DOCUMENT RESUME

ED 107 522 SE 019 211

AUTHOR Lyerly, Ray L.; Mitchell, Walter, III
TITLE Nuclear Power Plants. Revised.
INSTITUTION Atomic Energy Commission, Washington, D. C. Office of Information Services.
PUB DATE 73
NOTE 62p.
AVAILABLE FROM USAEC Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830

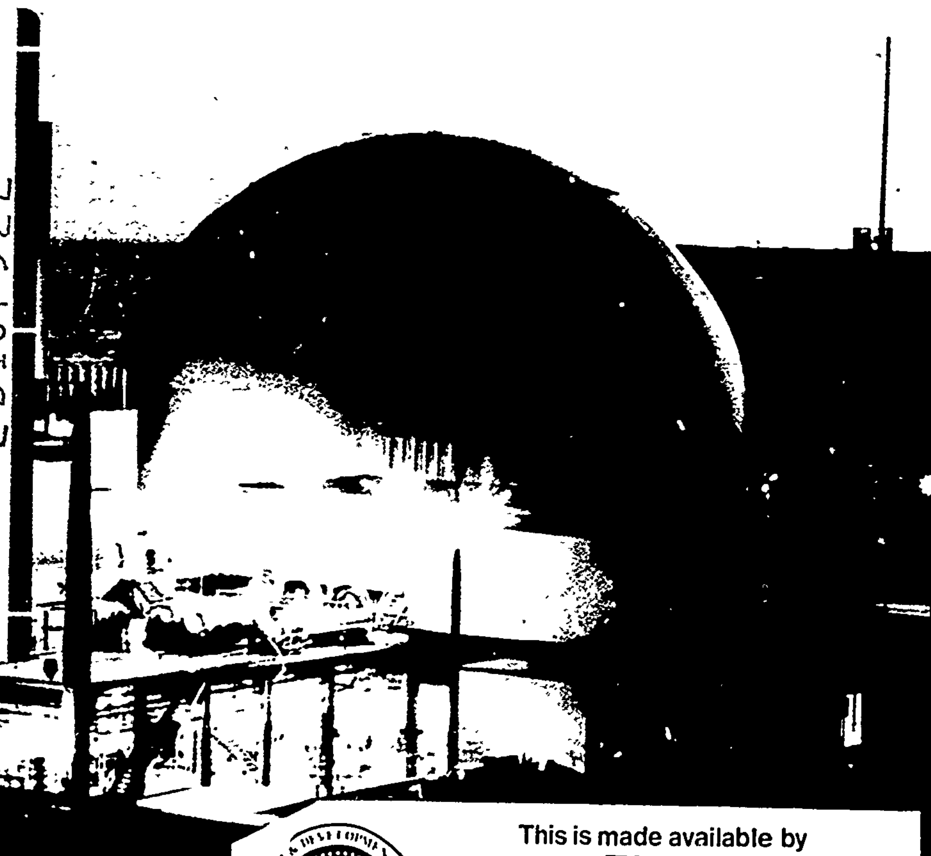
EDRS PRICE MF-$0.76 HC-$3.32 PLUS POSTAGE
DESCRIPTORS Economics; Electricity; *Energy; *Nuclear Physics; Physics; Radiation; Scientific Research; *Utilities
IDENTIFIERS AEC; Atomic Energy Commission; Nuclear Reactors; *Power Plants

ABSTRACT

This publication is one of a series of information booklets for the general public published by the United States Atomic Energy Commission. Among the topics discussed are: Why Use Nuclear Power?; From Atoms to Electricity; Reactor Types; Typical Plant Design Features; The Cost of Nuclear Power; Plants in the United States; Developments in Foreign Countries; and The Last Word. A list of suggested references, including books, reports, articles, and motion pictures, is included. School and public libraries may obtain a complete set of booklets without charge. (BT)

NUCLEAR POWER PLANTS

by Ray L. Lyerly and Walter Mitchell, III



This is made available by
ERDA
United States Energy Research
and Development Administration
Technical Information Center

Nuclear energy is playing a vital role in the life of every man, woman, and child in the United States today. In the years ahead it will affect increasingly all the peoples of the earth. It is essential that all Americans gain an understanding of this vital force if they are to discharge thoughtfully their responsibilities as citizens and if they are to realize fully the myriad benefits that nuclear energy offers them.

The United States Atomic Energy Commission provides this booklet to help you achieve such understanding.

THE COVER

The San Onofre Nuclear Generating Station near San Clemente, California, one of the new generation of nuclear power plants, with an electrical capacity of 430,000 kilowatts. It began commercial operation in 1967. (See page 40.)

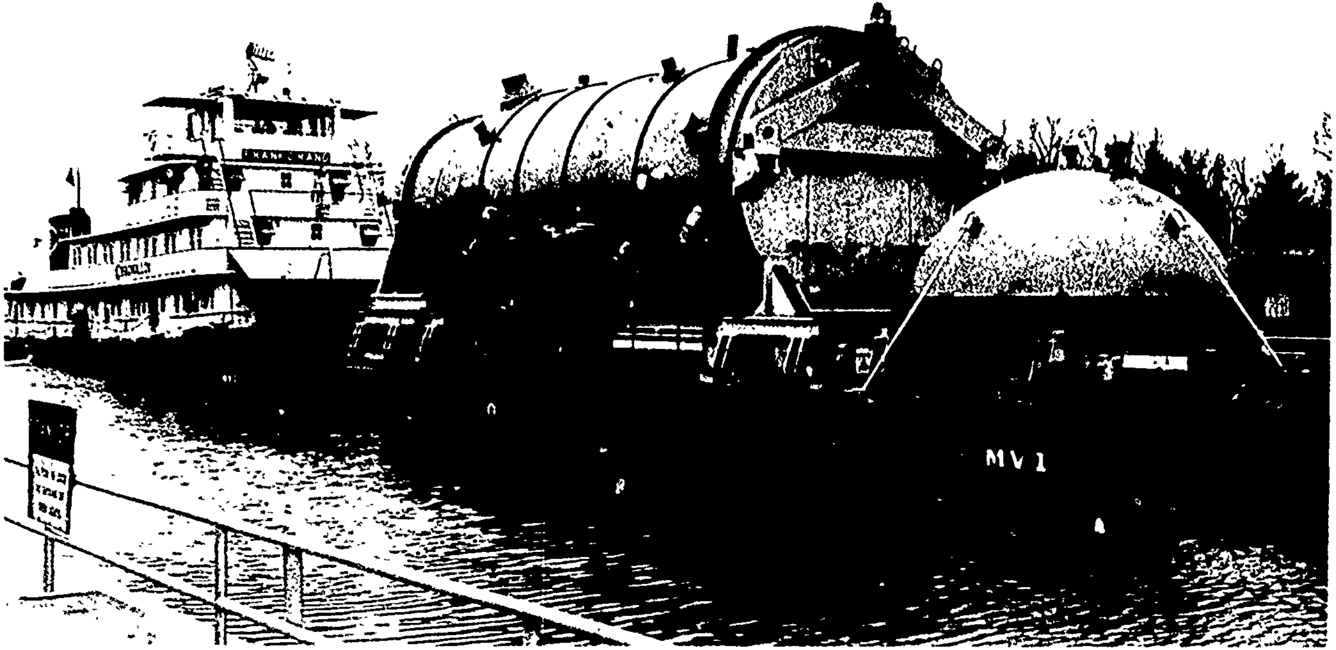
NUCLEAR POWER PLANTS

by Ray L. Lyerly and Walter Mitchell, III

CONTENTS

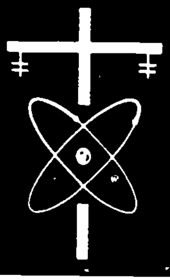
UNITED STATES ATOMIC ENERGY COMMISSION
Office of Information Services

Library of Congress Catalog Card Number: 67-60199
1967; 1973 (rev.)



