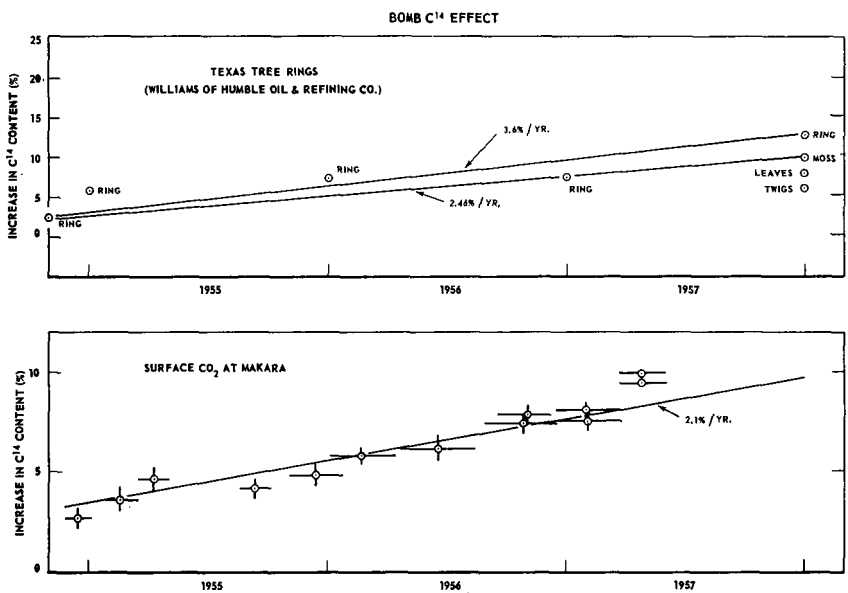


Figure 14.

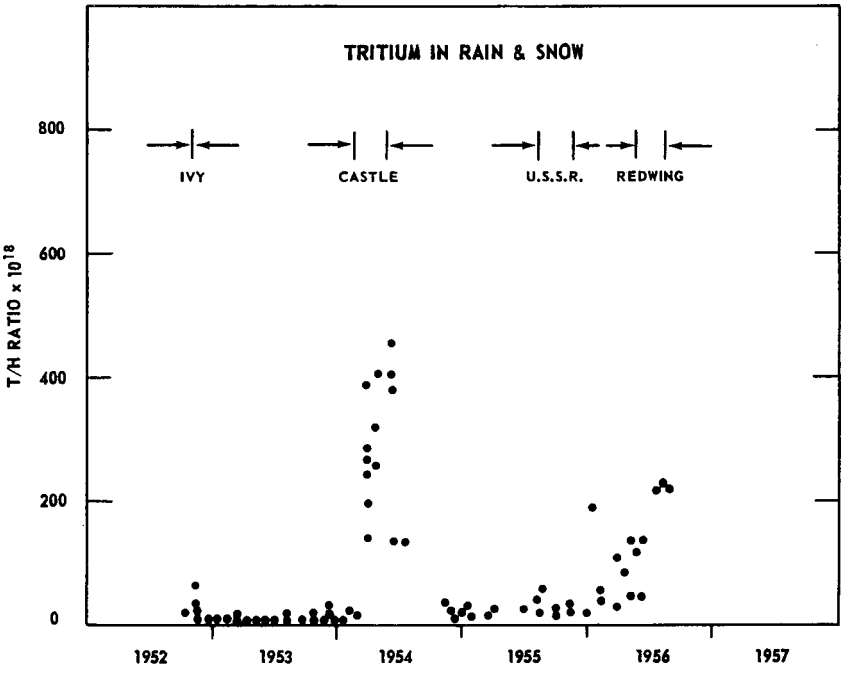


Figure 15.

STATEMENT BY DR. W. F. LIBBY ON CARBON 14 FROM BOMB TESTS

Bomb tests to date have produced enough carbon 14 so that when it has come to mixing equilibrium it will have increased the amount naturally present in all living matter by one-third of 1 percent.

The normal radiation dose from carbon 14 may be compared with the increase in the dose from cosmic rays as the elevation increases. In these terms the normal carbon 14 dose (1.5 mr/year) is equal to about a 100-foot increase in elevation. Therefore, the extra radiation dose from this product of nuclear tests is equivalent to an increase in altitude of a few inches.

In the years before equilibrium with the deep ocean is reached—about 500 years—the level will temporarily rest at about a 3-percent increase or the equivalent of a 3-foot altitude increase. This is after the first period of perhaps 10 or 20 years before dilution in the top layer of the ocean and with living and dead organic matter occurs, when the increase will be about 20 percent, or about 20 feet equivalent altitude increase. Because the lifetime of radiocarbon is very long—8,000 years on the average—the equilibrium situation is the more significant.

APPENDIX 13

Information On Detonations Released For Use In Seismological Studies

This press release was issued by the National Academy of Sciences–National Research Council during the January–June reporting period:

TO INTERESTED SEISMOLOGISTS— *April 15, 1958*

The United States Atomic Energy Commission, acting upon requests from seismology groups, has recently declassified and made available certain data on nuclear explosions resulting from bomb-test programs, 1954–1957. These data are in turn now being forwarded to you at the suggestion of the Division of Earth Sciences, National Academy of Sciences–National Research Council.

