ARMY NUCLEAR POWER PROGRAM

U.S. ARMY ENGINEER REACTORS GROUP

THE ARMY NUCLEAR POWER PROGRAM

The Army Nuclear Power Program (an outgrowth of Army study groups dating from 1952) was established in 1954 to carry out the responsibility of the Department of the Army to develop, with the Atomic Energy Commission, land-based nuclear power plants for all three services. In 1958, the Chief of Engineers established the U. S. Army Engineer Reactors Group (USAERG) as a framework for carrying out the missions. The USAERG functions through the Nuclear Power Division, Office of the Chief of Engineers; the scientific and technical activities of the Army Reactors, Division of Reactor Development, Atomic Energy Commission; and the engineering, research and development, construction, operational, training, and health and safety activities of the Nuclear Power Field Offices, Fort Belvoir, Virginia, and Idaho.

In October 1955, construction began on the first of the five nuclear power plants that have been operated under the Army Nuclear Power Program. The SM-1 (APPR-1), Fort Belvoir, a stationary, medium-power, pressurized-water reactor with gross electrical output of 2000 KW, the first of its kind, began to produce electrical power April 1957. Here the Army has continually trained enlisted men from the three services to qualify as nuclear power plant operators and maintenance men, and has conducted advanced training for officers and civilian engineers and some research, development, and testing.

Two other plants resemble the SM-1. The PM-2A, the world's first portable plant, was installed in the ice cap of Greenland and brought critical 2 October 1960. It was designed to provide power (2000 KWe gross) and heat ($1x10^6$ BTU/hr) for the U. S. Army Polar Research and Development Command facility and served as a test reactor at a remote installation. It made an illustrious record by running almost uninterruptedly for 3540 hours. In the summer of 1963, it was shut down and its core removed to allow for radioactive decay prior to plant removal in the summer of 1964 and shipment back to the United States where its components are being examined for useful data. The SM-1A, sister to the SM-1, produces 2000 KWe gross and 38,000 lbs/hr steam heat for Fort Greely, Alaska. It first went critical 13 March 1962 and is now operated by the U. S. Army, Alaska.

The PM-1, the first Air Force plant, has been furnishing electrical power and space heating for the Sundance, Wyoming, radar station since February 1962. It is a pressurized-water reactor but includes several radical departures from the SM-1 design, including the magnetic-jack control-rod drives. It is designed to put out 1250 KWe and $7x10^6$ BTU/hr. All liquid wastes are concentrated and disposed of as sludge.

The PM-3A, Antarctica, a sister to the PM-1, is the Navy's first land-based power reactor. It is modular, skid-mounted, and installed mostly above ground. It is isolated from the outside world from March to September. Since going critical 3 March 1962, it has been supplying electricity (1750 KW gross) and heat ($3x10^6$ BTU/hr) for the McMurdo polar research station.

The MH-1A, a 10,000 KWe barge-mounted plant, the first floating nuclear power plant to produce power for off-ship consumption, is nearing completion.

Other plants under research or development are the Standard Plant (similar to the PM-1 and prefabricated in packages for air shipment), the mobile energy depot (for field use to preclude the long logistical tail needed for POL fueling), second-generation plants, and lunar power projects.

THE SM-1 NUCLEAR POWER PLANT

US ARMY NUCLEAR POWER PROGRAM

The SM-1. The U. S. Army's first nuclear powered generating station began operation 15 April 1957.