The vessel and head of Unit #2 of the Dresden Nuclear Power Station is shown on its 740-mile barge trip from Mount Vernon, Indiana, where it was fabricated, to Morris, Illinois. It weighs 800 tons and is approximately 72 feet long and 22 feet in diameter. *(See Figure 18 on page 28.)*

NUCLEAR POWER PLANTS



By RAY L. LYERLY and
WALTER MITCHELL, III

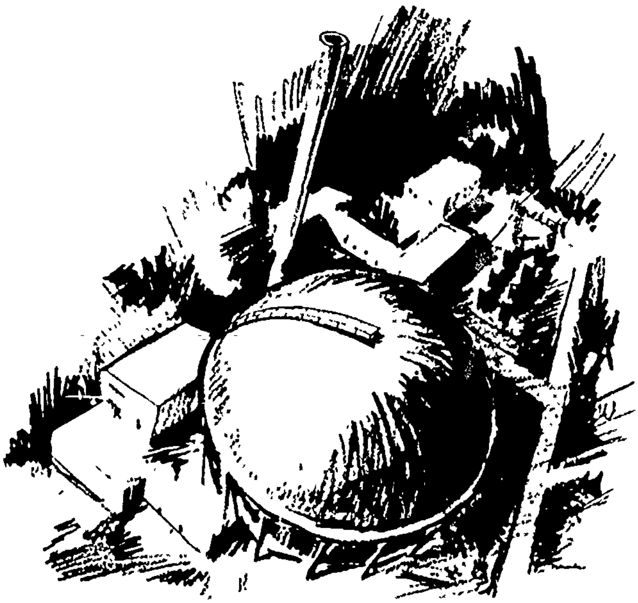
WHY USE NUCLEAR POWER?

Millions of Americans use electricity derived from atomic energy. Millions more of us will light our homes and power our appliances with electricity from nuclear plants that are now being built. And in the future we, and the other peoples of the world, undoubtedly will find that nuclear energy is the source of a large portion of our electric power.

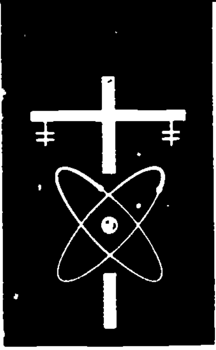
What is behind this pattern of change? Why have we entered an era in which nuclear power plants—unknown a relatively few years ago—are a commercial reality, providing guaranteed performance at attractive cost? To answer these questions we must look to the future as well as the present.

In our growing world, our energy needs are growing even faster than our population. Projected energy requirements for the future suggest strongly that we must employ atomic energy to generate electric power or face depletion of our fossil-fuel resources—coal, oil, and gas. In short, both conservation and economic considerations will require us to use nuclear energy to generate the electricity that supports our civilization.

Until we reach the time when nuclear power plants are as common as fossil-fueled or hydroelectric plants, many people will wonder how the nuclear plants work, how much they cost, where they are located, and what kinds of reactors they use. The purpose of this booklet is to answer these questions. In doing so, it will consider only central station plants, which are those that provide electric power for established utility systems.



6



FROM ATOMS TO ELECTRICITY

A nuclear power plant is similar to a conventional thermal power plant: Each type uses steam to drive a turbine generator that produces electricity. The heat energy of the steam is converted to mechanical energy in the turbine, and the generator then converts the mechanical energy into electrical energy, or electricity. Although the turbine functions equally well no matter where the steam comes from, the origin of the steam is important to us, for it is here that nuclear and conventional plants differ.

How is steam produced? Well, conventional plants burn coal, oil, or gas, and heat from the combustion of these fossil fuels boils water to make steam. In nuclear plants, on the other hand, no burning or combustion takes place. Nuclear fission is used instead. The fission reaction generates heat, and this heat is transferred, sometimes indirectly, to the water that produces the steam. Consequently, it can be said that the fission reaction in a nuclear plant serves the same purpose—the generation of heat—as the burning of a fossil fuel in a conventional plant. We will take a look at nuclear reactor systems a little later, but first we should review the fission reaction.

The fission process requires a particular kind of heavy element, such as uranium or plutonium, as a basic material. Let us consider uranium. Natural uranium is a mixture of three isotopes, atomic forms that are chemically alike but vary in mass. An atom of one of these isotopes, uranium-235, can readily undergo fission when a free neutron (an energetic subatomic particle) strikes its heavy central nucleus. The nucleus breaks into two pieces that fly apart at high speed; in addition, two or three new neutrons are released, as illustrated in Figure 1. The kinetic energy of the flying fission fragments is converted to heat when they collide with surrounding atoms, and the released neutrons cause a chain reaction by initiating new fissions in other ^{235}U atoms.

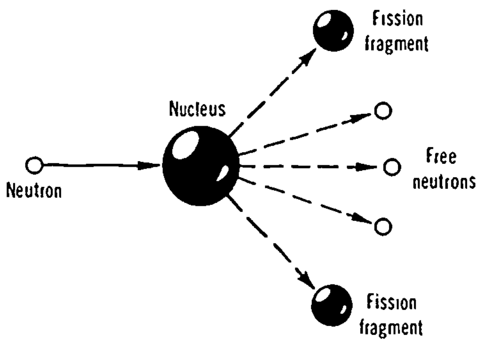


Figure 1 *A typical fission reaction.*

Sustaining the chain reaction is important because more than 30 billion fissions must occur in one second to release each watt of energy. If the chain reaction is to be useful, the fissions must occur at a desired rate, and the heat that is generated by the process must be removed. The job of the nuclear reactor, then, is to provide an environment in which fission reactions can be initiated, sustained, and controlled, and to make possible recovery of the resultant heat.*

The essential components of a reactor are:

—the fuel, which fissions to produce neutrons and to release energy;

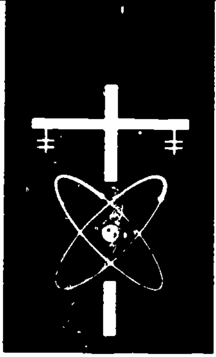
—the control elements, which are used to set the energy release rate; and

—the cooling fluid, which removes the heat generated in the reactor.

Some of the relationships between reactors and the actual production of steam are illustrated in the next section, which describes some common nuclear steam-supply systems.

---

*For more about fission and the operation of reactors, see *Our Atomic World* and *Nuclear Reactors*, other booklets in this series.