OPERATION CASTLE

Shot Name	Geographical coordinates		Type Shot	Date	Eniwetok Local Time
	N-Lat	E-Long			
Bravo	11°41′27″	165°16′25″	Ground	Mar. 1, 1954	0645:00.0
Romeo	11°41′27″	165°16′23″	Barge	Mar. 27, 1954	0630:00.4
Koon	11°29′48″	165°23′03″	Ground	Apr. 7, 1954	0620:00.4
Union	11°39′59″	165°23′14″	Barge	Apr. 26, 1954	0610:00.7
Yankee	11°39′56″	165°23′13″	Barge	May 5, 1954	0610:00.1
Nectar	11°40′14″	162°11′47″	Barge	May 14, 1954	0620:00.4

OPERATION REDWING

Zuni	11°29′48″	165°22′09″	Ground	May 28, 1956	0556:00.3
Apache	11°40′17″	162°12′01″	Barge	July 9, 1956	0606:00.2
Navajo	11°39′48″	165°23′14″	Barge	July 11, 1956	0556:00.3
Tewa	11°40′26″	165°20′22″	Barge	July 21, 1956	0546:00.0

OPERATION PLUMBBOB

					Pacific daylight time
Rainier	37°11′45″	116°12′11″	Underground	Sept. 19, 1957	0959:59.5
Hood	37°08′05″	116°02′27″	Balloon	July 5, 1957	[1] 0440:00.4
Diablo	37°09′01″	116°06′31″	Tower	July 15, 1957	[1] 0430:00.1
Shasta	37°07′41″	116°06′23″	Tower	Aug. 18, 1957	[1] 0500:00.0
Smokey	37°11′14″	116°04′04″	Tower	Aug. 31, 1957	[1] 0530:00.1

[1] Pacific Daylight Time of shock arrival at the ground.

APPENDIX 14

THE PRESIDENT'S MESSAGE ON INTERNATIONAL AGREEMENT WITH EURATOM

JUNE 23, 1958.

To the Congress of the United States:

I am transmitting today for approval by the Congress an International Agreement between the Government of the United States and the European Atomic Energy Community which will be a first step toward mutually beneficial cooperation in the peaceful applications of atomic energy between this new European Community and the United States. The specific program which I am asking the Congress to consider and approve on an urgent basis is a joint undertaking by the United States and Euratom to foster the construction in Europe by 1963 of approximately six major nuclear power reactors which would produce about one million kilowatts of electricity.

This International Agreement is being submitted pursuant to the provisions of sections 11 (L) and 124 of the Atomic Energy Act of 1954, as amended. The cooperation to be undertaken after approval of the International Agreement will be pursuant to the terms and conditions of an agreement for cooperation entered into in accordance with section 123 of that act.

The elements which combine to make such a joint program possible are the same that led to the first great break-through in the development of atomic energy fifteen years ago: the intimate association of European and American scientists and close association between European and American engineers and industries. While the joint nuclear power program draws heavily on the history of atomic energy development there are important new elements which reflect the changing world scene.

The first is the changing face of Europe symbolized by the European Atomic Energy Community, which now takes its place beside the Coal and Steel Community, and the European Economic Community (Common Market) in a further major step toward a united Europe. The inspiration of European statesmen which has now come to fruition in Euratom is the simple but profoundly important idea that through concentration of the scientific and industrial potentialities of the six countries it will be possible to develop a single major atomic energy complex, larger than the sum of the parts, and designed to exploit the peaceful potential of atomic energy. One motivation which has therefore led to the creation of this new Community is the growing sense of urgency on the part of Europeans that their destiny requires unity and that the road toward this unity is to be found in the development of major common programs such as Euratom makes possible. Another important motivation is the present and growing requirement of Europe for a new source of energy in the face of rapidly increasing requirements and the limited possibilities of increasing the indigenous supply of conventional fuels. The Europeans see atomic energy not merely as an alternative source of energy but as something which they must develop quickly if they are to continue their economic growth and exercise their rightful influence in world affairs. The success of this undertaking, therefore, is of vital importance to the United States, for

the 160 million people on the Continent of Europe are crucial to North Atlantic strength.

It is therefore gratifying that the reactor research, development, testing, and construction program in the United States has progressed to the point that United States reactors of proven types are available and will be selected for commercial exploitation in the joint program of large-scale nuclear reactors.

The abundance of conventional fuel in the United States and hence our lower cost of electricity as contrasted with higher energy costs in Europe means that it is possible for nuclear power reactors to produce economic electrical energy in Europe before it will be possible to do so in most parts of the United States.

The basic arrangements which have been worked out with Euratom are designed to take advantage of many favorable factors and circumstances. They promise to result in a program that will initially be of great benefit to Euratom and the United States, and thereafter to nations everywhere that choose to profit from Euratom's experience. American knowledge and industrial capacity will be joined with the scientific and industrial talents of Europe in an accelerated nuclear power program to meet Europe's presently urgent need for a new source of energy.

