June 1, 1961

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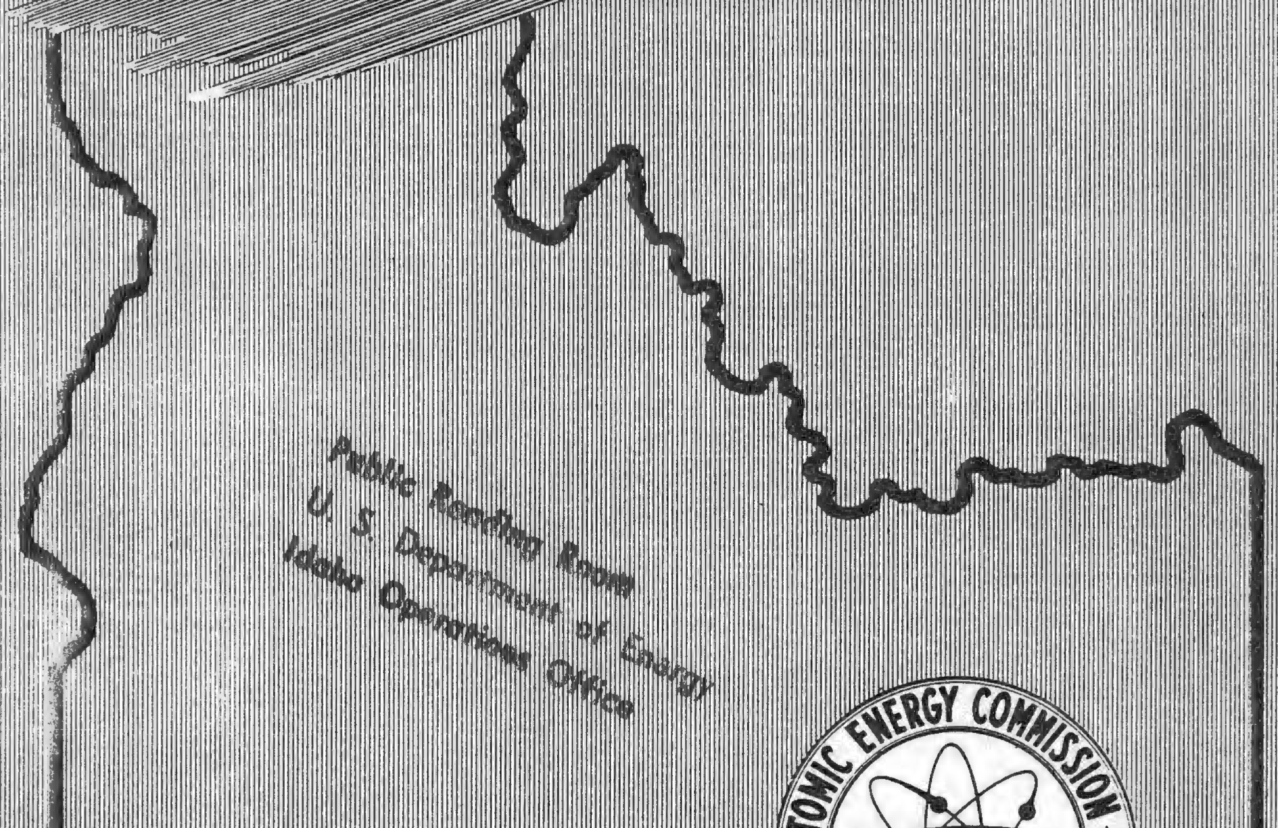
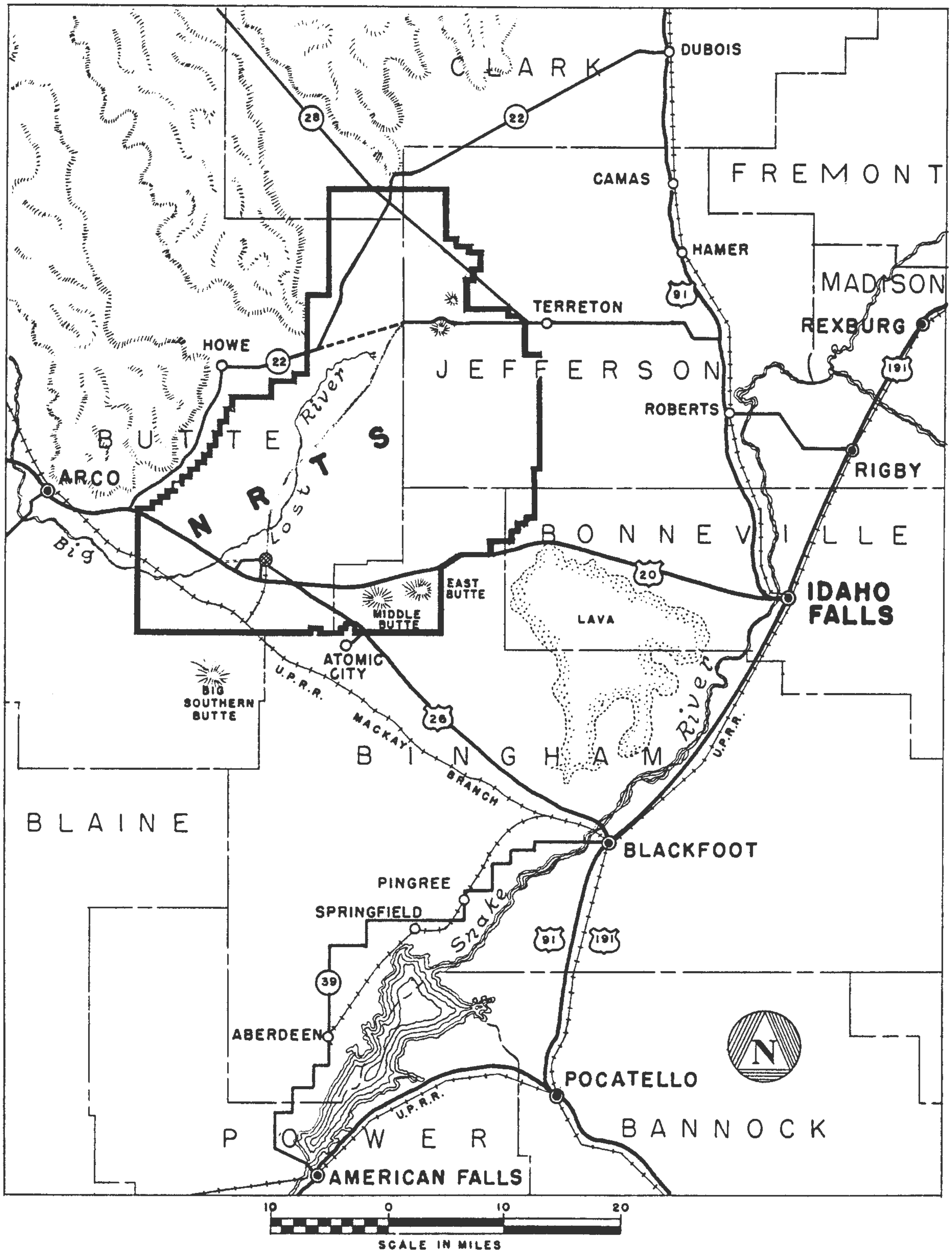
NATIONAL REACTOR TESTING STATION



ATOMIC ENERGY COMMISSION ★ UNITED STATES OF AMERICA



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NATIONAL REACTOR TESTING STATION
UNITED STATES ATOMIC ENERGY COMMISSION
(Revised June 15, 1961)

The National Reactor Testing Station was established in 1949 as a place where the U. S. Atomic Energy Commission could build, test, and operate various types of nuclear reactors, allied plants and equipment with maximum safety. Today, the NRTS is one of the Commission's principal centers for developing peacetime uses of atomic energy. It has the world's largest and most varied collection of reactors -- research, testing, power, and propulsion.

The National Reactor Testing Station's broad mission is to further the Commission's reactor development program. To that end, more than 40 facilities had been placed in operation, or under construction or design as of June 15, 1961.

The Station is administered by the Idaho Operations Office of the U. S. Atomic Energy Commission from offices at 550 Second Street, Idaho Falls, Idaho. The Idaho Operations Office has a twofold primary mission: (1) administration of such basic Commission programs as the test irradiation services program, organic reactor program, the transient reactor experiment program, the chemical processing of highly enriched fuels and associated development, and the Army gas-cooled reactor systems and boiling water reactor programs; (2) providing various technical and common services in support of other Commission offices having projects at the NRTS.

GENERAL INFORMATION

Though planned in 1949 to accommodate 10 reactors by 1964, 29 had been brought to criticality (steady operation) by June 1961, of which 19 are operating. A complete tabulation of NRTS facilities is found on pages 11 and 12.

Centered on a former Naval Proving Grounds which served the Navy's Pocatello (Idaho) Ordnance Depot, the NRTS covers some 572, 000 acres of sagebrush land on the Snake River Plain in Southeastern Idaho. Most of the large withdrawal lies in Butte County, although it also extends into Bingham, Bonneville, and Jefferson Counties. Its 894 square mile size -- equivalent to more than three-fourths the state of Rhode Island -- enables scientists and engineers engaged in nuclear development to carry on experiments that would not be permitted in populous areas.

No one resides at the NRTS. The permanent employees live in some 30 communities adjacent to the testing station, the greatest percentage in Idaho Falls. All housing has been provided by private enterprise through normal financing. Project-operated bus service is provided from the major communities. The nearest NRTS boundaries are 29 miles west of Idaho Falls, 32 miles northwest of Blackfoot, 55 miles northwest of Pocatello, and 14 miles southeast of Arco.

Plant investment in facilities at the NRTS has reached $300,000,000. Construction underway or ready to start totaled another $77,000,000 as of May 17, 1961.

Six major operating contractors are engaged in activities at the NRTS: Aerojet-General Corporation, Argonne National Laboratory, Atomics International, General Electric Company, Phillips Petroleum Company, and Westinghouse Electric Corporation.