THE SM-1

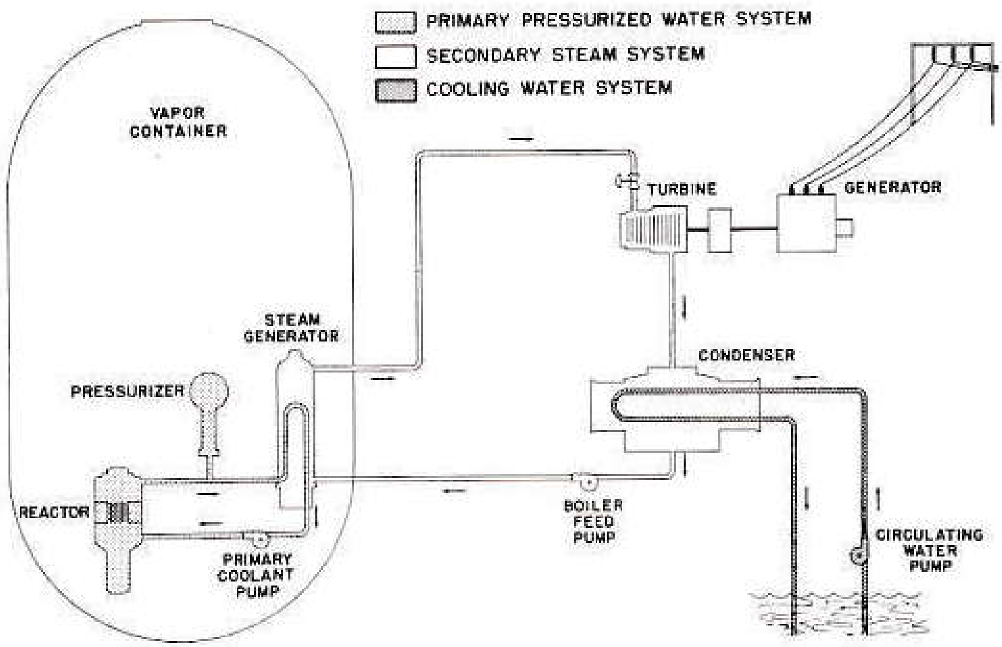
The SM-1 is the first prototype of a family of nuclear power plants under development by the Atomic Energy Commission and the Department of Defense for use by the three military services at remote installations. The mission of the SM-1 is to train nuclear power plant operators and accomplish Research and Development tasks. The initials SM stand for "Stationary, Medium power," and the number 1 means first model or prototype. This reactor has a capacity of generating 10,000 KW of thermal energy. The plant is approximately 20% efficient, since the generator produces 2000 KW of electrical energy, of which 200 KW is used by the plant. The SM-1 can generate enough power to supply a city of approximately 2,000 with all their electrical needs. Analysis of the electrical and heat requirements at many overseas installations and the examination of the fuel needs to meet these requirements indicated that many of the supply and transportation problems which attended the use of conventional fuels could be avoided if nuclear fuels were used. Economic studies, which assumed a plant to be in operation at certain remote installations where fuel costs are high, showed that its use would result in an over-all saving by the elimination of many transportation expenses. For example, to replace a reactor core similar to the SM-1 would cost approximately $200,000; the core would weigh about 700 pounds. In contrast, a conventional diesel engine plant supplying the same amount of power for a remote site such as Camp Century, Greenland, would require about 8,500 barrels of diesel fuel costing approximately $345,000 and weigh nearly 3,800,000 pounds. To transport and deliver this amount of fuel to Camp Century, would require six D-9 tractors each pulling two tankers, a total of 15 round trips of 280 miles across the ice-cap. The fuel consumption of the tractors making these trips would amount to about 225,000 gallons. However, a single aircraft could transport and supply a nuclear power plant with enough fuel to operate for one or two years. This would eliminate the consumption of vital oil supplies and release surface oil tankers for other important areas of operation. This means vital remote stations would be less dependent on long supply lines and large fuel storage sites which would be vulnerable to enemy action. Therefore the military need for a family of such nuclear power plants was established as a result of these studies by the U. S. Army Corps of Engineers in 1952.

At the request of the Corps of Engineers a design study for a nuclear power plant to meet military specifications was performed by a group at the Oak Ridge National Laboratory of the Atomic Energy Commission. At the conclusion of these studies, the Army recommended the construction of a prototype nuclear power plant in the United States. In late 1953 the Department of Defense approved the Army's proposal and requested the Atomic Energy Commission to initiate the necessary development program. The Corps of Engineers, representing the Army, was given the responsibility for development of the non-nuclear portion of the plant on behalf of the Department of Defense. Shortly thereafter a joint organization was established to coordinate AEC and DOD activities, the Army Nuclear Power Program.

Early in 1954 the Commission invited proposals from thirty-three major industrial firms for complete design, construction, and test operations of a prototype nuclear power plant. Eighteen proposals were received in response to this invitation, and in December 1954 the contract was awarded to ALCO Products Incorporated. The contract provided for guaranteed operation, to be established by a 700 hour performance test and a six-month operating test during which time the plant would be producing electrical power. The provision for a fixed price contract was the first such agreement in the awarding of reactor contracts.

A survey of various locations was made within the United States, and with the approval of the Atomic Energy Commission's Advisory Committee on Reactor Safeguards, a site within the U. S. Army Engineer Research and Development Laboratories area at Fort Belvoir, Virginia, was selected. Since the plant was to be located in a heavily populated area, precautions were taken in the design to insure maximum safety of operation.