REACTOR TYPES

If you went into an appliance store and told a salesman, "I'm interested in buying a coffeepot", he would probably ask, "What kind?" Depending on your reply, you might be shown a percolator, a drip pot, or some other sort of coffee maker: Each type brews coffee, but each does it in a different way. Reactors, of course, aren't coffeepots, but reactors do have a common product—heat—and they do come in several types.

Before we consider the differences in reactors, let's take a moment to consider something that has a bearing on the development of nuclear power plants in our country. This is the fact that our nuclear fuel resources are not unlimited. It is obvious that nuclear power plants would not have much of a future if they used up the available fuel in a relatively short time.

What is not so obvious is that among the different types of nuclear reactors there are wide differences in their *net consumption* of nuclear fuel. On one end of the scale, there are reactors that have a high net fuel consumption; these are used in most of the commercial nuclear power plants operating in the United States today. Next, come reactors with a low, but positive, net fuel consumption. The ultimate reactors, insofar as fuel conservation is concerned, are those that have a *negative* net fuel consumption, which means that they produce more fuel than they use.* These are known as breeder reactors and will be popular for central station nuclear power plants that begin operation in, say, 10 or 20 years. The breeding principle has

*Actually, they produce new *fissionable material* that can be processed for use as fuel.

proved workable, and economically attractive reactors must now be developed so that breeder plants can be built.*

In the descriptions that follow, we will note the relative fuel consumption of each type. What we will see for each is actually the nuclear steam-supply system—that is, the components used to produce steam for the power-generating portion of the plant, shown in Figure 2. In this portion, steam passes through the turbine and imparts energy in the form of rotary motion to the turbine shaft. The shaft turns the generator rotor and produces electric power.

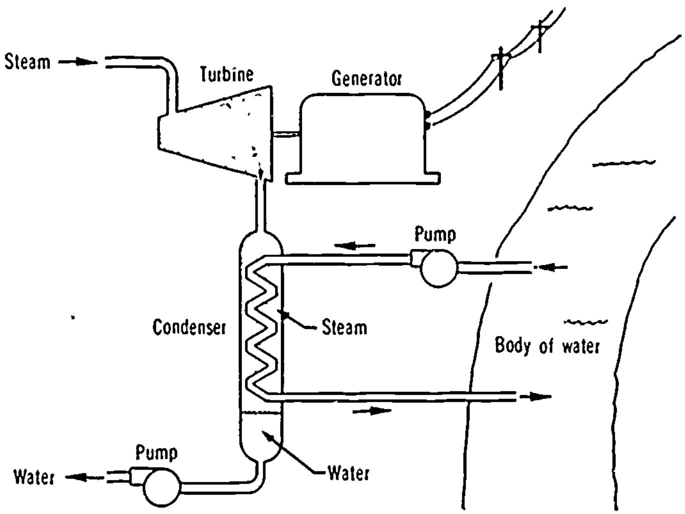


Figure 2 *The power-generating portion of a nuclear power plant.*

When the "spent" steam leaves the turbine, it enters the condenser, passes over cooling tubes, and is turned back into water. This water is pumped back to the nuclear steam-supply system, where the cycle starts all over again with conversion of the water to high-pressure, high-temperature steam. Figure 2 shows the most common method of cooling: Pumping cool water through the condenser tubes and back to the source (river, lake, or some other large body of water).

*For a more detailed discussion of fuel and its use in reactors, see *Atomic Fuel*, a companion booklet in this series.

The basic components of the power-generating portion of a nuclear power plant are the same regardless of the kind of reactor supplying the heat.

Boiling-Water Reactors

The name of this one tells the story. As shown in Figure 3, water enters the reactor and is heated as it passes up between the elements of nuclear fuel. Soon steam collects in the upper portion of the reactor and leaves through an outlet pipe. The pipes identified as "steam" and "water" would be connected to those similarly labeled in Figure 2 to form a complete power plant.

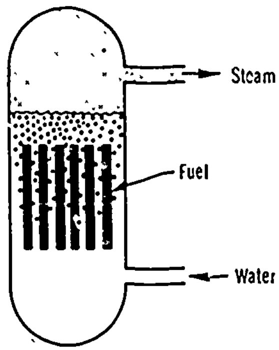


Figure 3 *Nuclear steam-supply components in a boiling-water reactor.*

The water and steam in a typical boiling-water reactor are kept at a pressure of 1000 pounds per square inch (psi); this is equivalent to the pressure at a depth of about one-half mile beneath the surface of the sea. The pressure raises the boiling point of the reactor water to a high value, so that when steam is produced, its temperature and pressure are great enough for efficient use in the turbine.

As you know, the steam from a pot of boiling water on a kitchen stove has a temperature of 212°F. Steam at that temperature has too low an energy value for use in a turbine. In order to increase the energy, the steam temperature must be raised. In a reactor, this is done by operating it at high pressure. The principle is similar to that of a pressure cooker, which cooks food faster because it gets hotter. At the typical boiling-water reactor pressure of 1000 psi, the temperature of the steam is about 545°F.

A nuclear steam-supply system based on a boiling-water reactor may appear relatively simple compared with some of the systems discussed and illustrated on the following pages. While the boiling-water system has only a few principal components, these are much larger than those in a pressurized-water system, for example. A central station nuclear power plant with an electrical output of around 800,000 kilowatts requires a boiling-water reactor vessel (the container that holds the nuclear fuel) about 70 feet high by 20 feet in diameter. A pressurized-water reactor vessel for a plant of the same capacity is only about 40 feet high by 16 feet in diameter. However, there are some additional large components in the pressurized-water system, so things come out about even on an overall component weight basis.

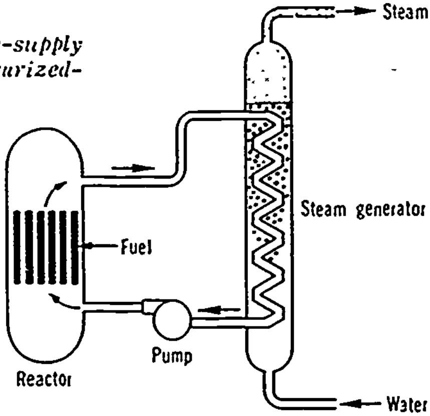
Boiling-water reactors have been built and improved over the years, and today they are sold on a commercial basis in the United States. Their net nuclear fuel consumption is high, like that of pressurized-water reactors, which we will discuss now.

Pressurized-Water Reactors

A pressurized-water reactor operates at conditions under which the water passing through the reactor does *not* boil. Pressure in the reactor and the piping loop connected to it (see Figure 4) is about 2250 psi, or more than twice that in a boiling-water reactor. This very high pressure permits the water to be heated to 600°F without boiling. The heated water goes to a steam generator that, as the name implies, makes the steam that drives the turbine.

In the steam generator, the hot reactor water passes through tubes that are surrounded by water from the turbine portion of the plant; this water is at a pressure well below that of the reactor water system. The tubes containing hot reactor water heat the surrounding water and make steam, which goes to the turbine at a temperature of about 500°F. The reactor water leaving the steam generator has been cooled by giving up some of its heat, so it is pumped through the reactor to be heated again and start another cycle.