Manager of the Idaho Operations Office is Allan C. Johnson and the Assistant Manager, Technical Operations is W. L. Ginkel. The office reports to the Reactor Development Division, Atomic Energy Commission, Washington, D. C.

Idaho Operations Office Division Directors and heads of offices include: E. W. Bosse, Reactor Division; J. M. Brooke, Security Division; M. C. Corbett, Office of Information; W. A. Erickson, Contract Administration Division; V. V. Hendrix, Technical Services Division; J. R. Horan, Health and Safety Division; J. R. Howard, Organization and Personnel Division; K. K. Kennedy, Chemical Processing and Development Division; H. M. Leppich, Engineering and Construction Division; Howard Noble, Contracts and Supply Division; R. W. Scott, Finance Division; H. K. Shapar, Office of Chief Counsel.

SIGNIFICANT ACCOMPLISHMENTS

The National Reactor Testing Station has contributed substantially to beneficial use of the atom. Some important NRTS "firsts" are: producing the first usable quantities of electricity; proof-testing the feasibility of nuclear propulsion for both submarine and surface ships; demonstrating the principle of breeding nuclear fuel; powering of a turbojet engine exclusively from nuclear heat; and demonstrating the advantages of using organic substances (hydrocarbons) as reactor moderator and coolant; operation of a large reactor using a full core loading of the artificial fuel, plutonium; and operation of a high flux reactor with 20 per cent rather than 93 per cent enriched uranium as fuel.

Countless contributions to advancement of reactor technology have been made by the nation's two largest test reactors, the MTR and ETR, which are at the Station. It is said practically every reactor in existence owes some debt to the knowledge gained through test irradiations in the MTR.

Another significant contribution being made at the NRTS is in the field of reactor safety. Known as the Special Power Excursion Reactor Tests, this activity consists of a major portion of an intensive AEC program of reactor safety investigations, designed to provide better information to industry for evaluation of reactor hazards.

The first production of usable amounts of electricity from nuclear heat occurred at the Experimental Breeder No. 1 in December 1951. Four years later, another reactor, BORAX-III, supplied all the electricity needed to meet the demand load of the city of Arco, Idaho.

Three significant developments in the field of nuclear propulsion have taken place at the NRTS. On March 31, 1953, the prototype of the nuclear submarine Nautilus was placed in operation, heralding the era of submarine propulsion. The feasibility of powering a turbojet engine by nuclear heat alone was first demonstrated at the NRTS in January 1956. Two and one-half years later, when the first reactor of the Large Ship Reactor sustained criticality, the feasibility of using nuclear power for large surface naval ships was proved.

PHYSICAL CHARACTERISTICS

The NRTS is located on a level plain at an average elevation of 4,865 feet. Underlying the sagebrush covered topsoil are strata of gravel which, in turn, generally rests on a base of lava rock. Depth to the lava rock varies considerably, making it possible for engineers to provide a wide variety of footing conditions. In general, construction of roads, railroads, etc., requires only the stripping off of the overburden and brush, then grading the gravel and adding to it the required depth from nearby gravel barrow areas. The plain is a major geographic, geologic, and economic segment of southern Idaho. The Station itself comprises 894 square miles of sagebrush and basalt fields. It is nearly 39 miles long from north to south, and about 36 miles wide in its broad southern part.

Although annual precipitation in the NRTS area averages less than 10 inches, under it is a natural underground reservoir of water having an estimated lateral flow of not less than 323,000,000 gallons per day. This water is supplied, in the main, from streams--Birch Creek, Big and Little Lost Rivers--that start in the mountains to the north, and disappear into the porous soils of the NRTS area.

Average annual temperature at the Station is 42 degrees, with extremes of 102 and -43 degrees. The prevailing dry, sunny, and breezy weather has proved excellent for operations requiring use of cooling towers to dissipate reactor heat and stacks to disperse waste gases.

FACTS AND SIDELIGHTS

The NRTS is served by a branch line (freight only) of the Union Pacific Railroad, the official siding being Scoville. Highways serving the project include U. S. 20, connecting Idaho Falls and Arco, U. S. 26, connecting Blackfoot and Arco, and the Pole Line Road, connecting Terreton and Howe.

The NRTS is a controlled area, open only to those with official business. Visits are limited to those persons having passes issued by the Security force. Members of the Security force have been deputized as state police. An air space restriction designation prohibits unauthorized air travel over the area.

Nuclear research and development programs of all three military branches--the Air Force, Army, and Navy--are conducted at the NRTS. Private industrial firms carry out the work under contract to the Services and the Commission.

A burial ground for radioactive solid and semisolid wastes is situated in the central southern part of the station near Big Lost River. Contaminated material and some semisolid chemical wastes are buried there in alluvial sediment trenches.

The devising of a centralized security plan when the Station was established, with spot emphasis on specific areas, made it possible to eliminate costly fencing, lighting, and patroling the site perimeter--thus obviating construction of some 125 miles of fence, lighting, and patrol roads. More than $1, 000, 000 of the allocation for administration and service, covering such items as warehousing, garage, shops, service buildings, infirmary, transportation equipment, maintenance equipment, etc., for central facilities was saved by consolidation of facilities, designing for the most economical construction, and utilization of surplus from other Commission offices.

While the Station itself is situated in a comparatively isolated country, it is encircled by more than 30 adjacent communities where workers reside. The housing and service capabilities of these communities made it unnecessary to establish a Federal community. Most of the communities have experienced a steady growth pattern, particularly Idaho Falls, where nearly 70 per cent of the permanent force resides and where the Commission has its Idaho Operations Office headquarters. Records of the city building inspector there show that since the Station was established in 1949, 3,959 dwelling units had been constructed up to December 31, 1959, an annual average of 396 units. This compares with 151 units a year for the four-year period, 1945-48.

Specific examples of population growth are the following estimated 1959 populations for key cities adjacent to NRTS as compared with the 1950 census figures, given in parentheses: Arco, 2, 000 (961); Blackfoot, 8, 000 (5, 180); Idaho Falls, 30, 000 (19, 218); Pocatello, including Alameda, 40, 000 (30, 825); Rexburg, 5, 000 (4, 253); Shelley, 2, 100 (1, 856).

The Station and its technological program have afforded new opportunities for the young people of Idaho, particularly college graduates, to mature into highly skilled lines of work and yet remain in their home state or region.

Also, the atomic energy work has been responsible for a considerable influx of new citizens into the area from many parts of the world. On the Station's employment rolls are workers from every state in the Union, including Alaska and Hawaii, and seven other nations--England, Canada, China, Germany, Poland, Scotland, and Wales.

The Station's permanent operating force, consisting mostly of workers employed by firms under contract to the government, reached the 4,500 mark during 1959. Government employees on the permanent payroll number about 350. In addition, the construction, or temporary, work force has averaged nearly 900 annually for the past 10 years. The annual permanent force payroll, including AEC employees, approached $30 million in 1959.

In addition to permanent force payroll, construction worker wages together with contractor procurement and purchase orders for equipment, supplies, materials, and services required to operate, maintain, and expand the National Reactor Testing Station have averaged more than $27 million annually for the past 10 years. Thus, the total impact, moneywise, of NRTS activities on the economy of the area and the Nation in 1959 approximated at least $55 million.

The NRTS is the largest single employer of engineers in Idaho and adjoining states. More than 600 with engineering degrees are employed as engineers and more than 100 additional engineers are employed in administrative or technical positions. More than 500 other holders of college degrees, including at least 200 physicists and chemists, are also employed at the Station.

HISTORY OF THE SITE

As in much of the Intermountain area, the fur trappers are credited with being the first white men to enter the part of Idaho occupied by the NRTS. Thyery Godin, a French-Canadian trapper, discovered the Lost River in 1820, naming it the Godin River. He was a member of the Snake River expedition of the North West Company which left Fort Nez Perce on the Columbia River (at present-day Wallula, Wash.) in 1819-20 under the leadership of Donald McKenzie. His son, Antoine, also was a member of the expedition. Later, both men accompanied trapping expeditions into the same Snake River country led by Alexander Ross and Peter Skene Ogden in the middle 1820s.

The trappers deployed themselves in small bodies to work different areas, and most of the rivers and natural features on both borders of the Snake River Plains were discovered and named by them. The elder Godin was killed by Blackfoot Indians.

Seeking revenge for his father's death, Antoine Godin, in the summer of 1832, precipitated the dramatic Battle of Pierre's Hole in the present Teton Valley just west of the Grand Tetons. The trappers were just breaking up their annual rendezvous when a large party of Blackfeet came into sight. Antoine and a Flathead Indian rode forth to parley with the Blackfoot spokesman. When they started to talk, the Flathead suddenly shot the leading Blackfoot, just as Antoine grasped his hand in a gesture of friendship. It was a gross violation of plains ethics, and erupted into a huge pitched battle between the trappers, Flatheads, and Nez Perces on one side, and the Blackfeet on the other. The latter dug into the ground in a wooded area and though many were killed and wounded on both sides, the Blackfoot survivors managed to get away during the night. A few years later, Antoine Godin, now a marked man among the Blackfeet, was at Fort Hall, near present-day Pocatello, when Blackfeet appeared across the river and killed him.

Twin Buttes served as a guidepost for gold seekers. Cowboys and herdsmen guided large herds of cattle, horses, and sheep eastward past the Buttes on their way from Oregon to eastern markets and east-slope ranches. Two early-day stagecoach lines crossed near the Buttes, and, for a time, the general area was a rendezvous for horse thieves.

Big and Little Lost Rivers were as well-known as Twin Buttes to pioneers of the West. The fact that both rivers disappear into the sinks of the reactor testing station captured the imagination of early-day travelers, the general area being known as the "Lost River Country."