The vapor container, which is shown and outlined in the simplified flow diagram on page 5, is designed to withstand the pressure developed by the vaporization of the entire volume of water in the primary and secondary systems, and to contain any airborne radioactivity or missiles released by the maximum credible accident. The container is a steel shell, 7/8 of an inch thick with 2 feet of concrete on the inside and has been thoroughly tested with helium leak detectors to assure that it is vapor tight. As a radiation shield to protect operating personnel, an additional three feet of concrete was added to the lower portion on the outside. All nuclear portions of this plant are inside the vapor container.



SM-1 Simplified Flow Diagram

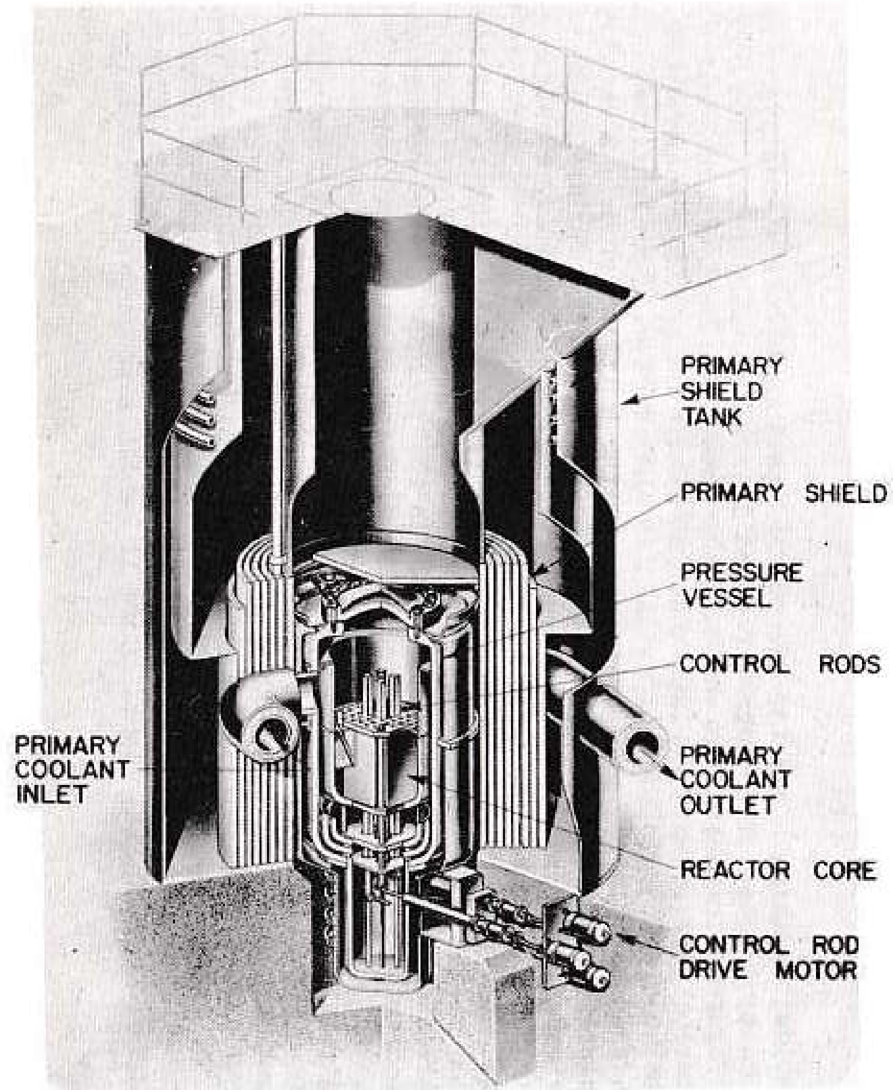
The design of the plant, conceived by the Oak Ridge National Laboratory and detailed by ALCO, was based upon a pressurized water reactor operating at a thermal power level of 10 megawatts. The net electrical power output (2,000 KW) of the plant is utilized to supplement the utility power supplied to the Fort Belvoir power distribution system.

Construction of the plant began on October 5, 1955; and the first electrical power was produced on April 15, 1957. The 700 hour performance test was completed before July 10, 1957. The Corps of Engineers assumed full responsibility for operation of the SM-1 on July 1, 1960.

The basic process in a nuclear reactor such as the SM-1, is the fissioning of U^{235}. The U^{235} captures a thermal neutron (a neutron with low energy and in equilibrium with the surrounding molecules). The neutron produces an excitation within the U^{235} nucleus causing it to split into two fragments. An average of 2.5 high energy neutrons are released per fission. The high energy neutrons are slowed down to thermal neutrons in the water and are again available for fissioning. The energy evolved when the fission fragments are slowed down produce the largest portion of the heat within the fuel elements.