The plants to be built will be paid for and operated by the existing public and private utilities in the six countries; components will be manufactured by American and European industry. Through this association the basis will be laid for future mutually beneficial commercial collaboration in the atomic energy business. The major portion of the fund for the construction of the plants will come from European sources of capital. The United States, through the Export-Import Bank, is prepared to supplement these funds by making available to the new Community a long-term line of credit.

A central purpose of the proposed joint program is for Euratom and the United States Government to create an institutional and economic environment which will encourage the European utilities to embark quickly upon a large-scale nuclear power program. As this program goes forward, it will make possible significant progress in the development of atomic power elsewhere in the world.

The expectation that nuclear power will be economic rests on the inherent promise of achieving substantially lowered fuel costs which will more than compensate for the higher capital costs of nuclear plants. The principal immediate problem is to limit during this developmental phase the economic uncertainties connected with the burning of nuclear fuel in these reactors. To assist in meeting this problem the United States will provide certain special and limited guarantees and incentives to permit American fuel fabricators and the European utilities and industries to enter into firm contractual arrangements with greater certainty as to the actual costs of nuclear energy from the reactors than is now possible.

Of major importance, the new European Community and the United States will establish a jointly financed research and development program, the purpose of which will be to improve the performance of these reactors and thus to further the economic feasibility of nuclear power. Information developed under the joint program will be made available to American and European industry for the general advancement of power reactor technology.

In addition to the International Agreement submitted herewith, the necessary requests for Congressional action required to carry out the program will be submitted shortly.

I believe that the initiation of this program of cooperation with Euratom represents a major step in the application of nuclear technology for the benefit of mankind.

The United States and Euratom have reaffirmed their dedication to the objectives of the International Atomic Energy Agency and intend that the results of this program will benefit the Agency and the nations participating in it. Consideration is now being given to ways in which the United States can work with the Agency in carrying forward its functions. A proposed agreement for cooperation with the International Atomic Energy Agency is now being negotiated and is under review by the Agency. This agreement provides principally for the transfer of the special nuclear material already offered to the Agency by the United States, for certain services such as chemical processing, and for the broad exchange of unclassified information in furtherance of the Agency's program.

In recognition of the importance of the joint United States-Euratom program, I must stress its urgency. It was only on the first of January of this year that the new Community came into being, determined to fulfill its obligation to create the conditions which will permit the earliest development of nuclear power on a major scale. The Community is determined, as are we, that the joint program should be initiated this year. I am sure that the Congress, having in mind the political and economic advantages which will accrue to us and our European friends from such a joint endeavor, will wish to consider quickly and favorably the proposed program.

DWIGHT D. EISENHOWER.

APPENDIX 15

Memorandum of Understanding Between United States and Euratom

This document, developed by the Joint United States-Euratom Working Party and negotiated as a first step in reaching an understanding with respect to the proposed Joint United States-Euratom Program, served as a basis for negotiations leading to the Agreement for Cooperation.

MEMORANDUM OF UNDERSTANDING REGARDING THE JOINT NUCLEAR POWER PROGRAM PROPOSED BETWEEN THE EUROPEAN ATOMIC ENERGY COMMUNITY (EURATOM) AND THE UNITED STATES OF AMERICA

The steps taken by the Member States of the European Atomic Energy Community (Euratom) towards a united Europe and the consistent support of the United States for their efforts are an acknowledgment that, in a world being rapidly transformed by technical and political change, the problems our countries face call for increasing solidarity.

The Member States of Euratom urgently need nuclear power to be in a position to meet future energy requirements and to assure continued economic progress.

Both Euratom and the United States must carry through the nuclear revolution in industry with maximum speed and efficiency in order to remain in the forefront of progress and to open new horizons for further economic and social advance.

In order to achieve these objectives a large-scale joint development program of power reactors will be launched.

Euratom will benefit by the experience and capacity which the United States can provide to make a quick start on such a program. This will in turn provide the United States with the opportunity to accelerate its own industrial development of nuclear power for peaceful purposes by associating itself with the program. Conventional energy is generally more costly in Europe than in the United States, so that nuclear power approaches the competitive range of energy costs in Europe, a stage which will be reached only later in the United States.

For these reasons, the Commission of the European Atomic Energy Community and the Government of the United States of America have agreed to this Memorandum of Understanding which outlines a joint United States—Euratom development program of large-scale nuclear power reactors to be constructed in the European Atomic Energy Community in the next few years.

The aim of the joint program will be to bring into operation in the Community by 1963 about 1,000,000 electrical kilowatts of installed nuclear capacity in reactors of proven types developed in the United States, thus increasing substantially the total capacity envisaged by existing programs in the Member States.

The program is consistent with, and in fact a point of departure towards, the program outlined in "A Target for Euratom".[1]

It is understood that the establishment and initiation of the joint program is subject to appropriate statutory steps, including authorization by the competent bodies of the Community and of the Government of the United States.

The joint program will be conducted so as to obtain the maximum support of the industries of the Community and the United States; indeed, their active participation is indispensable to the success of the program.

It is the hope and expectation of the Commission and the Government of the United States that the proposed program will lead to further cooperation between the Community and the United States in other fields related to the peaceful uses of atomic energy.