During World War II, the U. S. Navy was given jurisdiction over about 270 square miles of the plain for a proving ground and gunnery range extending from the vicinity of Scoville northward to State Highway 28. An area southwest of the Naval Proving Grounds was used by the U. S. Air Force as an aerial gunnery range during World War II. The present Station includes all the former military proving grounds and a large adjacent area, consisting almost entirely of lands withdrawn from the public domain for use of the Commission. The Navy administration, shop, warehouse, and housing areas became the Central Facilities Area.

OPERATIONS

The operations responsibilities of the Atomic Energy Commission's Idaho Operations Office embrace three broad categories of reactor development--power, research, and testing. In Fiscal Year 1960, these activities and supporting programs at the NRTS had an annual budget in excess of $25 million.

IDO administers the following operations:

> The Commission's program for developing organic reactors, a concept that is showing increasing promise for economic nuclear power.
>
> The Commission's principal program for test irradiation services, utilizing two large high flux test reactors at the NRTS and three private industrial reactors elsewhere.
>
> A large chemical processing plant for recovery of highly enriched uranium from partially burned reactor fuels.
>
> The Commission's major effort in the field of reactor safety--a series of experiments known as SPERT I, II, III, and IV (Special Power Excursion Reactor Tests) which are exploring with sudden power surges the dangers of nuclear runaway in an effort to identify and exploit self-stabilizing phenomena inherent in water-cooled reactors.
>
> A major portion of the Army's compact reactor development program, including the GCRE-I (Gas Cooled Reactor Experiment), ML-1 (Mobile Low-Power Reactor), SL-1 (boiling water prototype) and two portable improvements on the SL-1--the PL-I and PL-II (Portable Low-Power Reactors 1 and 2).

IDO also oversees the furnishing of common services which support all programs at the National Reactor Testing Station. Such services include transportation, waste disposal, utilities, environmental safety, security protection, general maintenance, library and technical information service, cafeteria and food service, medical service, and motor vehicle service which are described in more detail on ensuing pages.

Engineering and Construction--In addition to responsibilities for directing operation of the National Reactor Testing Station, the Idaho Operations Office directs a site building program that has grown to a plant investment of more than $265,000,000 since 1949. This responsibility not only includes engineering and construction in support of its own program but a substantial part of the engineering and construction necessary to carry out the programs of other operation offices which have facilities at the NRTS.

The Division of Engineering and Construction's NRTS program averaged 38 contracts for 112 projects costing $15,000,000 annually from 1950 through 1955 and increased steadily to a 1958 program that consisted of 80 contracts for 264 projects totaling $24,800,000. The 1959 program was larger dollarwise with fewer contracts and projects.

Health and Safety--The Health and Safety Division of Idaho Operations Office is responsible for the protection of property and the health and safety of people, plants, and animals in and near the National Reactor Testing Station area. Assurance is given to employees, visitors and residents of adjacent areas that no current or future health hazards can result from routine or experimental activities at the NRTS.

Health and Safety Division interests encompass all phases of occupational safety. The program includes development and enforcement of traffic and industrial safety policies; maintenance of a professional fire department and the training of plant fire brigades; administration of an ecology program to determine the influence of various radioactive materials on soil, as well as plant and animal life; maintenance and development of radiation instrumentation to provide a sixth sense to detect radiation hazards, maintenance of a complete program to provide chemical or radiochemical analysis for any substance which is a potential health hazard, as requested by IDO or its contractors; furnishing a comprehensive personnel metering program for radiation monitoring program, including a fixed air monitoring network and various subsurface water investigations, as well as inspection of radioactive shipments; administering an active medical program to provide "human maintenance", as well as the treatment for injuries and diseases sustained by AEC and contractor personnel, and responsibility for the safe disposal or radioactive material, as well as the organization and training of a radiological assistance team for on-site as well as off-site incidents.

The Division also coordinates cooperative research programs with other Government agencies such as the U. S. Weather Bureau for diffusion and climatological research, the Geological Survey for radioactive waste disposal studies, and the U. S. Public Health Service.

Licensee Inspection--The Idaho Operations Office inspects licensed users and refiners of radioactive materials for compliance with Government regulations concerning the health and safety of individuals engaged in such programs. Its area of responsibility for licensees embraces Colorado, Idaho, Montana, Utah, and Wyoming, and extends as directed to other states for inspection of uranium ore processors.

Security--Over-all responsibility for the security of the NRTS is vested in the Security Division of the Idaho Operations Office. This division is staffed and equipped to safeguard Government property, protect classified matter, effect appropriate clearances for personnel employed at the NRTS. Centralized inspection and planning provides the NRTS activities with a common set of security standards and security education media. Recruitment and inter-job training courses are offered for AEC and contractor patrolmen. In emergency, the AEC's Security Division would implement disaster plans and coordinate evacuations and other such procedures.

Radiological Assistance--Special teams have been organized at the National Reactor Testing Station to provide assistance to the states of Colorado, Idaho, Montana, Utah, and Wyoming in case of incidents involving radioactive materials. These teams, under the direction of the Idaho Operations Office, consist of trained medical and monitoring personnel who respond to radiation accident calls. The teams, part of a nationwide network, are capable of evaluating situations, and recommending measures to control radiation hazards in the interest of public safety. The teams include medical personnel trained in radiation therapy who may be called upon by local physicians to advise on the treatment of radiation exposure, if any.

COMMON SERVICES

Utility and other services available to all contractors at the NRTS are centered in the Central Facilities Area. With exception of such IDO-furnished common services as the security headquarters, the Station's own weather bureau, three fire stations, a medical dispensary, and the Health and Safety Laboratory, the CFA is operated for the AEC by Phillips Petroleum Co. as a general supply, utility, and on-site central service establishment for the entire Station.

Utility-wise, Phillips staffs and maintains: a site-wide communications system, including telephone and teletype service, radio communications, and fire and security alarm systems; the Station's high voltage power distribution system for the entire site, including dispatching facilities, high voltage switching operations, and system maintenance and billing service, a complete network of roads and streets; on-site railroad facilities serving several areas and connecting with a branch line of the Union Pacific Railroad Co. at the site boundary; road and street maintenance; a system for disposal of slightly radioactive liquid wastes; a trash and garbage removal collection service; a sewage system; and a water distribution system supplied by deep wells.

In addition, the Commission's bus fleet, consisting of more than 90 large passenger buses, is operated by Phillips to transport NRTS operating personnel between their homes (in Arco, Blackfoot, Idaho Falls, Pocatello, and Rexburg-Rigby) and their various places of work at the NRTS--distances ranging from approximately 21 to 75 miles. Furthermore, Phillips operates shuttle busses between Headquarters in Idaho Falls and the Station on a convenient schedule, and furnishes passenger car and "taxi" service on call. The latter is available not only for NRTS official visits, but for special pickup and charter service in the area as official business requires.

Nonutility services provided for the AEC by Phillips, and optionally available to the entire NRTS, include a technical information library and service; warehousing; procurement of all kinds of supplies and materials; photography and photo processing; reproduction and printing; a mail, parcel post, express, and freight handling service that utilizes a fleet of AEC trucks as well as common carriers to accommodate the bulk of all shipping of materials to and from the NRTS; cafeterias; equipment operators and labor pool; equipment and vehicle pool; craft and maintenance shops (sheet metal and welding, radio, plumbing and steam-fitting, paint, machine work, equipment repair, lead, electric, carpentry) laundering of radioactively contaminated apparel and articles; material storage yards; and other services.

Phillips-maintained buildings and plants situated in the Central Facilities Area include a communications center, a chemical and engineering laboratory supplementing the ICPP, and the bus and taxi terminal.

Several contractor offices and the suboffices of some IDO Headquarters functions are also situated at the CFA, together with a materials testing laboratory operated for the Commission by F. C. Torkelson Co., and an aggregate yard and concrete batching plant operated for the Commission by Fluor Corporation, Inc.

DEVELOPMENT

In addition to its operations program, the Idaho Operations Office is responsible for a second major area of programmatic activity, namely, the research and development effort that has augmented the Station's original role as purely a testing station. Important R&D work is being accomplished at the NRTS in the fields of (1) reactor safety studies; (2) reactor engineering; (3) new methods for chemically processing reactor fuel elements for recovery of unburned U-235 and management of resultant radioactive waste products; (4) basic nuclear physics research; (5) improved instrumentation and techniques for the radiation protection of personnel, and (6) measurement of nuclear reactivity changes in irradiated materials for the purpose of improving the components of future reactor construction.

PROGRAM FUNCTION AREAS

The program function to date at the National Reactor Testing Station embraces more than 40 facilities, which are either directly administered by the Idaho Operations Office or derive from IDO joint-interest support and, in some areas, direction.

Five of the 19 operating reactors are zero power or criticality experiment facilities. The other 14 are "full-fledged" type. Included are two testing reactors of world-wide renown for their high neutron flux capabilities.

One of the facilities, the Central Facilities Area, is predominantly nontechnological, although it contains the health-physics laboratories of IDO's Health and Safety Division and the Chemical Engineering and Developmental Laboratory. The summary on the following pages lists all facilities at NRTS that are operable, operating, under construction, being designed, or have been dismantled or are in standby status.