Figure 4 *Nuclear steam-supply components in a pressurized-water reactor.*



As you can see, a nuclear steam supply that uses a pressurized-water reactor consists of two separate water systems that meet in the steam generator. The water in one system does not mix with that in the other, but heat is transferred from the reactor system to the steam system.

More information on pressurized-water reactors is given in the next section.

Gas-Cooled Reactors

The schematic diagram for a gas-cooled reactor in Figure 5 bears a strong resemblance to the diagram for a pressurized-water reactor. The principle of operation is the same for both types: A working fluid transports heat from the reactor to the steam generator, where the heat makes steam for the turbine.

In a gas-cooled reactor, the working fluid is a gas, usually helium or carbon dioxide. The gas, at a pressure of a few hundred psi, is circulated through the reactor, the piping, and the steam generator by a blower (fan). The blower is an impressive piece of machinery, by the way. The energy required to drive the blowers (there would be several) for the reactor of an 800,000-kilowatt power plant would operate 400,000 20-inch window fans like those used in homes.

The material identified in Figure 5 as "moderator" has not been discussed before. The moderator is a substance put in a reactor to slow the neutrons and increase their effectiveness in causing fissions. In water-cooled reactors it is not necessary to add solid moderator components,

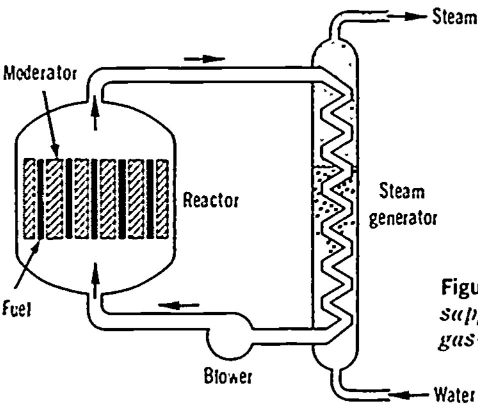


Figure 5 *Nuclear steam-supply components in a gas-cooled reactor.*

because the cooling water serves this purpose. Gas isn't a very good moderator, however, so in gas-cooled reactors a special material, usually graphite, is built in.

Graphite is a natural choice because it can withstand the very high temperatures that exist in gas-cooled reactors (in some, the gas is heated to nearly 1400°F). The high operating temperatures are put to good use. Steam as hot as about 1000°F is produced; at this temperature and at the high pressure that goes with it, the steam can drive a very efficient turbine.

In addition to its high-temperature performance, a gas-cooled reactor has the desirable characteristic of low net fuel consumption; very advanced models, in fact, may be able to produce more fuel than they consume. But, alas, all is not good. There are disadvantages, too. Principal among these is the relatively large-size reactor needed for a given rate of heat generation. Gas, unfortunately, just doesn't remove heat very well. Consequently, the rate of heat generation per unit volume of reactor must be fairly low to match the relatively poor heat-removal capability of the gas.

Heavy-Water Reactors

In most respects, heavy water (D_2O) is like ordinary water (H_2O). (In the formula D_2O, the D stands for deuterium, a heavy isotope of hydrogen.) It's really not *very* heavy (heavy water doesn't feel any heavier, if you hold a bottle of it, than ordinary water), but the presence of deuterium instead of ordinary hydrogen in a reactor has pronounced and desirable nuclear effects. There are also some pretty strong effects on economics, since D_2O costs around $28.50 per pound.

Heavy water is usually used in tube type reactors, in which the nuclear fuel is positioned inside process tubes that penetrate a tank. The tank contains the heavy water, which surrounds the fuel-containing tubes and acts as a moderator, much as graphite does in gas-cooled reactors. The fuel is in a form that does not occupy all the space in the process tubes, so there is room for a cooling fluid to flow along the fuel elements and remove the heat that is generated. Figure 6 shows the general arrangement of a heavy-water reactor.

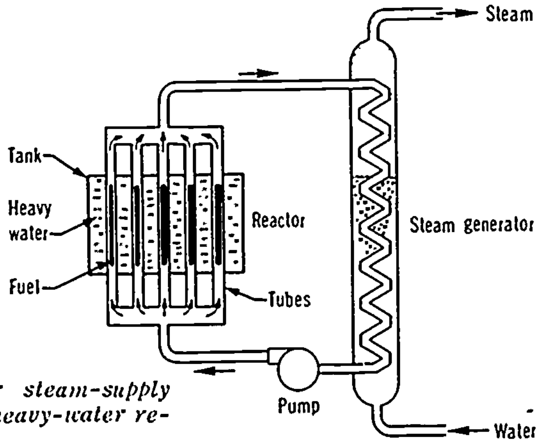


Figure 6 *Nuclear steam-supply components in a heavy-water reactor.*

Any of several cooling fluids—organic compounds, gas, water, or heavy water—can be used in heavy-water reactors, since the heavy-water moderator is separated from the cooling fluid by the walls of the process tubes.

Temperatures in heavy-water reactors depend upon the kind of cooling fluid used, among other things, but steam hotter than 700° F can be produced.

In terms of nuclear fuel utilization, the heavy-water reactor is an interim type: Its net fuel consumption is quite low and it can operate on natural uranium, which makes it attractive to use in some countries during the period in which designs for economical breeder reactors are being developed.

Breeder Reactors

Several reactors have a potential for breeding—that is, for producing more nuclear fuel than they consume—because of the materials, or combinations of materials, that are used to build them.

How does a breeder work? As you recall, a uranium-235 atom can fission when its nucleus absorbs a neutron. The fission reaction releases free neutrons (see Figure 1) that may, in turn, initiate other fissions. All the neutrons released, however, are not absorbed by fissionable material; some are absorbed in the structural material of the reactor, the control elements, or the coolant; some escape from the reactor and are absorbed by shielding; and some are absorbed by *fertile material*. When the nucleus of an atom of fertile material absorbs a neutron, the fertile atom can be transformed into an atom of a *fissionable material*—the substance that forms the basis for the nuclear chain reaction. By careful selection and arrangement of materials in the reactor—including, of course, fissionable and fertile isotopes—the neutrons not needed to sustain the fission chain reaction can fairly effectively convert fertile material into fissionable material. The breeder reactor improves the efficiency of the neutron process both by increasing the number of free neutrons released in fission and by decreasing the number of neutrons wasted, thereby making a larger number available for absorption in fertile material. If, for each atom of fissionable material that is consumed, more than one atom of fertile material becomes fissionable material, the reactor is said to be breeding. One fertile material is uranium-238, which is always found in nature with fissionable uranium-235. When uranium-238 absorbs neutrons it is converted to fissionable plutonium-239. Another fertile material is thorium-232, which can be converted to fissionable uranium-233.

Some of the reactors that are *possible* breeders may not prove capable of breeding in actual practice, but one type has already operated successfully in several plants. This is the liquid-metal-cooled breeder reactor shown in Figure 7.