They also see in the joint program a new type of cooperation among allies on a fully equal footing based on organic links forged by common effort, and holding out hopes of new steps for the further development of the Atlantic Community.

The Commission of the European Atomic Energy Community and the Government of the United States reaffirm their dedication to the objectives of the International Atomic Energy Agency and intend that the results of their program will benefit the Agency and the nations participating in it.

1. *Objectives*

The objectives of the joint program will be:

A. To bring into operation by 1963, within the European Atomic Energy Community, large-scale power plants using nuclear reactors of proven types, on which research and development has been carried to an advanced stage in the United States, having a total installed capacity of approximately one million kilowatts of electricity and under conditions which would approach the competitive range of conventional energy costs in Europe.

B. To initiate immediately a joint research and development program centered on these types of reactors.

2. *Selection and Approval Under the Program*

Under the joint program, reactor projects may be proposed, constructed and operated by private or governmental organizations engaged in the power industry or in the nuclear energy field.

The Commission and the Government of the United States will establish jointly, technical standards and criteria (including those relating to radiation protection and reactor safety) and the procedures for selection and approval of reactor projects under this program.

In the evaluation and selection of such reactor projects, the technical and economic features will be considered and approved jointly by the Commission and the United States Government.

Other features of such reactor projects will be considered and approved by the Commission.

Reactors now being planned or constructed in Member States of the Community will be eligible for, and will receive, early consideration under the criteria established pursuant to this section.

[1] Report submitted by Louis Armand, Franz Etzel and Francesco Giordani at the request of the Governments of Belgium, France, the Federal Republic of Germany, Italy, Luxembourg and the Netherlands.

It is intended to take and announce decisions on the above matters at the earliest practicable date.

3. *Capital Costs*

The total capital cost[2] of the nuclear power plants with an installed capacity of approximately one million kilowatts of electricity to be constructed under the program is presently estimated not to exceed the equivalent of $350,000,000 to be financed as follows:

A. Approximately $215,000,000 to be provided by the participating utilities and other European sources of capital, such financing to be arranged with the appropriate assistance of Euratom: and

B. Up to $135 million to be provided by the United States Government to Euratom in the form of a long-term line of credit on terms and conditions to be agreed, such funds to be relent by Euratom for the construction of facilities under this program.

4. *Fuel Cycles*

The Commission and the Government of the United States will enter into special arrangements with respect to the fuel cycles for reactors to be constructed and operated under the proposed program according to the principles set forth in Attachment A to this memorandum.

5. *Chemical Processing*

The United States Atomic Energy Commission is prepared to process in its facilities, at established United States domestic prices, spent fuel elements from the reactors to be included in the present program. The United States Atomic Energy Commission agrees to assist in the development of chemical processing techniques in Europe by providing technical advice and assistance both to "Eurochemic" (which is to design and build a pilot plant at Mol, Belgium), and to the Community in the design and construction of future plants which the Community may decide to design and construct, or to sponsor.

6. *Research and Development*

A. The Commission and the Government of the United States intend to initiate promptly a joint program of research and development to be conducted both in the United States and in Europe on the types of reactors to be constructed under the proposed program.

This Research and Development program will be aimed primarily at the improvement in performance of these reactors and at lowering fuel cycle costs.

It will also deal with plutonium recycling and other problems relevant to these reactors, thus contributing to the overall advance of the nuclear power art.

The research and development program will be established for a ten (10) year period. During the first five (5) years the financial contribution of the Community and the United States will amount to about $50 million each. Prior to the completion of the first 5-year period, the Parties will determine the financial requirements for the remaining 5-year period and will undertake to procure funds necessary to carry out the program. Funds for the second 5-year period may be in the same order of magnitude.

[2] Exclusive of the fuel inventory.

The administration of this program will be conducted under mutually agreed arrangements.

B. In addition, both the Commission and the United States Atomic Energy Commission will push forward and extend their own research and development programs, either direct or sponsored, on all peaceful aspects of nuclear science and industry, in particular in such fields as advanced civilian reactor design, fuel technology, reactor operation, chemical processing, radioisotopes utilization, waste disposal, and public health.

Information resulting from such work outside of the joint program will be exchanged by the respective Commission fully and promptly.

7. *Special Nuclear and Other Materials*

The Government of the United States will make available to the Community, as needed, enriched uranium for the nuclear power reactors to be included within the proposed program, in sufficient quantity to meet inventory and operating requirements for a twenty (20) year operating period.

The Government of the United States also will provide the Community special nuclear materials as may be agreed for research and development and the operation of research and test reactors associated with the proposed power program, in sufficient quantity to meet inventory and operating requirement for a twenty (20) year operating period. In addition, source material, special reactor material and other materials needed for carrying out the program will be provided under terms and conditions to be agreed upon.

8. *Availability of Information*

A. *Nonpatentable information developed in joint program*

(1) The program contemplated by this Memorandum of Understanding, including projects selected for inclusion therein, should serve to benefit other projects and programs (both private and governmental) within the Community and the United States. Accordingly, under mutually agreed arrangements, all information developed in connection with the joint program of research and development, and all information developed in connection with the selected projects, concerning designs, plans and specifications, construction costs, operations and economics, will be delivered currently to the Parties as developed and may be used, disseminated, or published by each Party for any and all purposes as it sees fit without further obligation or payment. There will be no discrimination in the dissemination or use of the information for the reason that the proposed recipient or user is a national of the United States or of any Member State of Euratom.