FACILITIES AT THE NATIONAL REACTOR TESTING STATION

Reactors Operable or Operating
(June 15, 1961)

	Name	Abbreviation
1.	Engineering Test Reactor	ETR
2.	Experimental Breeder Reactor No. 1	EBR-I
3.	Gas Cooled Reactor Experiment	GCRE
4.	Large Ship Reactor "A"	A1W-(A)
5.	Large Ship Reactor "B"	A1W-(B)
6.	Materials Testing Reactor	MTR
7.	Organic Moderated Reactor Experiment	OMRE
8.	Shield Test (Pool) Facility Reactor	SUSIE
9.	Special Power Excursion Reactor Test No. 1	SPERT-I
10.	Special Power Excursion Reactor Test No. 2	SPERT-II
11.	Special Power Excursion Reactor Test No. 3	SPERT-III
12.	Submarine Thermal Reactor	S1W (STR)
13.	Transient Reactor Test Facility	TREAT
14.	Mobile Low Power Reactor No. 1 (Army)	ML-1
	(Zero Power)	
15.	Argonne Fast Source Reactor	AFSR
16.	Engineering Test Reactor Critical	ETRC
17.	Reactor Measurement Facility (MTR)	RMF
18.	Zero Power Reactor No. 3	ZPR-III
19.	Advanced Reactor Measurement Facility	ARMF

Reactors Dismantled or In Standby Status

1.	Boiling Water Reactor No. 1	BORAX-I
2.	Boiling Water Reactor No. 2	BORAX-II
3.	Boiling Water Reactor No. 3	BORAX-III
4.	Boiling Water Reactor No. 4	BORAX-IV
5.	Heat Transfer Reactor Experiment No. 1	HTRE-I
6.	Heat Transfer Reactor Experiment No. 2	HTRE-II
7.	Heat Transfer Reactor Experiment No. 3	HTRE-III
8.	Critical Experiment	CET
9.	Hot Critical Experiment	HOTCE
10.	Stationary Low Power Reactor No. 1	SL-1

Facilities (Other Than Reactors) In Operation

	Name	Abbreviation
1.	Army Administration and Hot Cell Area	AREA
2.	Idaho Chemical Processing Plant	ICPP
3.	Expended Core Facility	ECF
4.	Fuel Element Cutting Facility	FECF
5.	Gamma Irradiation Facility	GIF
6.	Health and Safety Laboratory	HSL
7.	Chemical Engineering Laboratory	CEL
8.	Waste Calcination Facility	WCF

Facilities (Other Than Reactors) Not Presently In Use

1.	Flight Engine Test Facility	FET
2.	Low Power Test Facility	LPTF
3.	Initial Engine Test Facility	IET
4.	Assembly and Maintenance Area	AMA

Reactors Under Construction

1.	Boiling Water Reactor No. 5	BORAX-V
2.	Experimental Breeder Reactor No. 2	EBR-II
3.	Special Power Excursion Reactor Test No. 4	SPERT-IV
4.	Experimental Organic Cooled Reactor	EOCR
5.	Natural Circulation Reactor	NCR

Other Facilities Under Construction

1.	Hot Pilot Plant	HPP

Reactors Under Design

1.	Experimental Beryllium Oxide Reactor	EBOR
2.	Advanced Test Reactor	ATR

MAJOR PROJECTS

The installations at NRTS are variously distributed about the site in nine major program function areas. These are: Army Reactor Experiment Area, Chemical Processing, Experimental Breeder Reactor I, Experimental Breeder Reactor II, MTR-ETR complex, Naval Reactors Facility, Central Facilities Area, Organic Reactor Area, and Special Power Excursion Reactor Test Area.

Army Reactor Experimental Area

Work in the growing complex comprising the Army Reactor Experimental Area is aimed at perfecting a family of small reactors designed to meet military requirements such as compactness, light weight, transportability, portability, semimobility, or mobility. Power requirements range from two hundred to several thousands kilowatts. With the Army Nuclear Power Program increasing in scope and new plants being built, a standard training program for nuclear power plant operators (for the Armed Forces) has been adopted. This consists of an eight-month academic and speciality course at Fort Belvoir, Va., and a four-month course in plant operation at the NRTS. The SM-1 in Virginia is also utilized for this training.

Stationary Low Power Reactor No. 1--The first small reactor in the AREA, the SL-1 is a direct-cycle boiling water reactor of 3,000-kilowatt gross heat capacity, with enriched uranium fuel, and moderated and cooled by natural circulation of light water. It is operated for the Commission by Combustion Engineering, Inc. The SL-1 plant is operated as a stationary facility to demonstrate that a power reactor of this type could be disassembled and air-transported in component packages to remote military sites.

The SL-1 is designed to produce 200 kilowatts of electricity and 400 kilowatts of space heat. The power is intended to operate radar equipment and the heat to warm offices, barracks, or other installations. Each SL-1 component was designed to measure less than 8 x 9 x 20 feet and weigh less than 10 tons to meet the air-transportability requirement.

A saturated steam flow of 9,000 pounds per hour is generated in the SL-1 pressure vessel at 300 psi and 420° F. About 85 per cent of the steam is used to generate electricity, the other 15 per cent bypassing the turbine potentially for space heating. The SL-1 reactor core is designed to operate continuously for three years without refueling. A replacement core could be brought in by air and the refueling operation completed with equipment available at the site. Another innovation is the use of an air-cooled condenser which greatly reduces the requirement for water during plant operation--an important factor in arctic operations. It is estimated that a portable plant, based on the SL-1 could be built and installed at a remote site for $2 million.

The SL-1 was designed and test-operated by Argonne National Laboratory. It achieved criticality August 11, 1958 and was turned over to Combustion Engineering, Inc., in February 1959. Prior to turnover, the facility was known as the Argonne Low Power Reactor. As of December 31, 1959 the plant had operated for 3,969 equivalent full-power hours, or 1 megawatt year of its expected 6 megawatt year core life.

PL-1 and PL-2 -- Development work on the SL-1 has led to improved boiling water plants that are intended to be portable. These are called the PL-1 (Portable Low Power No. 1, a 200 kw(e) reactor with space heating) and the PL-2 (an 800 kw(e) reactor with space heating). These plants are designed to be built into modules, skid mounted, and fitted into current Air Force cargo aircraft. At the erection site, the modules will be placed in prefabricated arctic buildings and fitted together with a minimum of construction and fabrication time. Some modules that need service evaluation will be tested at the NRTS using the SL-1 plant. At present, the PL type condenser is being piped into the SL-1 in conjunction with the SL-1 power extrapolation program.

Training--Based on construction plans for the SL-1 plant, the Army Corps of Engineers in the spring of 1956 organized a Cadre of men from the Army, Navy, and Air Force to operate the plant. This unit, called the SL-1 Cadre, is part of the U. S. Army Engineer Reactors Group. The Cadre has the dual role of operating the SL-1 plant as a prototype crew, under the direction of the contractor, and of training new operators for boiling water plants for the Armed Forces.

Gas Cooled Reactor Experiment--The GCRE is a water-moderated, nitrogen-cooled, direct- and closed-cycle reactor. It generates 2,200 kilowatts of heat, but no electricity. The reactor achieved criticality February 23, 1960. The experiment is the initial phase in the development by the Commission of a mobile nuclear power plant for the Department of the Army. The reactor facility was designed, built, and is being operated for the Commission by Aerojet-General Corporation.

The facility is being used to develop engineering and nuclear data for improved components. It is aimed at satisfying the military need for a truly portable power source. Patterned after Switzerland's Escher-Wiess system of power production with conventional fuels using rotating equipment as part of a closed gas cycle, it is unique in United States nuclear or conventional power application. In a direct- and closed-cycle, gas-cooled reactor system, the gas, heated in the reactor core, is used to drive the turbine and is returned direct to the core.

Mobile Low-Power Plant No. 1--Criticality of the Gas Cooled Reactor Experiment was a major step toward development of a prototype power plant to be known as the Mobile Low-Power Plant No. 1 which is being developed by Aerojet-General Corporation. It will combine the direct- and closed-cycle, gas-cooled reactor system with a gas turbine-driven power conversion system being developed by the Corps of Engineers in the Gas Turbine Test Facility at Ft. Belvoir, Va. The prototype reactor will generate about 400 kilowatts of electricity and operate at least one year at full power before refueling. The entire power plant will be transportable in four packages totaling less than 38 tons. Either standard Air Force cargo planes or standard Army low-bed trailers could be used to transport the packages. The reactor plant could be put in operation 12 hours after delivery at a site. Other characteristics are: adequate shielding to permit relocation 24 hours after shutdown, simplicity of operation and maintenance by enlisted technicians at remote installations, significant reliability for continuous operation under extreme climatic conditions, and ruggedness to withstand shipment and handling under adverse conditions. The Mobile Low-Power Reactor No. 1 is scheduled for criticality in 1961. The ultimate objective is to produce by mid-1962 procurement drawings and specifications, based on a thoroughly tested prototype reactor. The drawings and specifications would enable the military services to procure plants direct from industry.

Nuclear Test Plant -- The Nuclear Test Plant, now under design, will comprise a pressurized and boiling water nuclear test facility consisting of the reactor and components (exclusive of the core), pressure vessel, instrumentation, control system, cooling system and primary plant components. The NTP is intended to be used for full-scale testing, steady-state and transient, of prototypes of reactor cores to be used in field nuclear power plants of the Army Nuclear Power Program, and will, consequently, have no permanent core of its own. Cores to be tested in the plant will be boiling water reactor and pressurized water reactor cores. Significant characteristics of the NTP are: heat dissipating capacity of 5 to 60 megawatts(t), operating pressures ranging from 500 to 2,500 psi, and temperature ranges from 500° to 670°F. Conceptual design of the reactor is being performed by Combustion Engineering Inc. Facility design work is being accomplished by C. F. Braun Co.

Hot Cells -- Two hot cells with an adjacent shop and maintenance area support AREA reactors. The hot cells are utilized in rough metallurgical work and shipping preparation of radioactive specimens for refined investigations.

Idaho Chemical Processing Plant

The Idaho Chemical Processing Plant, operated for the Commission by Phillips Petroleum Company, is a multipurpose facility capable of recovering unburned U-235 from spent fuel elements discharged from a wide variety of research, test, and power reactors. Highly enriched uranium fuels from approximately 40 different reactors are presently scheduled for processing in this facility.

Of the Commission's several processing plants throughout the country, the ICPP design probably would be the most readily adaptable to a privately owned industrial processing plant. It has been used both as a production facility and as an engineering scale process demonstration facility. Although its main processing load has been aluminum-uranium alloy fuels (such as those of the MTR), the first successful processing of significant quantities of zirconium and stainless steel fuels took place here. Among fuels of these types that have been processed are the first cores from Nautilus and Sea Wolf submarines and the first Organic Moderated Reactor Experiment core.