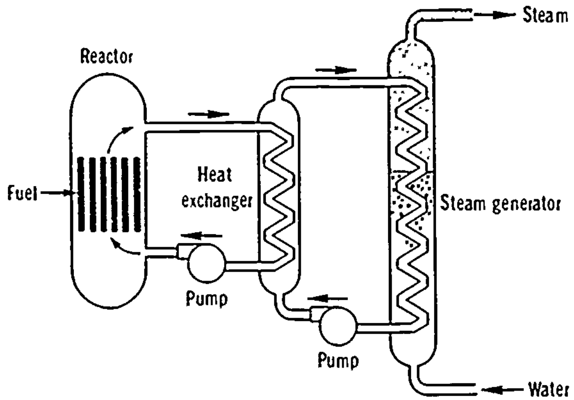


Figure 7 *Nuclear steam-supply components in a liquid-metal-cooled breeder reactor.*

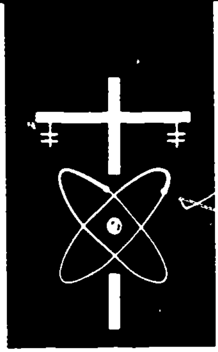
Systems and components for the breeder differ from those for other types of reactors. One item we haven't seen in the diagrams for other reactors is an intermediate heat-transfer loop between the reactor coolant system and the turbine water-steam system. Both the primary reactor coolant system and the intermediate loop use liquid metal because it has excellent heat-transfer and nuclear characteristics; the metal is usually sodium. Incidentally, the idea of a liquid metal should not be startling, for mercury, a substance familiar to everyone, is a liquid metal.

The liquid metal in the reactor is heated to about 1000° F, and then goes to the heat exchanger, where it transfers its heat to the liquid metal of the intermediate loop. The metal in the intermediate loop moves to the steam generator, where it heats water to produce steam at about 900° F.

Like other coolants, liquid metal has some desirable and some undesirable features. It is good because it does an excellent job of neutron conservation and of removing heat and does not have to be used at high pressure to attain high temperatures. The fuel in a liquid-metal-cooled breeder reactor can be operated at very high-power densities because the heat can be removed rather handily. To put it another way, the heat for a power plant of a given capacity can be supplied by a liquid-metal-cooled breeder reactor that is much smaller than any other reactor that could do the job.

One of the undesirable features about liquid metal is its tendency to react chemically. For example, there is a strong reaction whenever liquid metal comes in contact with water or steam, and if a leak occurs in a steam generator that contains liquid metal an intense reaction results. To isolate the reactor from any possible difficulty, liquid-metal-cooled reactors are provided with the intermediate heat-transfer loop. This extra loop, of course, adds to the cost of the plant.

We have now taken a quick tour through the common reactor systems and have noted a few characteristics of each. In the next section, we will explore one kind of nuclear power plant in detail.



TYPICAL PLANT DESIGN FEATURES

If you want to know more about the sizes, shapes, features, and relationships of components in a nuclear power plant, then this section is for you.

We will look closely at a plant typical of some being bought and built by utility companies today. The choice of a reactor for our "typical" plant is an arbitrary one: It uses a pressurized-water reactor, but other reactor types, equally successful, might have been chosen, as they have by many utilities. Our plant will produce about 800,000 kilowatts of electric power and will have taken around 4 years to construct.

A flow diagram for our installation is shown in Figure 8; this diagram is basically a combination of Figures 2 and 4. Although only one reactor coolant loop is shown for simplicity, numbers indicate where two other parallel loops begin and end. A reactor of this size requires more than one primary loop principally because of limitations in the capacities of pumps and steam generators.

The parallel steam pipes from the three steam generators are joined into a single, larger pipe that is connected to the high-pressure turbine. The steam flows into the turbine and gives up some of its energy to turn a shaft; it cools, drops in pressure, and forms some moisture. Leaving the high-pressure turbine, the steam passes through a moisture separator and enters the low-pressure turbine. Here the steam pressure drops still more, imparting additional energy to the shaft. The shaft turns the generator, which produces the electric power.

The steam—its usable energy by now pretty well exhausted—moves on to the condenser, where cooling pipes

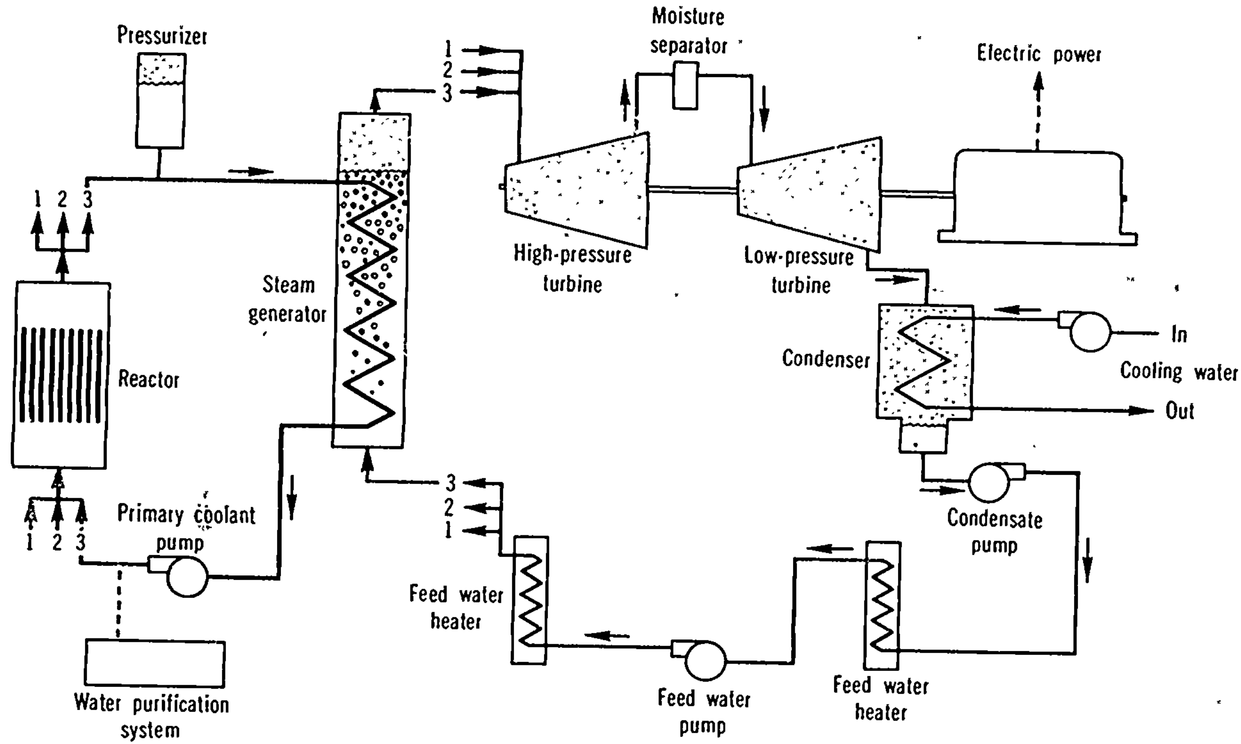


Figure 8 *A complete nuclear power plant based on a pressurized-water reactor.*

turn it into water. In the process, the pressure is lowered to less than atmospheric pressure. The water (called condensate) formed in the condenser, is pumped through a heater and partially preheated. By this time, the water is called feed water because it is used to "feed" the steam generators; before entering the steam generators, however, it is pumped through another heater. The preheating improves the efficiency of the plant. Several heaters usually are used, but, for simplicity, only two are shown here.