(2) Both Commissions shall have access to the records of the participating contractors pertaining to their participation in research and development projects under the joint research and development program, or pertaining to the performance of fuel elements that are the subject of United States guarantees.

(3) The Parties will further expedite prompt exchange of information through symposia, exchange of personnel, setting up of combined teams, and other methods as may be mutually agreed.

B. *Patentable Information*

As to any invention made or conceived in the course of or under the joint program of research and development:

1. The United States shall without further obligation or payment be entitled to assignment of the title and rights in and to the invention and the patents in the United States, subject to a nonexclusive, irrevocable, and royalty-free license, with the right to grant sublicenses, to the Community for all purposes.

2. The Community shall without further obligation or payment be entitled to assignment of the title and rights in and to the invention and the patents in the Community, subject to a nonexclusive, irrevocable, and royalty-free license, with the right to grant sublicenses, to the United States for all purposes.

3. With respect to title and rights in and to the invention and patents in third countries:

a. The Community, if the invention is made or conceived within the Community, or the United States, if the invention is made or conceived within the United States, shall be entitled to assignment of such title and rights, subject to a nonexclusive, irrevocable, royalty-free license, with the right to grant sublicenses, to the other for all purposes.

b. If the invention is made or conceived elsewhere, the Party contracting for the work shall be entitled to assignment of such title and rights, subject to a nonexclusive, irrevocable, royalty-free license, with the right to grant sublicenses, to the other for all purposes.

C. As to inventions and patents under paragraph B of this article neither Party shall discriminate in the granting of any license or sublicense for the reason that the proposed licensee or sublicensee is a national of the United States or any Member State.

D. As to patents used in the work of the joint program, other than those under paragraph B, which the United States owns or as to which it has the right to grant licenses or sublicenses, the United States will agree to grant licenses or sublicenses, covering use either in or outside the joint program, on a nondiscriminatory basis to a Member State and to industry of a Member State, if the Member State has agreed to grant licenses or sublicenses as to patents used in the work of the joint program which it owns or as to which it has the right to grant licenses or sublicenses on a nondiscriminatory basis to the United States and to industry of the United States, covering use either in or outside of the joint program.

E. The respective contractual arrangements of the Parties with third parties shall contain provisions that will enable each Party to effectuate the foregoing provisions of B and C as to patentable information.

F. It is recognized that detailed procedures shall be jointly established to effectuate the foregoing provisions and that all situations not covered shall be settled by mutual agreement governed by the basic principle of equivalent benefits to both parties.

9. *Training*

The Commission and the United States Atomic Energy Commission will work closely together to develop training programs to satisfy the requirements of the programs described in this memorandum. The United States Atomic Energy Commission will assist the Commission in satisfying these needs by making its facilities and experience available.

10. *Cooperative Activities in Industry*

It is expected that the program to be initiated under the terms of this Memorandum of Understanding will increase the cooperation already existing between

individuals and organizations, both privately and publicly owned, engaged in nuclear industry, in the United States and in the countries of the Community.

The Commission and the Government of the United States will use their best efforts to foster such cooperation.

11. *Safeguards and Controls*

Both Euratom and the United States recognize the extreme importance of assuring that all activities under the joint program shall be directed solely toward the peaceful uses of atomic energy. In accord with this objective:

A. Euratom guarantees that:

1. No material, including equipment and devices, transferred pursuant to the Agreement for Cooperation between the United States and the Community to the Community or to authorized persons within the Community will be used for atomic weapons, or for research on or development of atomic weapons, or for any other military purpose;

2. No such material will be transferred to unauthorized persons or beyond the control of the Community, except as the United States may agree to such transfer and then only if the transfer of the material is within the scope of an Agreement for Cooperation between the Government of the United States of America and another nation or group of nations;

3. No source or special nuclear material utilized in, recovered from, or produced as a result of the use of materials, equipment, or devices transferred pursuant to the Agreement for Cooperation between the United States and the Community to the Community or authorized persons within the Community will be used for atomic weapons, or for research on or development of atomic weapons, or for any other military purpose;

4. The Community will establish and maintain a mutually satisfactory system of safeguards and controls, to be applied to materials, equipment, and devices subject to the guarantees set forth in paragraphs 1 through 3 above.

B. Euratom undertakes the responsibility for establishing and implementing a safeguards and control system designed to give maximum assurance that any material, equipment, or devices made available pursuant to the Agreement between the United States and Euratom, and any source or special nuclear material derived from the use of such material, equipment or devices, shall be utilized solely for peaceful purposes. In establishing and implementing its safeguards and control system the Community is prepared to consult with and exchange experience with the International Atomic Energy Agency with the objective of establishing a system reasonably compatible with that of the International Atomic Energy Agency. The United States and Euratom will formulate and agree upon the principles which will govern the establishment and operation by Euratom of a mutually satisfactory safeguards and control system under the Agreement for Cooperation between the United States and Euratom. These principles are set forth in Attachment B and will be included in the text of the Agreement.