The SM-1 contains a reactor core of 38 stationary fuel elements and seven movable control rods. The primary coolant enters the reactor core and cools the core by removing heat from the fuel elements. The heat absorbed raises the temperature of the primary coolant about 20°F. (average temperature 440°F, flow rate 4000 GPM.) To prevent boiling in the reactor, a pressurizer, operating at a pressure of 1200 psia, is placed in the primary system. Because of the high pressure of the primary system, the reactor core is housed in a steel pressure vessel. Surrounding the pressure vessel is the primary shield which consists of 8 alternate layers of two inches of steel and one inch of water. Surrounding the primary shield is the primary shield tank, which is filled with water to a height of 12 feet above the top of the pressure vessel. This steel and water shielding reduces the radiation in the vicinity of the reactor and allows access to vapor container equipment when the reactor is shutdown.

The initial core, Core I, was removed from the SM-1 and replaced with Core II in May of 1961. Core I was purchased for approximately $200,000 and, with slight modifications, produced 3.6 megawatt years of electricity. A fairly high burnout rate was achieved with Core I, approximately 30-40%, which means that 60-70% of the uranium fuel can be recovered for future use. This will be accomplished at the Chemical Processing Plant located at the National Reactor Test Station, Idaho Falls, Idaho. Core II, which also cost approximately



Primary Shield Tank, Pressure Vessel,
and Reactor Core

$200,000, is similar to Core I, but contains certain modifications and improvements.

The control rods used in the reactor consists of a stainless steel basket mounted on a rack. Each of the control rods are driven by an individual control rod drive mechanism. The upper half of the control rod contains an absorber element and the lower half a fuel element. Absorber elements may contain neutron absorbing elements such as boron, europium cadmium, or hafnium. In the SM-1 at present, 1 boron and 6 europium absorbers are in the core. By absorbing neutrons, the rate of the fissioning process is reduced; therefore, the process of controlling the reactor is done by positioning the control rods. When the control rod is partially lifted out of the reactor core the portion of the control rod containing the absorber elements is partially removed. This allows the fission process to begin.

Volunteer military personnel from the Army, Navy and Air Force are selected on the basis of their ability and experience for training in the Nuclear Power Plant Operation course, here at Fort Belvoir. The Nuclear Power Plant Operators Course is a one year course of instruction consisting of an Academic Phase, a Specialty Phase, and the Operations Phase.

Control Room. This is the nerve center of operation at the SM-1. From this room the reactor is controlled by manipulation of the control and safety rods. The various meters, indicators and recorders, shown in the photo, are indicating or recording various plant parameters.

The Academic Phase provides students with the necessary background in preparation for further technical instruction in the operation and maintenance of nuclear power plants. This phase of instruction is comprised of mathematics, physics, nuclear engineering, electrical engineering, mechanical engineering, health physics, and nuclear power plant information. Successful completion of all courses in the academic training is required before students continue into the specialty training.

In the second phase of instruction, the students are trained in one of four specialties: Mechanical, electrical, instrumentation, or process control. The placement of students is determined by previous experience and qualifications demonstrated during academic training.

The last course of study is devoted to the Operations Phase. During the Operations Phase each student spends approximately 500 hours at the SM-1 preparing to graduate as a Nuclear Power Plant Operator. When properly qualified, these men will operate and maintain the SM-1 and other military nuclear power plants currently under construction or already in operation at sites throughout the world.

SM-1 TECHNICAL DATA

Plant

Net output	1855 Kilowatts

Reactor Conditions

Power	10 Megawatts
Core type	Heterogeneous
Core Life (full load)	$1\frac{1}{2}$ years minimum
Fuel	Enriched uranium
Fuel cladding	Stainless steel
Moderator	Water
Reflector	Water
Coolant	Water
Coolant pressure	1200 psi
Coolant flow	4000 gpm
Coolant inlet temperature	431°F
Coolant outlet temperature	450°F
Shielding	Steel, Water, Concrete

Steam Conditions

Steam pressure	200 psia
Steam temperature	407°F
Flow	34,000 pounds/hour
Cooling water source	Gunston Cove

TO:

ADDRESS

CITY ZONE STATE

NUCLEAR POWER FIELD OFFICE

FORT BELVOIR, VIRGINIA