To pump the water from the condenser through the heaters and into the steam generators, its pressure must be raised from less than 14.7 psi (atmospheric pressure at sea level) to about 800 psi. More than one pump is needed for this, and two are shown here. The pipe leaving the last feed-water heater branches into parallel pipes so that feed water is supplied to the steam generator in each parallel reactor loop.

Thus, we can make a general statement that the parallel loops of the nuclear steam-supply system furnish steam to a single-loop, power-generating system, although there are exceptions to this design in industry.

Considering the primary, or reactor, coolant system again, note that each loop has its own pipes from the reactor, but that usually only one pressurizer and one water purification system are provided. The pressurizer, as its name indicates, keeps the reactor system at the proper pressure. The purification system continuously removes impurities from the water.

Keep the flow paths in Figure 8 in mind as we turn now to some individual components of a nuclear power plant.

The Reactor Vessel

The reactor is the furnace of the plant—the concentrated source of the tremendous amount of heat that is converted to electric power. Figure 9 shows a vertical cross-section through a reactor pressure vessel and the arrangement of basic reactor components. The steel vessel, its walls around a foot thick, is designed to contain water at an operating pressure of 2250 psi, with inlet and outlet temperatures of about 550° F and 600° F, respectively.

The vessel weighs about 1 million pounds empty, and more than half again as much when full of water and with the core installed.

The vessel, about 40 feet high with an outside diameter of 16 feet. has the function of enclosing the reactor core,

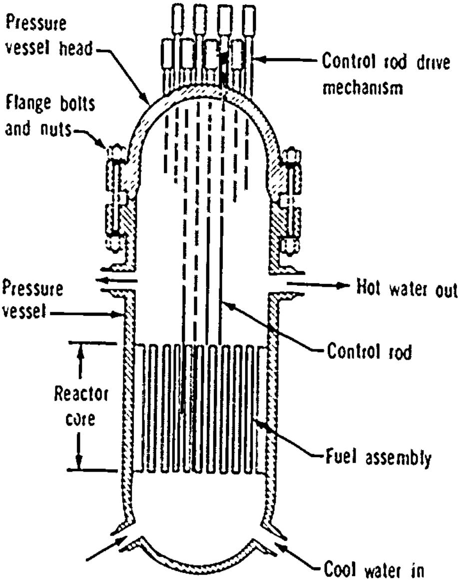


Figure 9 *Vertical cross section view of a pressurized-water reactor vessel.*

which is composed of fuel elements and control rods. The cool-water connections of some vessels are at the same level as the hot-water connections; this arrangement is a design variation on the typical vessel shown here. Internal baffles direct the cool water to the bottom of the vessel so that it can then flow up through the reactor core.

When the reactor is not operating, the top, or head, may be removed for access to the core. Figure 9 shows how the head is bolted to the main part of the vessel, and Figure 10 shows a head being installed. The photograph shows the holes for the bolts, the drive shafts for the control rods, and, at the top of the vessel head, the control-rod drive mechanisms.

The Core

The heart of our nuclear power plant is the nuclear fuel—a ceramic material called uranium dioxide (UO_2).

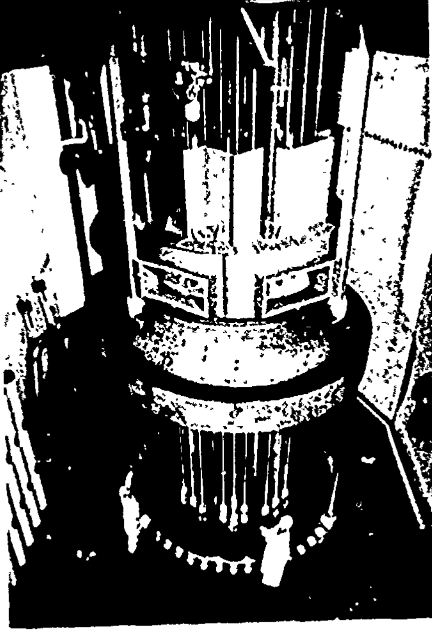


Figure 10 *Reactor vessel head being installed at a nuclear power plant.*

The UO_2 is enclosed in sealed tubes a little less than a half inch in diameter and about 12 feet long. These tubes are made of Zircaloy, which is an alloy of the metal zirconium. About 200 of these tubes are arranged in a square pattern to form a fuel assembly (see Figure 11). The tubes in each assembly are close together but do not touch. They are held apart by egg-crate-like spacer grids so that the cooling water can flow along them and remove their heat.

Each fuel assembly in our reactor example is 8 inches square by 12 feet long and weighs 1300 pounds (UO_2 is almost as heavy as lead). Our reactor core contains about 200 fuel assemblies, and there are passages for control rods in the assemblies. The core is nearly 12 feet across, and the square assemblies are arranged so that from the top the core looks circular.

The heat-generation rate of the core is determined by movable control rod assemblies, which can be moved up or down so that they leave or enter the region of the nuclear fuel. The rods contain material that acts as a brake on the chain reaction; that is, when a rod is in the core it absorbs neutrons and prevents them from causing fissions. By moving the rod assemblies—there may be as many as 90 of them—in or out of the core, the heat-generation rate

Figure 11 *A fuel assembly for a nuclear power plant.*

Figure 12 *Lowering a fuel assembly into a reactor core.*

can be decreased or increased so that the plant produces the desired amount of electric power.

The Primary Coolant System

The primary coolant system consists of stainless steel piping and other components that contain the cooling water. Remember that large reactors use several primary coolant loops that operate in parallel. A lot of water flows through the reactor — around 2 million pounds (330,000 gallons) per minute — equivalent to the flow from over 100,000 garden hoses. (Reactor temperature and pressure cause the water to weigh approximately 6 pounds per gallon.) Each loop carries a portion of the total flow, and each has a steam generator and a pump. Some reactors have two pipes and two pumps between the outlet of each steam generator and the inlet to the reactor vessel.

The steam generators are 10 or 15 feet in diameter, about 60 feet high, and weigh roughly half a million pounds. Water flowing through tubes inside heats the surrounding feed water, producing steam with a pressure of 800 psi and a temperature of 520°F. The steam generators deliver around 10 million pounds ($5\frac{1}{2}$ million cubic feet) of steam per hour to the turbine.

A primary coolant pump, driven by an electric motor rated at several thousand horsepower, raises the coolant pressure about 100 psi for another trip through the reactor. piping, and steam generator.

In an actual installation, the primary coolant loops are arranged around the reactor as in Figure 13, which shows the "nuclear" pieces in a nuclear power plant. The rest of the installation is identical with any other generating station and we needn't discuss its details.

The Overall Plant

Our plant's central control room, with appropriate instruments, switches, indicators, and controllers for the nuclear steam-supply system and the power-generating system, looks about like the control room in any large industrial plant, except for some instruments that indicate or record conditions in the reactor. This reactor instrumentation replaces the boiler instrumentation of a conventional power plant. Control-room personnel who operate the plant are highly qualified, having received extensive training and having passed comprehensive examinations to obtain the required licenses.