C. As has been requested by Euratom, the United States will provide assistance in establishing the Euratom safeguards and control system, and will provide continuing assistance in the operation of the system.

D. There will be frequent consultations and exchanges of visits between the Parties to give assurance to both Parties that the Euratom safeguards and control system effectively meets the responsibility and principles stated in B above and that the standards of the materials accountability systems of the United States and Euratom are kept reasonably comparable.

E. In recognition of the importance of the International Atomic Energy Agency, the United States of America and the European Atomic Energy Community will consult with each other from time to time to determine whether there are any areas of responsibility with regard to safeguards and control and matters relating to health and safety in which the Agency might be asked to assist.

F. A continuation of the cooperative program between the United States and Euratom will be contingent upon Euratom establishing and maintaining a mutually satisfactory and effective safeguards and control system which is in accord with the principles originally agreed upon.

12. *Third Party Liability*

The Community and the Government of the United States recognize that adequate measures to protect equipment manufacturers and other suppliers as well as the participating utilities against now uninsurable risk are necessary to the implementation of the joint program. The Euratom Commission will seek to develop and to secure the adoption, by the earliest practicable date, of suitable measures which will provide adequate financial protection against third party liability. Such measures could involve suitable indemnification guarantees, national legislation, international convention, or a combination of such measures.

13. *Tariffs*

The Commission will take all action open to it under the Treaty to minimize the impact of customs duties on goods and products imported under this joint program.

14. *Existing Agreements*

Existing agreements for cooperation in the field of nuclear energy between Member States and the United States of America are not modified by the joint program, but will be subject to appropriate negotiations pursuant to article 106 of the Treaty. Modifications may be made as necessary to permit transfers of reactor projects now contemplated under existing agreements that qualify for and are accepted under the joint program.

15. *Administration of the Program*

In order to assure the initiation and effective execution of this program, agreement will be reached on the overall organization needed to establish and carry out the joint program, including the establishment of such joint groups as are required.

THE COMMISSION OF THE EUROPEAN ATOMIC ENERGY COMMUNITY (EURATOM),
L. ARMAND,
H. L. KREKELER,
PAUL DE GROOTE,
ENRICO MEDI,
EMANUEL SASSEN.

THE UNITED STATES OF AMERICA,
JOHN FOSTER DULLES,
LEWIS L. STRAUSS.

At Brussels on May 29, 1958, and at Washington on June 12, 1958.

Attachment A

PRINCIPLES FOR THE SPECIAL ARRANGEMENTS WITH RESPECT TO THE FUEL CYCLES FOR REACTORS TO BE CONSTRUCTED AND OPERATED UNDER THE PROGRAM

A. *Objective*

The objective of the fuel cycle program is that arrangements for supplying fuel elements for the million kilowatt cooperative program will meet either criterion (1) or (2) below:

(1) The integrity of the stainless steel or zirconium clad fuel elements for light-water cooled and moderated reactors is guaranteed to an average irradiation level [1] of 10,000 megawatt days per metric ton of contained uranium;[2] and the charge [3] for fabrication of fuel elements starting with uranium hexafluoride is:

(*a*) $100 per kilogram of contained uranium for fuel elements made of uranium dioxide having a U–235 isotopic concentration no greater than 3 percent by weight, diameter between 0.25 and 0.50 inches, and stainless steel cladding; or

(*b*) $140 per kilogram of contained uranium for similar fuel elements clad with zirconium cladding; or

(*c*) appropriately adjusted charges for fuel elements having different claddings or falling outside of the limitations on size, shape, or U–235 concentration.

Note: For each type of fuel element, there will be computed, as mutually agreed, "computed fuel cycle costs" based on guaranteed average irradiation levels and fabrication charges, and taking into account all charges for fuel fabrication, inventory, burnup, chemical reprocessing, and transportation and the credit for plutonium. If the irradiation level and fabrication charge used in this computation are those given in A (1), the computed fuel cycle cost is defined as the "standard fuel cycle cost."

(2) The irradiation level in the integrity guarantee and the fabrication charge for fuel elements differ from the values specified in (1), but the combination gives a computed fuel-cycle cost equal to or less than the standard fuel cycle cost.

B. *Guarantees*

1. Arrangements for supplying fuel elements that meet criterion (1) or (2) may be received from commercial sources but, in the event of failure of fuel elements, such arrangements may not sufficiently cover the extra costs of reprocessing and transporting irradiated fuel elements to meet the standard fuel-cycle cost. Under

[1] Average irradiation level will be based on a weight of fuel equivalent to the nominal fuel loading of the reactor.

[2] Adjustments of the integrity guarantee may be required if cladding materials other than stainless steel or zirconium are used.

[3] Fabrication charges will be subject to escalation on the basis of a mutually determined index.

such conditions, the United States Commission will, for the purposes of prorating the chemical processing and/or transportation costs, offer to guarantee an average irradiation level, which, in combination with the guarantees offered by the manufacturer, would result in a computed fuel-cycle cost equal to the standard fuel-cycle cost. When such guarantees are made, if the average irradiation level actually attained is greater than the irradiation level guaranteed by the United States Commission, one-half of the resulting savings in costs of reprocessing and/or transportating irradiated fuel will be credited to the United States Commission, up to the sum of previous payments by the United States under this guarantee for the particular reactor concerned.