The ICPP was first operated in 1953 and since that time has recovered with 99.99 percent success all significant quantities of highly enriched uranium discharged by Commission reactors such as the MTR, ETR, EBR, STR and numerous research reactors.

It employs both batch and continuous dissolver systems followed by three cycles of liquid-liquid solvent extraction to separate U-235 from fission product and from structural and alloying material contaminants. Two different solvent extraction systems are usually used, namely, a tributyl phosphate "head end" extraction followed by two cycles of methyl isobutyl ketone extraction which yield an essentially pure solution of uranyl nitrate product.

The main process building, which houses the bulk of equipment and controls, is a 240 x 100-foot structure, largely below ground. It is 90 feet high from subfloor level to pitch of the roof. In one section, the building is approximately 60 feet below the ground level. The main building encloses a usable floor area of 63,174 square feet. Structurally, the building consists of two levels. One level is reinforced concrete, the other of transite and structural steel. Most process equipment containing radioactive materials is located within concrete walls. Chemical make-up tanks and auxiliaries are located in the transite-steel section. The concrete section is divided into two rows of cells with operating, service, and access corridors between the two.

A water-filled storage basin provides interim holding facilities pending dissolution of the fuel in the main process equipment. The various chemical steps are performed in separate concrete-walled cells lined with stainless steel and containing various vessels, piping, and other chemical equipment. This plant differs from the large separation plants at Hanford and Savannah River in that it was designed for direct maintenance--that is, decontamination to tolerable levels permits personnel access for cleanup and repairs to the processing equipment instead of performing such maintenance remotely by means of "slave" cranes, manipulators, and special connectors.

Process and material accounting requirements dictate rigorous statistical and analytical control of the process. Extensive laboratories and instrumentation are available for performing analyses on highly radioactive as well as cold samples. Significant contributions to the field of radioactive analyses have been made during the seven years of ICPP operation.

The liquid wastes resulting from process and containing the bulk of radioactive fission products are presently stored in 300,000-gallon underground tanks, although construction is currently underway to erect a facility to process and reduce these wastes to solid form for safer and more economical storage.

The Waste Calcination Facility, scheduled for operation early in 1962, is the first large scale facility to be constructed for the demonstration of processes for reducing highly radioactive waste solutions to a solid state requiring one seventh less storage space. This facility will permit full-scale studies of fixation of radioactive materials with a goal of minimizing storage and surveillance costs. Special studies also will be conducted to measure the radioactive decay heat generation and methods of heat removal from stored solid wastes.

Other associated activities in the ICPP area are:

Fuel Storage Building--Irradiated fuel is stored here prior to processing in the uranium recovery system. Lead shielded fuel transfer casks weighing up to 75 tons can be received from either truck or rail shipments. Straddle carrier trucks are also used for transporting smaller casks within the NRTS area.

Fuel Element Cutting Facility--This facility is designed to do certain mechanical operations to remove nonuranium containing components from fuel elements and to reduce the size of pieces that must be handled in the processing equipment. The hot cell, unloading devices, and associated handling equipment are located in an addition to the Fuel Storage Building.

Waste Disposal Building -- Gaseous and low-level liquid wastes are treated here to prevent their being a hazard to the environment. In addition to filtration of gaseous wastes, there are provisions for storage of some gases to permit decay of the radioactive components before release to the atmosphere. There are also facilities for separation of the long-lived radioactive rare gases, krypton and zenon. Low-level liquid wastes are concentrated by evaporation and the concentrates stored in underground stainless steel tanks.

Isotope Recovery -- The short-lived barium 140 isotope is recovered from MTR fuel elements to provide a high intensity gamma radiation source for experimental purposes.

Experimental Facilities -- These include:

Multicurie Cell -- A shielded cave where small-scale chemical operations can be performed at full radiation levels.

Analytical Facilities -- Adequate laboratories are available for both process control and support of the process development activities. Facilities include mass and emission spectrometry, X-ray diffraction and a wide variety of other instruments and chemical analytical tools.

Developmental Laboratories -- These facilities permit laboratory scale investigations of new processes that will be required for newer high temperature reactor fuels as well as improvements on processes already in use.

Chemical Engineering Laboratory -- Situated in a converted warehouse at the Central Facilities Area (about three miles from the ICPP), this laboratory is designed to conduct solvent extraction and fuel element dissolution studies on nonradioactive materials for processes prior to "hot" operations. New equipment is also tested prior to installation in radioactive systems. This laboratory is also currently engaged in obtaining operating experience and data on liquid metal heat transfer, off gas cleanup, fluidization, etc. in support of the Waste Calcination Facility.

Hot Pilot Plant -- This facility is now under construction. It will be used for testing of either separate unit operations or complete processes using fully irradiated reactor fuels. This plant, scheduled for completion during 1960, will make it possible to carry new processes from conception through laboratory and pilot plant testing to demonstration in the ICPP.

Experimental Breeder Reactor No. 1 Complex

The Experimental Breeder Reactor No. 1 Complex, situated in the southwest part of the Station, comprises the Experimental Breeder Reactor No. 1, the Argonne Fast Source Reactor, BORAX-V, and the Zero Power Reactor No. 3. First construction work by the Commission at the NRTS commenced in this area in May 1949 with drilling of EBR-I well. Thus, the EBR-I became the first major facility to be constructed at the newly established NRTS. Its construction was completed in April 1951.

The Argonne Fast Source Reactor, operated by the Commission's Argonne National Laboratory, is an experimental reactor for use as a tool in the study of physics of fast breeder reactors. It was placed in operation during October 1959, with a design power of one kilowatt. The reactor serves essentially as a source of neutrons to be used in the development of improved instruments and improved techniques for making measurements in the neutron energy range characteristic of fast reactors. It is designed to augment studies of fast reactor physics being carried out in ZPR-III (Zero Power Critical Facility No. 3). In addition to studies of fast reactor neutron spectra, the reactor is utilized for developing and checking out new detectors as required in fast power reactor experiments; for preparing radioactive metallic foils used in developing counting and radiochemical techniques; and for checking out complex experimental systems in advance of their use in ZPR-III or other reactors.

Borax-V, operated by the Commission's Argonne National Laboratory, is the fifth in a series of NRTS reactors which ushered in intensive work on boiling water reactors wherein the coolant moderator boils in the reactor core and passes saturated steam directly to the turbine for power generation. This system makes possible a relatively simple design with advantages in performance and low costs. For most boiling water reactors no intermediate heat exchanger is used to transfer heat from the coolant to another medium, as is the case with indirect cycle systems. In a direct cycle system, the temperature at the turbine throttle is essentially the same as the reactor outlet temperature, a decided advantage in efficiency of power production.

BORAX-I was constructed in 1953 to demonstrate the feasibility of this type of reactor concept. The facility was deliberately destroyed in July 1954 to determine its inherent safety under extreme conditions.

BORAX-II was constructed in late 1954 for further tests and new core combinations were tried using varying enrichments of uranium 235 in the metal fuel plates. The power level was 6 megawatt (thermal).

BORAX-III, operated in 1955, was designed for 15 megawatt (thermal) compared with 1.4 megawatt (thermal) in BORAX-I, and with a 2,000-electrical-kilowatt turbine generator to investigate use of boiling water reactors for generating electric power. It produced sufficient power experimentally to power and light the city of Arco, Idaho--an American first.

BORAX-IV operated from December 1956 until June 1958. This reactor, 20 megawatts (thermal), was used principally to test high thermal capacity fuel elements made from mixed oxides (ceramics) of uranium and thorium.

The new ceramic core of uranium-thorium oxide fuel elements demonstrated the feasibility of stable operation with this fuel, which can operate at higher temperatures, is less reactive with water coolant in case of cladding rupture, is cheaper to manufacture, and has higher burnup possibilities. It also produced measurable quantities of the artificial, thorium-derived fuel, uranium 233. BORAX-IV was operated satisfactorily with several experimentally defective fuel elements in the core. Relatively minor contamination of auxiliary equipment resulted.

BORAX-V, with a design power of 40 megawatts (thermal), will provide an extremely flexible facility to demonstrate the safety aspects and feasibility of an integral nuclear superheat system when completed during the fall of 1960. In BORAX-V, it is expected that improved efficiency from manufactured steam will be obtained by incorporating as a design feature a number of superheat fuel assemblies in the reactor core lattice which will elevate saturated 500° F. steam from the core to 600 psig-850° F. steam in the superheat portion of the reactor. This increased cycle efficiency holds promise of being an important factor in reducing the power-producing costs of nuclear plant.

Experimental Breeder Reactor No. 1, operated by the Commission's Argonne National Laboratory, sustained initial criticality in 1951. It has demonstrated that a nuclear reactor, designed to operate in the high energy neutron range, is capable of breeding (creating more fuel than its operation consumes) and also has the potential for achieving economically competitive nuclear power. The EBR-I was the first reactor of sizable power to use liquid metal as a coolant, and to produce usable amounts of electricity from nuclear sources. The reactor is unmoderated and uses sodium-potassium alloy (NaK) as coolant. The EBR-I uses enriched uranium (largely U-235) as fuel, and has a blanket of natural uranium (largely U-238) around the core as the "fertile" material in which breeding takes place. The liquid metal coolant permits the neutron energies to be kept high to promote the breeding of fissionable material. In addition, the coolant enables high-temperature and low-pressure operation, both conducive to efficient power production. Active experimental work on this liquid metal-cooled, fast-neutron reactor was started in 1946.

Operating on its third core since late 1957, the EBR-I is currently being used for experiments to determine the effects of fuel element bowing upon operating the neutrons produced by the fission of uranium atoms enabling the neutrons to penetrate rather than bounce off other uranium atoms and thus continue the chain reaction. During the surge, the abnormal amount of heat generated in the fuel due to fission is transferred instantaneously to the graphite which absorbs the released energy. As the graphite becomes hot, its efficiency in slowing down neutrons decreases. Consequently fewer neutrons capable of producing fission are available, permitting the surge to be held to a safe level. For this reason, the reactor is said to have self-limiting operational characteristics.