When you see an exterior view of a nuclear plant, you may wonder which pieces go in which building. Figure 15 shows the location of components in a pressurized-water plant, with "nuclear" components inside a leaktight steel or concrete containment building (the vertical cylinder with a dome top in the figure). A containment building actually can have any one of several different shapes, and in some plants no containment feature may be visible at all. In the newer plants that use boiling-water reactors, for example, containment is provided, but it doesn't show.

The power-generating components are housed in a typical industrial structure called a turbine building. One more conventional structure is the plant "ventilation stack". In

Figure 13 *Cutaway view of a nuclear steam-supply system based on a pressurized-water reactor. Note size of man entering door at right.*

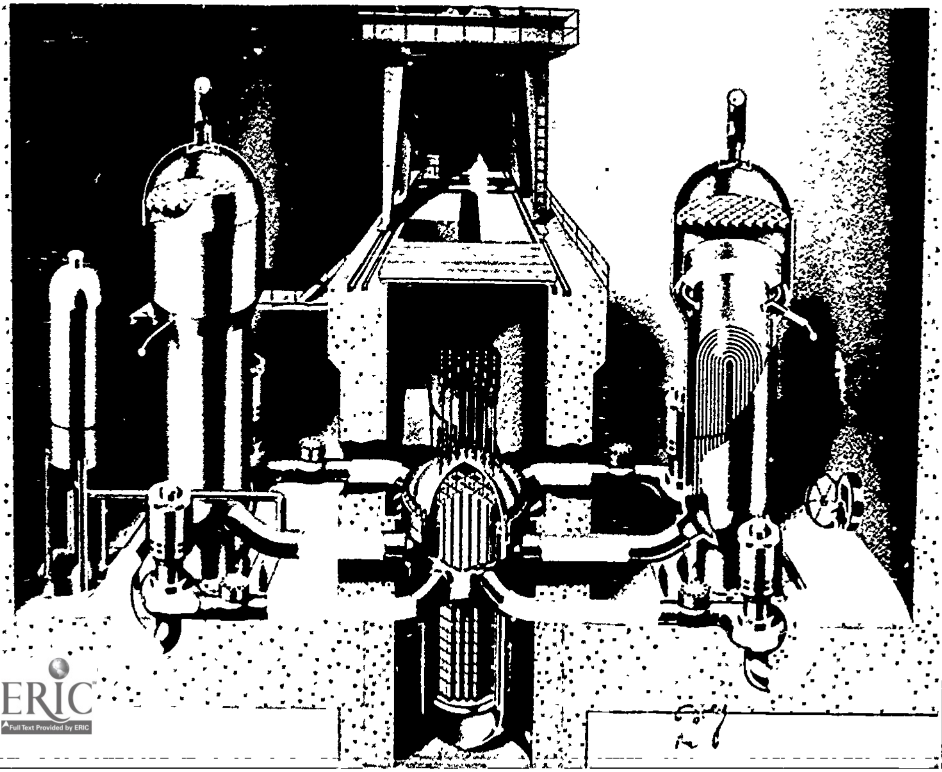


Figure 14

a conventional plant, the stack discharges the products of combustion from the boiler—it is a "smokestack". In a nuclear plant, on the other hand, the stack discharges ventilating air, which sometimes contains extremely small amounts of highly diluted, filtered gaseous wastes, strictly controlled to rigid standards.*

One final word about our typical plant: It is a very large industrial installation and is owned by a company whose purpose is "to generate electric power reliably and economically for its customers."

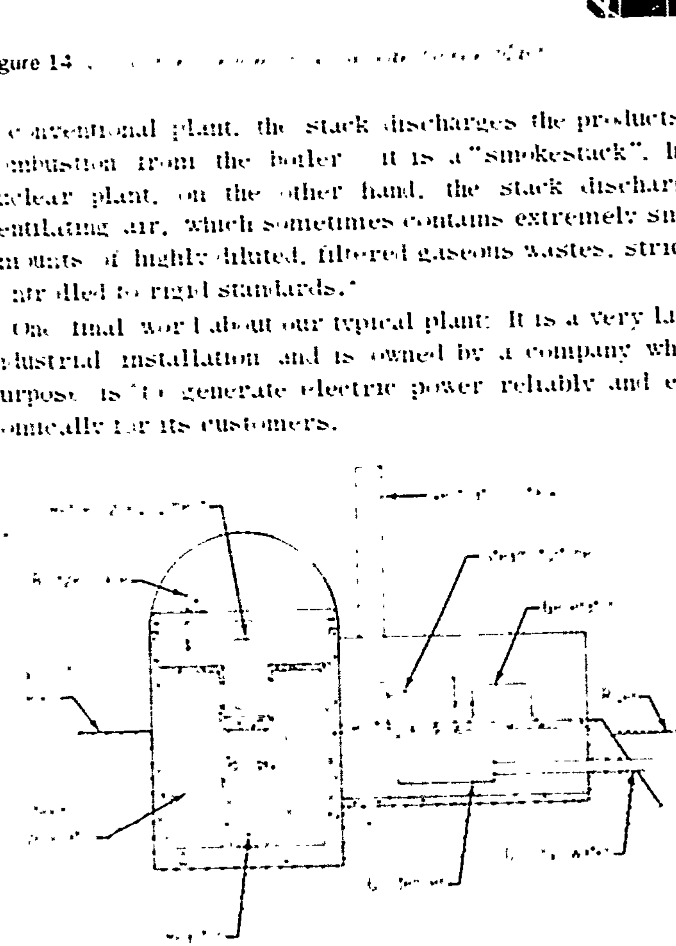


Figure 15

THE COST OF NUCLEAR POWER

Beginning about 1965, nuclear power plants became economically competitive with conventional steam power plants in many sections of the United States and the rest of the world.

A utility company spends money on two principal items in order to generate electricity for its customers. The first is the power plant itself, and the second is the fuel that the plant consumes. At present, it costs more to build a nuclear plant than it does to build a conventional plant. This, however, is only half the story because the fuel costs for the nuclear plant are lower. Consequently, in locations where fossil-fuel costs are fairly high (generally areas some distance from coal mines or gas and oil fields), a utility may save money by "going nuclear" when it expands. Companies buying nuclear power plants today can expect their investment to be divided as shown in Figure 16.

The competitive position that nuclear power holds today has been attained in a remarkably short time. Only ten years ago, it was very expensive to obtain usable electric power from atomic energy. The rapid change in the economic position of this important energy resource is a result of the combined efforts of government and industry. In order to speed the development of nuclear technology, and thus assure that the energy resources of our country can be used to meet our power requirements, the U. S. Atomic Energy Commission (AEC) for many years has sponsored research work and supported projects aimed at demonstrating the performance and costs of different types of nuclear power plants.