2. In the event that acceptable arrangements for supplying fuel elements meeting the criteria of A above are not received from commercial sources, the United States Commission will guarantee the fuel elements supplied under the following arrangements:

(*a*) If the fabrication charge guaranteed by the manufacturer is equal to or less than the value specified in A (1) above, the United States Commission will guarantee an average irradiation level which, when combined with this fabrication charge, will give a computed fuel-cycle cost equal to the standard fuel cycle cost.

(*b*) If the average irradiation level guaranteed by the manufacturer is equal to or greater than the value specified in A (1) above, the United States Commission will guarantee a fabrication charge which, when combined with the average irradiation level in the manufacturer's integrity guarantee, will give a computed fuel-cycle cost equal to the standard fuel-cycle cost.

(*c*) If the average irradiation level is less and the fabrication charge is greater in the manufacturer's guarantee than in A (1) above, the United States Commission will offer to guarantee the values in A (1).

In cases (*b*) and (*c*) above, when the average irradiation level attained exceeds that guaranteed by the United States Commission, one-half of the resulting savings in fabrication costs will be credited to the United States Commission, up to the cost of payments by the United States Commission for fabrication charges for the particular core concerned.

If the average irradiation level does not meet that guaranteed in (*a*), (*b*), or (*c*) above, the United States Commission will adjust the charges for fabrication, chemical reprocessing, and transportation to the level that would have been incurred had that guarantee been met.

3. Fuel-element guarantees may also be developed for proven types of reactors other than light-water cooled and moderated, determined by the Euratom Commission and the United States Commission to be eligible for consideration under the joint program.

4. The guarantees provided by the United States Commission under paragraphs 1, 2, or 3 of this section will be applicable to all loadings made in the reactor during ten years of operation or prior to December 31, 1973, whichever is earlier.

5. In determining whether a guaranteed average irradiation level has been attained, account will be taken not only of all material discharged because of actual failure of integrity, but also material whose discharge, in the joint opinion of the Euratom Commission, the United States Commission, and the fabricator involved, was required for purposes of safe operation or economic operation (assuming for the latter determination that no guarantees were in force).

6. The technical and economic criteria under which proposals will be evaluated for acceptance will include minimum standards for fabrication charge and integrity guarantee for fuel elements. These criteria will also provide, as may be

agreed, that subsequent reactor cores can be furnished by other than the initial fabricators.

7. In order to qualify for the guarantees by the United States Commission provided in paragraphs 1, 2, and 3 of this section, fuel elements must be fabricated by a United States manufacturer or by a manufacturer in Euratom countries under agreement with a United States firm or firms. However, reactors under the joint program may be fueled with elements from other sources. In such cases, the United States Commission will offer to perform chemical reprocessing services at its published charges with respect to any source or special nuclear material obtained from the United States. If adequate facilities are not available in Euratom countries when needed, the United States Commission will give sympathetic consideration to furnishing reprocessing services on material not furnished by the United States Commission.

8. The United States Commission guarantees will, in general, be extended to the utility through the fabricator of the fuel. In the event that it is determined by the United States Commission that the fabricator is not meeting adequate performance standards, or, if it is mutually determined that a more advantageous source is available, other contractual arrangements will be made for supplying fuel elements under the guarantee.

Attachment B

PRINCIPLES FOR ESTABLISHING THE SAFEGUARDS AND CONTROL SYSTEM UNDER THE AGREEMENT FOR COOPERATION

The principles which will govern the establishment and operation of the safeguards and control system are as follows:

The Euratom Commission will:

1. Examine the design of equipment, devices and facilities, including nuclear reactors, and approve it for the purpose of assuring that it will not further any military purpose and that it will permit the effective application of safeguards, if such equipment, devices and facilities:

a. Are made available pursuant to this Agreement; or

b. Use, process or fabricate any of the following materials received from the United States: source or special nuclear material, moderator material or any other material relevant to the effective application of safeguards; or

c. Use any special nuclear material produced as the result of the use of equipment or material referred to in *a* and *b*.

2. Require the maintenance and production of operating records to assure accountability for source and special nuclear material made available or source or special nuclear material used, recovered, or produced as a result of the use of source or special nuclear material, moderator material or any other material relevant to the effective application of safeguards, or as a result of equipment, devices and facilities made available pursuant to this Agreement.

3. Require that progress reports be prepared and delivered to the Euratom Commission with respect to projects utilizing material, equipment, devices and facilities referred to in paragraph 2 above.

4. Establish and require the deposit and storage, under continuing safeguards, in Euratom facilities of any special nuclear material referred to in 2 above which is not currently being utilized for peaceful purposes in the Community or otherwise transferred as provided in the Agreement for Cooperation between the United States and the Community.

5. Establish an inspection organization which will have access at all times—

a. to all places and data, and

b. to any person, who by reason of his occupation deals with materials, equipment, devices or facilities safeguarded under this Agreement,

necessary to assure accounting for source or special nuclear material subject to paragraph 2 and to determine whether there is compliance with the guarantees of the Community. The inspection organization will also be in a position to make and will make such independent measurements as are necessary to assure compliance with the provisions of this Attachment and the Agreement for Cooperation.