MTR-ETR Complex

America's and probably the world's largest and most advanced nuclear test facilities, the Materials Testing Reactor and the Engineering Test Reactor, provide extensive facilities at the NRTS for the irradiation of materials in environments of high neutron flux. Both are heterogeneous, light-water-cooled- and -moderated reactors which use highly enriched uranium as fuel. Together, these reactors are providing answers to the myriads of problems that must be solved before atomic power can take its full place in the world's economy. While intended primarily for the AEC's test program, the test irradiation facilities provided by the MTR and ETR also have been made available to educational, research, industrial, and commercial installations, and other federal agencies. The Commission's programs have constituted the major portion of the work load at each reactor, however. Customers wishing to use these irradiation facilities must make written application and are required to design, fabricate, and ship the experiments and necessary equipment to the NRTS in a ready-to-install condition. The reactor complex, which includes the reactors and their associated experiments, is not a static affair, so it is necessary that each new irradiation experiment be integrated into the complex as it exists at the time of the irradiation program.

The great bulk of experiments can be classified into three groups: (1) the capsule or static specimen type, (2) the dynamic, small specimen type, and (3) the dynamic full scale component type.

The older of the two reactors, the MTR, achieved criticality in March 1952. The choice of core structure and fuel elements of every reactor designed in this country since 1952 has been influenced by information obtained from tests in the MTR. The radiation fields available in this reactor made possible greatly accelerated screening tests which were of immediate benefit to reactor design. The successful operation of the MTR was in itself a great experiment that resulted in a whole family of plate-type reactors, including the ETR. The MTR is known as the granddaddy of all plate-type reactors and of all plate-type tank reactors. In its earliest stages, the MTR contributed vitally to work on pressurized water reactors, and more recently to the Yankee, the Dresden, the organic reactor, the liquid metal fuel reactor, and even the homogeneous reactor. In the military reactor field, the MTR has accommodated some 10 major aircraft propulsion experiments, some 50 for the Navy, and several for the Army.

In addition, the MTR has made an outstanding contribution in the field of creating high-specific-activity radioisotopes for medical therapy and for industrial radiography.

The MTR and ETR operate on established schedules, calling for regular shutdowns to insert or remove experiments and related equipment, and to replenish or rearrange fuel loadings. The principal objective is to provide the greatest neutron flux for the highest percentage of operating time, recognizing at the same time that reactor safety requirements necessitate extensive experiment instrumentation to assure that any serious difficulties occurring in the experiment will shut the reactor down before damage occurs.

Radiation space in the MTR and ETR is allocated on a combined priority and first-come-first-served basis, the Washington Irradiation Board establishing the priorities. Principal users are the military and production programs of the AEC, although commercial sponsors occupy loop and capsule space regularly for such purposes as providing highly active isotopes like thulium as well as testing a variety of materials. Also, the intensely radioactive fuel elements from these reactors are used at the reactor site and distributed to Commission, Government, and commercial users requiring intense gamma activity for a variety of investigations from food sterilization to catalyzing chemical reactions.

Materials Testing Reactor, operated for the Commission by Phillips Petroleum Company, has been in business as an irradiation facility since March 1952 and during this period almost every conceivable material has been irradiated, either statistically in capsules, or dynamically in loops. The individual experiments range in complexity from the simple irradiation of cobalt 59 wafers in aluminum capsules to beam hole loop installations using high temperature fused salt fluids as their circulating medium. Its load of experiments, both within the tank and in the beam holes, has experienced a growth far beyond the expectations of the reactor's designers. The 40 megawatt (thermal) reactor provides neutron fluxes averaging 2.5×10^{14} and maximum fluxes of 5×10^{14}. The reactor initially was operated at 30 megawatts (thermal) until September 1955 when the thermal output was increased to 40 megawatts. The increases made more high flux space available and shortened irradiation periods in some cases. The reactor's enriched uranium fuel is contained in an active core which is inside a lattice region 16 x 28 inches in area and 24 inches high. It is surrounded by a 40-inch high reflector of beryllium pieces. Both lattice and reflector are encased in a 55-inch diameter aluminum tank which is extended by stainless steel sections above and below to form a 30-foot deep well which is closed top and bottom with heavy lead-filled steel plugs. Water flows through the reactor tank at 25,000 gallons per minute to carry off the 40,000 kilowatts of heat. The MTR, in its more than eight years of operation, has logged in excess of 49,000 operating hours and more than 20,000 neutron irradiations. It has been loaded with as many as 600 separate irradiation samples at one time. Since June 16, 1955, more than 163,000 separate gamma irradiations have been conducted at the Station using spent fuel elements from the MTR.

During August 1958, the MTR was operated using plutonium 239 as fuel at power levels up to 30 megawatts, the original design power of the reactor. A total of 262 megawatt days was achieved, with a normal complement of experiments in the reactor, before depletion of the core shut down the reactor. The performance of the fuel elements, fabricated at the Commission's Hanford, Washington, plant, was generally excellent and demonstrated the feasibility of fabricating a plutonium-fuel core capable of withstanding high-power, high-flux conditions. The test also demonstrated that a reactor fueled with plutonium can be satisfactorily controlled. In another special test, the MTR demonstrated the feasibility of using 20-percent-enriched uranium fuel elements, rather than the 93-percent-enriched elements usually used.

With some materials, three weeks exposure in the MTR is equal to two or more years in an actual reactor. Large quantities of radioactive cobalt (cobalt 59 transmuted into cobalt 60) used in cancer therapy have been produced in the MTR. In March 1960, 15 pill-size (one-third by one-sixteenth-inch) wafers of high specific activity cobalt 60, measuring 308 curies per gram or 308 times as potent as a gram of radium in cancer therapy, were produced for the Argonne Cancer Research Hospital, Chicago. The total weight of the 15 pieces was 11.7 grams, with a total curie activity of 3,600. The maxium cost for the irradiation was about $40,000 or $7,500 per year of useful life, compared to approximately $72 million or $45,000 per year of useful life for an equivalent specific activity of natural radium.

Engineering Test Reactor, operated for the Commission by Phillips Petroleum Company, is located in the same operating complex with the MTR. It is the AEC's largest and most advanced test research facility. Its operating level is 175 megawatts (thermal). The ETR was placed in operation in September 1957. Full power was achieved in April 1958. The Engineering Test Reactor grew out of the urgent need, largely within the Commission's activities, for more high flux testing space, and, particularly, more stable flux, a greater variety of fluxes than the MTR, and also "through" facilities. The bulk of this need was for evaluation of fuel, coolant, and moderator characteristics and compatibilities under environments similar to those which would exist in many types of potential reactors. The ETR provides several radiation spaces, up to 9 x 9 x 36 inches, within the high flux area of the core itself--another major departure from the MTR designed into the ETR. The facility provides an average neutron flux of $3\text{-}5 \times 10^{14}$ thermal.

The Engineering Test Reactor is loaded with 52 fuel elements and 16 control rods. The active section of the core is 36 inches high by 30 inches square and is capable of accommodating experimental facilities vertical and parallel to the fuel assemblies. A normal loading operates about 17 days (3,000 megawatt days) and reaches a burn-up of 27 per cent of the uranium-235. The reactor is cooled by 60,000 gallons of water per minute. The primary water system absorbs the reactor heat and in turn liberates it through four banks of three heat exchangers each (in parallel), to a secondary water system which in turn dumps the heat to the atmosphere through a conventional cooling tower. The reactor pressure vessel is about 35 feet long and 12 feet in diameter at the top, with a lower section diameter of 8 feet. It has a cluster of perforations in the bottom head to accommodate the control rod drives and experimental loops.

ETR Critical Facility, also operated for the Commission by Phillips, is a full-scale mock-up of the core and beryllium reflector of the Engineering Test Reactor. The

ETR aluminum reflector is not duplicated in the ETRC. Placed in operation in May 1957, its purpose is to permit reactor physics measurements to be made which will assist in the design of experiments for, and the operation of, the ETR, which is difficult to calculate. In addition, the facility is used for evaluating hazards associated with experiments, their coupling with the reactor and with each other. Some of the parameters which are investigated and which are significant with regard to experiment operation are excess reactivity, flux distribution, and flux perturbations. A complete library of experiment mock-ups is maintained which includes all experiments residing in the reactor core and beryllium reflector, enabling the operators to duplicate at any time the ETR loading in the critical facility for the purpose of determining the effect of a new irradiation program on those in progress. Another difficult problem solved by the ETRC is to calculate from one run to the next how much fuel should be added. To do this in the ETR would take much valuable time. The ETRC saves hundreds of thousands of dollars a year in time on the ETR by enabling experimental pretesting of planned loadings while the ETR is actually running on the previous loading.

MTR-ETR Hot Cell Building. Phillips operates a 10,000 to 20,000 curie capacity hot cell facility capable of handling one and one-half to three million electrical volts gamma radiation in support of the MTR-ETR irradiation programs. There are three hot cells in the facility. These hot cells are equipped with a number of machine tools, which can be operated remotely, and master slave manipulators to permit detailed examination and metallurgical testing of samples irradiated in the test reactors.

Nuclear Physics Research Facilities--Phillips conducts an important program of nuclear physics research for the Commission at MTR-ETR, where the availability of high neutron fluxes affords unique opportunities for conducting experiments that require sufficiently high flux to produce reactions large enough to measure, or to shorten the length of the experiment.

These experiments consist of measuring neutron cross sections of materials essential to reactor construction and nuclear theory development. Neutron cross sections are measures of the probability that neutrons will interact with nuclei of a given element, e.g. whether the neutrons will be absorbed or scattered, or whether nuclei will be fissioned. Type and magnitude of the interaction depend on nuclear properties of the particular element and the energy of the neutrons.