It is the understanding of the Parties that the above principles applicable to the establishment of Euratom's inspection and control system are compatible with and are based on art. XII of the Statute of the International Atomic Energy Agency, ch. VII of the Euratom Treaty, and those adopted by the Government of the United States of America in its comprehensive Agreements for Cooperation.

APPENDIX 16

Press Releases on Oak Ridge Nuclear Incident

July 8, 1958

The Atomic Energy Commission today released additional details concerning the criticality incident which occurred at the Y–12 Plant in Oak Ridge on June 16. Eight employees of the plant received significant exposures to radiation and were hospitalized for observation.

The accidental nuclear reaction occurred at 2:05 p. m., on June 16, in a 55-gallon stainless steel drum in an enriched uranium recovery area at the Y–12 Plant. The recovery area is located in a wing of one of the large buildings at the plant.

On the basis of presently available information, the following was the sequence of events leading to the nuclear incident:

A portion of highly enriched uranium-bearing solution leaked or otherwise flowed through a valved pipeline from a small diameter tank in one wing of the building to another small diameter tank in the recovery area. The solution also filled piping which connects the first tank with two other small diameter tanks in the area. All of the tanks, because of their geometrical configuration, were of the "always safe" type and a nuclear reaction could not occur even though the tanks were filled with enriched uranium solution.

Subsequent to this inadvertent transfer of enriched uranium, two of the three tanks in the recovery area were partially filled with water for routine leak testing following a monthly cleanout for inventory.

During this operation, an employee, unaware that enriched uranium had leaked or flowed into the tank and piping, drained the solution into a 55-gallon drum. As the valve on the drain line was opened, the enriched uranium solution which was in the tank nearest the valve preceded the water into the drum.

The enriched uranium in the drum was then in a "nonsafe" configuration and a nuclear chain reaction occurred. Although there was no explosion, there was an instantaneous emission of radiation.

Following the initial emission of radiation and upon water dilution, the material in the drum is believed to have pulsed in periodic emissions of radiation for a period not exceeding 4 minutes.

The initial emission of radiation activated the plant alarm system and plant emergency procedures were put into effect. Personnel evacuated the buildings and the main road to the plant was temporarily closed to traffic.

Radiation control specialists were brought in from other portions of the plant and other Commission plants in Oak Ridge to determine the source of the radiation.

By 5 p.m., radiation survey teams had established the drum as the source of the incident and defined the radiation field. The remaining portions of the building were then reoccupied.

Initial efforts following the incident were concerned with determining whether any individuals had been exposed to radiation, providing medical care, and to decontaminating and cleaning up the affected building wing.

Sheets of cadmium, a neutron-absorbing material, were inserted into the 55-gallon drum to insure that further nuclear reactions would not occur, and samples of the material in the drum were taken for analysis. Later, the contents of the drum were transferred to "always safe" containers.

Eight employees were in the vicinity of the drum at the time of the incident. All of them were carrying out routine plant operations and maintenance. One employee, a chemical operator, was participating in the leak testing which inadvertently set off the reaction. He was within 3 to 6 feet of the drum when the incident occurred. The other seven were from 15 to 50 feet away at the time. Two were engaged in installing ductwork; two electricians were engaged in removing conduit; two others, a welder and a machinist, were located on a mezzanine near the scene of the incident; and the seventh, a chemical operator, was in the process of starting up an evaporator some 50 feet away.

Two of the men reported seeing a blue flash at the time the reaction occurred, and some of the men reported a strange sweet smell in the air. They all evacuated the area quickly upon hearing the radiation alarm sound.

Since the determination of radiation exposure from a reaction of this type is complicated under any circumstances, special methods were used to determine the neutron and gamma exposure of the individuals nearby.

These methods included readings from indium foil which is incorporated in all Y-12 security badges; determining the radioactivity of sodium-24 in the bodies of those exposed through whole body and blood counting; and by measurements obtained through a mock-up of the accident. The latter series of experiments was conducted by the Oak Ridge National Laboratory on June 17 and 18.

Through use of these methods, it was estimated that the eight men received radiation exposures ranging from a high of 320 rad to a low of 20 rad.

Three of the men who received the lowest exposure were released from the hospital on June 26. Five others who received higher exposures remain at the Medical Division Hospital of the Oak Ridge Institute of Nuclear Studies where they are undergoing further observation and tests.

These five men are in satisfactory condition and they are permitted to leave the hospital to visit with their families for 8 hours each day.

July 14, 1958.

The five men who received higher exposures in the June 16 criticality incident at the Y–12 plant are again remaining around the clock at the Medical Division Hospital of ORINS where they continue to undergo observation and tests. Previously the men were permitted to leave the hospital for 8 hours each day. All five are permitted to remain out of bed and to visit the recreation rooms in the hospital.

Three of the men have experienced an anticipated further drop in certain of the blood elements. This secondary drop developed later than expected. This delay is regarded as a generally favorable sign. Some employees of Union Carbide Nuclear Co. have been contacted as possible blood donors in the event that therapeutic transfusions may be required.

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