Knowledge of neutron cross sections is basic to reactor design. Cadmium, having a high absorption cross section, is put in reactor control rods to soak up neutrons and thus slow the chain reaction. Beryllium, having a high-scattering cross section but a low absorption cross section, is placed around a reactor's core to reflect back escaping neutrons. These cross sections are easy to measure and for design purposes need not be known with great accuracy. Far more difficult to measure are the cross sections of the nuclear fuels, yet they must be known to high accuracy in order to predict the economics of nuclear power, as in the "breeding" process, for example. (Breeding is the creating of more artificial nuclear fuel in a reactor than is consumed in its operation.) In the Th-U^{233} breeding chain, present estimates of the time needed to create a net gain of as much fuel as was originally put into a reactor vary from about 15 years to over 40 years. An error of but 1% in one of the cross section values involved in the calculation would alter the estimated "doubling time" by many years. Hence, accurate knowledge of cross sections is one of the keys to economic development of nuclear power.

At MTR-ETR, three major instruments are used in cross section measurements taking advantage of reactor-furnished neutrons having a wide range of energies. In different ways, the three instruments serve to separate these neutrons into narrow energy bands useful for cross section investigations. Each of the three is suited to measurements over a certain portion of the energy range of interest.

The Neutron Crystal Spectrometer directs an intense beam of neutrons from the MTR's core at a crystal which can diffract, from the beam, neutrons of a single energy, much as a prism breaks up a beam of light into the spectrum. The neutron energy of the selected beam can easily be varied to cover cross section measurements up to energies of about 10 ev.

The Fast Neutron Chopper - Time of Flight Spectrometer sorts the neutrons according to energy in a different way, covering a higher energy range than does the crystal spectrometer. The chopper is a shutter that rotates at high speed to "chop" the neutron beam from the reactor into "bursts" of about a millionth of a second in duration. By electronically timing the arrival of neutrons after they have traveled over a long course (often 45 meters) the numbers of neutrons at each speed (energy) are counted. The effect of samples inserted in the beam can be interpreted in terms of cross sections since the samples invariably change the number of neutrons of each energy.

The Slow Neutron Velocity Selector employs two choppers to provide bursts of neutrons having energies over a narrow band that can be directed onto samples to study the angular and energy distributions of the neutrons scattered by the samples. Such scattering studies are of particular value in the design of reactors where weight and size considerations are paramount, as with propulsion reactors for aircraft, rockets, etc. The two choppers rotate at high speed with an accurately controlled phase difference between them. The first chopper lets through bursts of multi-energy neutrons which spread out according to energy as they speed toward the second chopper. The second chopper lets through only a selected narrow energy band of neutrons from each burst. Between the choppers are two collimators rotating in phase with them to suppress fast neutron background.

The Reactor Services Building in the test reactor area provides space for assembling and pretesting of experimental apparatus before insertion in the MTR-ETR.

Reactivity Measurement Facility, is a detector-reactor which determines reactivity changes in materials which have been irradiated in the MTR-ETR. It is used to assay new and spent fuel elements, and to assist in experiment scheduling by evaluating reactivity losses and flux depressions caused by in-pile apparatus. It is operated by Phillips Petroleum Company. The RMF started operating in 1955.

The Advanced Reactivity Measurement Facility augments the Station's capabilities for precise determination of nuclear characteristics of reactor fuels and materials, as part of the Commission's program to achieve more efficient reactor fuel utilization and to improve the quality of reactor core components. Teamed with the RMF, the facilities afforded are considered to be the most sensitive devices for reactivity determinations in existence. The ARMF incorporates many of the features of the RMF but, in addition, the ARMF has greater mechanical stability, specially designed fuel elements to obtain better nuclear characteristics, and improved instrumentation. With completion of the new ARMF building, the RMF is to be moved from its old location in the MTR storage canal.

The Gamma Irradiation Facility, situated just outside the MTR-ETR exclusion area, is a water-filled canal 17 feet deep, 40 feet long, and 6 feet wide where experiments requiring high gamma fluxes can be performed by the contractor, Phillips Petroleum Company, on an unclassified basis. Gamma fields as high as 20 million roentgens per hour are provided by using spent MTR fuel elements as sources. This facility is widely used in investigations concerned with food preservation, radiation effects on plastics and other materials, and sterilization of heat-sensitive chemicals.

Naval Reactor Facility

Three major installations comprise the Naval Reactor Facility. These are the Submarine Prototype (S1W), the Large Ship Reactor (A1W), and the Expended Core Facility (ECF).

It was in the S1W, formerly the Submarine Thermal Reactor or STR, that the United States' nuclear navy was born. The project--aimed at freeing our naval vessels from their ancient need for refueling at sea or frequent returns to port--achieved success with an initial power run in the Nautilus prototype on May 31, 1953. Then followed attainment of full design power on June 25, 1953, and shortly thereafter accomplishment of a simulated "voyage" nonstop from Newfoundland to Ireland, "submerged" and at full power, lasting more than 66 hours. This proved that atomic propulsion of ships was feasible and that the Nautilus, long before it set out to sea, could do the remarkable things it has since accomplished, including subnavigation of the polar ice cap from the Pacific to the Atlantic in the summer of 1958.

The logical next step was to develop a prototype for surface ships, since other problems, including the necessity of proving that reactors can be teamed up to work in tandem, remained to be solved. In October 1958, the first reactor of the Large Ship Reactor Facility sustained criticality, followed by the second reactor in July 1959, and full power operation with both reactors on September 15, 1959. The Aircraft Carrier Enterprise and Missile Cruiser Long Beach are to be powered by A1W prototype plants. Eight reactors are required for aircraft carrier propulsion.

The S1W is popularly called the atomic submarine plant. It is operated for the Commission and the U. S. Navy by Westinghouse Electric Corporation. The S1W facility still houses the prototype of the Nautilus, although the testing program has changed from one of simulating the Nautilus power plant to one of testing advance design equipment, prototyping new systems for current nuclear projects, and obtaining data for future naval vessel power plants. In addition, the S1W site continues to be a training center for Navy personnel who will man present and future underseas atomic craft.

The nuclear power plant and the associated propulsion equipment are installed inside two hull sections of a submarine originally built to duplicate the corresponding sections of the atomic submarine Nautilus. In this submarine hull, the research and development took place in a maze of pipes, wires, motors, valves, and instruments, which, on March 30, 1953, resulted in a successful reactor. It was brought to power on May 31 and several weeks afterward made the equivalent of an Atlantic crossing, submerged at top speed. Since then, the submarine prototype has continued to establish an outstanding performance record.

It operated over two and one-half years on its original uranium fuel charge. In 1956, the plant completed the longest full-power run ever attempted by any propulsion plant--land, sea, or air. During the test, it operated continuously for 66 days and nights. When it was routinely shut down at the end of the run, there still remained sufficient uranium fuel for many hundred additional hours of full-power operation. This unprecedented test gave engineers and scientists an opportunity to check out instruments and equipment under conditions more demanding than any the actual submarine would be subjected to. While the test was underway, Navy atomic crew trainees manned watch stations, just as if they were on a cruise in the Nautilus.

The Large Ship Reactor (A1W or LSR) is a prototype facility that consists basically of a dual pressurized water reactor plant within a portion of a steel hull of a large surface ship. All components are of a type that will withstand seagoing use. The first of the prototype's two pressurized water reactors sustained criticality in October 1958. Full power operation of the first reactor plant was achieved by the following January. Initial criticality of the second reactor was achieved in July 1959, and on September 15, 1959, both reactor plants operated at full power for the first time. This is the first nuclear plant to have two reactors powering one ship propeller shaft. The prototype powers the plant's propeller shaft through a geared turbine propulsion unit. The shaft is loaded by a special power-absorbing generator which will simulate loads placed on an aircraft carrier propeller during actual ship-at-sea conditions. From the tests under way, will come new and advanced reactors and cores for naval surface ships. The A1W reactors are designed for interchangeable use between cruiser and carrier-type ships.

The aircraft carrier, Enterprise, under construction at Newport News Shipbuilding and Dry Dock Co., will be powered by eight A1W-type reactors. The cruiser, Long Beach, being built by Bethlehem Steel Co., will utilize two A1W-type reactors.

The Expended Core Facility, also operated for the Commission and the U. S. Navy by Westinghouse, handles the dismantling and analysis of expended cores from the U. S. Nuclear Navy, preparatory for shipment to processing plants for recovery of enriched uranium in the spent fuel. It is a multiple-purpose building for the handling of spent fuel elements from naval reactor cores. Part of the building contains deep, water-filled pits for safe underwater disassembly and preparation of the radioactive fuel. Sections of the disassembled elements are sent to hot cells within the building for research and testing. The hot cell windows are six feet thick.

Organic Moderated Reactor Experiment

The Organic Moderated Reactor Experiment, operated for the Commission by Atomics International, was constructed and is being operated to demonstrate the technical and economic feasibility of using a liquid hydrocarbon as the coolant and moderator. Primary purpose of the reactor is to study the radiation and thermal stability of the organic materials used and the associated physical property changes under actual reactor operating conditions.

OMRE does not use water or liquid metal for a coolant or moderator. It employs a hydrogen-carbon compound called polyphenyl, a floorwax-like substance which becomes liquid when heated. The organic coolant is effectively noncorrosive, and has a comparatively high boiling point so that light-weight, ordinary steel, sufficient for low pressures and low corrosion, can be used for the reactor tank, valves, and piping. The polyphenyl coolant can be operated at high heat with little or no pressure without flashing into high-pressure steam as water coolant tries to do. The low induced radioactivity of the coolant requires minimum shielding with resultant ease of maintenance.

The OMRE reactor vessel is a mild steel pressure tank 4 1/2 feet in internal diameter, 28 feet high, with a wall thickness of 1 inch. The core, located in the low part of the pressure tank, is covered with a 14-foot pool of coolant to provide biological shielding. Plate-type stainless steel-uranium oxide fuel elements are being used. The reactor is pressurized with nitrogen, which provides an inert atmosphere above the reactor pool and maintains a pressure of 200 psig on the system. As the coolant has a relatively large volume change with temperature, an expansion tank is provided to allow operation over a wide range of temperatures without adjustment of coolant inventory. The reactor coolant is circulated at 9,200 gpm. The heat generated in the reactor is dissipated to the atmosphere in an airblast heat exchanger. A simple batch-operated purification system is provided for removal of the high boiling compounds which are formed by the radiolytic and pyrolytic damage to the coolant.

The coolant prior to irradiation is a commercial mixture of terphenyls and diphenyl.

Initially, criticality was sustained September 17, 1957, with full-power operation following in February 1958. The reactor generates from 5 to 15 megawatts of heat, which could be used in commerical plants for production of electricity or process heat, is dissipated to the atmosphere.

The OMRE has fulfilled its primary purpose of establishing the feasibility of operating this type of reactor. The reactor has been operated with a number of different concentrations of decomposed organic material in the coolant, and at various outlet temperatures, in order to determine the variations in decomposition of the organic material produced by changes in these conditions and the effect of decomposition product on heat transfer.

Criticality was achieved with a second core May 9, 1959. Later, a continuous purification system was installed. Plans call for additional modification of the OMRE to improve its usefulness for experiments. These modifications involve fuel handling, buildings, and support facilities with only minor modification to the reactor vessel itself.

The Experimental Organic-Cooled Reactor is under construction at NRTS to provide a facility for testing complete cores made up of experimental fuel elements, with the option of various moderator-coolant combinations. Because the OMRE was built as a minimum-cost ($1,800,000) facility to test the feasibility of the concept, it is lacking in the necessary organic loops needed for investigation of various organic coolants and experimental fuel elements. The EOCR is being designed to test coolants with various inhibitors, different types of reconstituted polymers, a number of bulk coolant temperatures, a number of fuel surface temperatures, various experimental fuel elements, and boiling as well as non-boiling conditions. The reactor will produce 40 megawatts of heat. No steam generation is planned.

Special Power Excursion Reactor Tests

The Special Power Excursion Reactor Tests (SPERT) project was organized in the summer of 1954 for studying reactor transient behavior and reactor safety. Reactor variables are so numerous and their interactions are so complex that only practical approach to their experimental study is to establish a base point by setting up reactors specifically for that purpose and examining them thoroughly. Then variables can be changed one at a time to weigh each against the combination. The SPERT reactors, of which there are now three in operation and one under construction, were designed for such purposes. They provide a wide range where variables such as plate design, core configuration, coolant flow, reflector, moderator, void, and temperature coefficients can be studied.

Operated for the Commission by Phillips Petroleum Company, the SPERT facilities are being utilized to obtain experimental information on reactor behavior from which an evaluation of reactor hazards can be obtained for the benefit of industry. The SPERT program is aimed at designing reactors with greater operational flexibility, yet greater safety, at less cost. Today, because sufficient information isn't available on reactor hazards, reactor design is conservative and reactor operation is restricted by stringent built-in opeational limits that are believed to be unnecessarily elaborate. Both contribute to the cost and complexity of reactor design and operation. The SPERT program is expected to lead to development of safe-design standards against which a reactor still on the drawing boards can be measured without the expense of costly mock-ups. Another goal is to arrive at realistic operational limits (ones actually proved to be safe) in place of the somewhat arbitrary limitations currently in effect.

The need to make a reactor self-stabilizing was realized as early as 1939 when an operating reactor first was deemed possible. It was realized at that time there existed a danger of a nuclear runaway.

The major portion of the Commission's intensive program of reactor safety is carried out in the SPERT reactors at the NRTS. They are providing nuclear industry with information for evaluating safe operating characteristics of boiling water, pressurized water, heavy water, and open pool reactors. The reactor experiments can be divided into four major classifications: static experiments to determine such core characteristics as void and temperature coefficients; step tests in which the system is suddenly made supercritical; ramp tests in which reactivity is added to the reactor at a constant rate; stability tests which may involve either spontaneous or externally induced oscillations. These tests are performed under various conditions of temperature, pressure, and coolant flow on cores of differing design.

Since the purpose of the SPERT reactors is to find basic explanations for reactor behavior under runaway conditions, it is necessary to conduct all operations from a central control building one-half mile from the reactors.

<u>SPERT-I</u>, placed in operation June 11, 1955, is an unpressurized, light-water-moderated and reflected reactor using 93 per cent enriched uranium fuel. The reactor tank, about four feet in diameter and 14 feet high, is filled with water to a level about two feet above the core. There are five cadmium blade-type control rods, four for reactor operation and one for the initiation of power excursions. They are opeated by drive mechanisms supported on a bridge across the shield tank. There are two instrumentation systems for SPERT-I, one for controlling the reactor and one for studying transients. A closed-circuit television camera mounted above the tank makes it possible to observe the reactor in operation by viewing it on a TV screen in the control room.

The SPERT-I reactor is an unpressurized, water-moderated reactor specifically designed to yield basic safety information and understanding of reactor behavior through transient testing. Some operations of SPERT-I have been devoted to aiding other Commission research programs because of its value as an experimental machine capable of producing bursts of high-energy neutrons for very short time periods. One contribution from the reactor was the successful demonstration in 1958 of a research reactor safety device--called a reactor fuse--capable of preventing a reactor runaway. The fuse, working independently of the mechanical control system, shut down the reactor by rapidly injecting a neutron absorbing gas into a chamber located within the reactor whenever the power rose at an excessive rate.

The SPERT-I tests are generally characterized by sudden power rises that are arrested by inherent shut-down or self-limiting tendencies of the reactor itself. Reactor power reaches a peak (one reached 2.8 billion watts, equivalent to the output of Grand Coulee Dam power plant) in a fraction of a second and, without manipulation of control rods, drops off to much lower but generally steady levels.

In some cases, however, instabilities have been observed following the power peaks. These divergent oscillations would probably destroy the reactor, despite its self-limiting characteristics, if allowed to continue. Determination of the precise causes of these oscillations in the face of inherent shutdown tendencies in water reactors is one of the important research goals that justified the construction of additional reactors in the SPERT family.

<u>SPERT-II</u> sustained initial criticality March 11, 1960. This facility consists of a reactor vessel and coolant flow systems designed for operation with either light or heavy water at pressures up to 375 pounds per square inch, temperatures up to 400^{o} F. and flow rates up to 20,000 gpm. Coolant flow may be provided in either an upward or downward direction through the reactor core at velocities up to about 25 feet per second to establish the desired initial conditions prior to transient testing of the reactor. No provision for continuous heat removal is included, however. SPERT-II is fueled with 93 per cent enriched uranium. Positions are provided in the reactor grid for 96 fuel assemblies, including the fuel sections of the control rods. The reactor vessel is a stainless-steel-clad, carbon-steel vessel, having a 10-foot inside diameter. It is 16 feet high. The reactor is housed in a 60 x 90-foot building of concrete block construction. The arrangement of reactor components enables insertion of reactor cores which have varying diameters and heights, and provides for varying thickness of either liquid or solid reflector to a maximum of 10 feet over-all diameter.

The operational program for SPERT-II calls for a series of nuclear physics measurements leading to a special program of reactor hazards studies.

The SPERT-II reactor can be operated with both light and heavy water as a moderator in order to determine experimentally the importance of prompt neutron lifetime on reactor kinetic behavior. The provision for control of pressure, temperature, and flow permits much wider investigation of reactor instability and is expected to extend the range of variables for step and ramp type tests.

SPERT-III was placed in operation in December 1959. It is considered to be the most versatile facility yet developed for studying the potential hazards of nuclear reactors. It provides the widest practical range of control over three variables--temperature, pressure, and coolant flow. Pressures from atomospheric to 2,500 psi water temperatures from 68° to 668° F., and coolant flow rates ranging from zero to 20,000 gpm with heat removal capacities up to 60,000 kilowatts for durations of 30 minutes, are attainable in the complex SPERT-III. The reactor vessel has an inside diameter of 4 feet and an over-all height of about 19 feet. Openings in the vessel head include five 1 1/2-inch openings for the control rod drives, and four 6-inch access ports. The access ports are utilized for inserting and removing instrumented fuel assemblies, and for connecting the control rod drives. Openings in the vessel shell include six 4-inch access ports, six 8-inch exit coolant water nozzles, while a flanged tee at the bottom of the vessel contains two 16-inch inlet cooling water lines, a drain, and two 3-inch access ports. The coolant system consists of two primary coolant loops, including pumps, heat exchangers, valves, a pressurizer, and the secondary coolant system. The reactor is fueled with 93 per cent enriched uranium. Positions are available for 68 fuel assemblies, including the fuel sections of the eight control rods.

SPERT-IV is under construction in the same section of the NRTS as the three earlier reactors in the SPERT series. This is to be a pool facility which will permit detailed study of reactor stability based on varying conditions of coolant flow, height of water above the core, and other hydrodynamic effects. The SPERT-IV reactor will permit detailed studies on phenomena of instability demonstrated in some of the more than 1,000 excursions conducted in SPERT-I. The basic SPERT-IV building will be 73 x 93-foot, with a maximum height of 45 feet.

Central Facilities Area

To reduce duplication of buildings, equipment, and personnel, the common needs of the various technical installations at the NRTS are met by a Central Facilities area which has been developed at the site of the former Naval Proving Grounds headquarters. Facilities located there include: medical dispensary, central security force, health and safety laboratory, and fire department--all operated by AEC personnel, and a meteorological unit of the U. S. Weather Bureau. Other central operations include a technical library, cafeteria service, craft shops, warehouses, and transportation system, and a chemical engineering and developmental laboratory, all operated by Phillips Petroleum Company.

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