Probably the most significant program began in 1955, when the AEC announced the Power Reactor Demonstration Program, under which it invited utilities and the manufacturing industry to participate in nuclear power plant

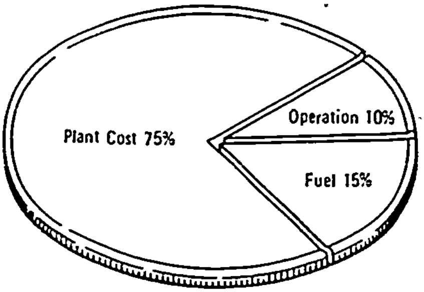
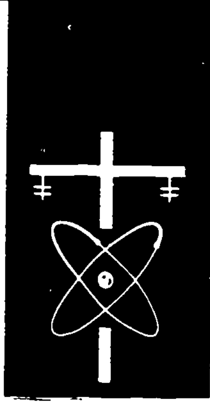


Figure 16 *Where the money goes in a nuclear power plant.*

demonstration projects. The terms of the program differ from project to project but are based on a sharing of costs by the AEC and the participating organizations. As a result of the program, more than 15 projects have been undertaken. The experience gained in designing, constructing and operating plants under the Power Reactor Demonstration Program has played an important part in the development of today's commercial nuclear power plants.

Many factors affect the cost of a nuclear power plant and the electric power it produces. For example, the size of the plant has an influence on the cost per unit of electricity: the larger the plant, the cheaper the power. Wages and materials costs differ substantially from region to region, as do taxes, the prices of land, and other items. An important factor is the length of time required to build the plant, for during the construction period costs *escalate*. Let's talk about escalation for a moment, assuming that the year is 1973. The typical nuclear plant described in the preceding section would cost about $400 per kilowatt of capacity to build, *if* the owner paid cash for the plant and it were possible to erect it overnight. That isn't the way things go, however, for utilities finance their plants and around eight years elapse between the time a nuclear plant is ordered and the time it goes into operation. The time is required for obtaining necessary permits and licenses, for actual construction, and for pre-operational testing. During those eight years, wages of workers increase, prices of equipment go up, and the utility pays interest on the money it has borrowed to build the plant. The effect of these factors is an increase in cost, which is called escalation.

Significant escalation occurs with all long-term projects such as conventional power plants, chemical plants, or similar industrial installations. In our example, the nuclear plant ordered in 1973 will go into operation around 1981 and will have cost $500 per kilowatt to build; the total power-generating cost in the 1980's will be slightly less than two cents per kilowatt-hour. Plants now in operation were built in less expensive times and produce cheaper power; the costs are roughly half those given above for future plants.



PLANTS IN THE UNITED STATES

The first full-scale nuclear power plant in the United States began operating in December 1957, at Shippingport, Pennsylvania. Since then, numerous other nuclear plants have joined in providing electric power from the peaceful atom. This section is devoted to descriptions of some of these plants.

Note that the plants shown in the photographs use different kinds of reactors and that their power outputs differ by substantial amounts. This is because some of the plants were built as demonstration units to determine relative advantages of one reactor type compared with another, and were built to the size requirements of a particular power company or system.

The extent of the nuclear power program is indicated by the fact that plants are located or planned for construction in the following states: Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, Tennessee, Vermont, Virginia, and Wisconsin. In addition, U. S. manufacturers have sold reactor plants in several foreign countries.

A rather special kind of nuclear power plant, the Hanford "N" Reactor (sometimes called the New Production Reactor), is at Hanford, Washington, about 150 miles southeast of Seattle. The reactor is owned and operated by the AEC and produces special nuclear material for government stockpile purposes; its original design, however, provided for the recovery of the waste heat. The Washington Public Power Supply System later received approval to build a nearby steam power plant in which the hot water from the reactor is used to generate steam. The plant has a generating capacity of 790,000 kilowatts of electric power, equivalent to that of two Bonneville Dams. This plant began serving the Pacific Northwest in April 1966.

Figure 17 *SHIPPINGPORT Atomic Power Station. Located at Shippingport, Pennsylvania, about 25 miles northwest of Pittsburgh. Pressurized-water reactor, 90,000-net-electrical-kilowatt capacity, designed by Bettis Atomic Power Laboratory of Westinghouse Electric Corporation. Started commercial operation in 1957, began operation at present power in 1965. Jointly owned by AEC and Duquesne Light Company. Operated by Duquesne Light Company. Shippingport was the first large nuclear power electric generating plant in the U. S. The reactor is in the large building in the center.*

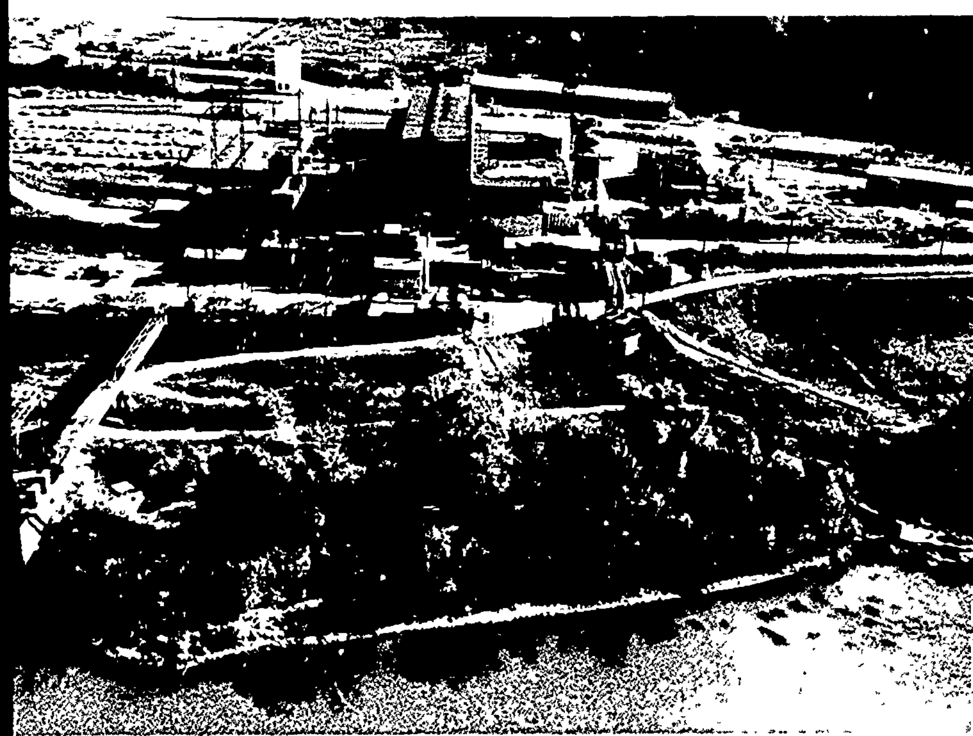


Figure 18 *DRESDEN Nuclear Power Station, Unit #1. Located at Morris, Illinois, about 50 miles southwest of Chicago. Boiling-water reactor, 200,000-net-electrical-kilowatt capacity, designed by General Electric Company. Started commercial operation in 1960. Owned and operated by Commonwealth Edison Company. Dresden Unit #1 was the second large nuclear power plant to be built in the U. S. Dresden Unit #2 and Unit #3 adjoin Unit #1. (See frontispiece.)*

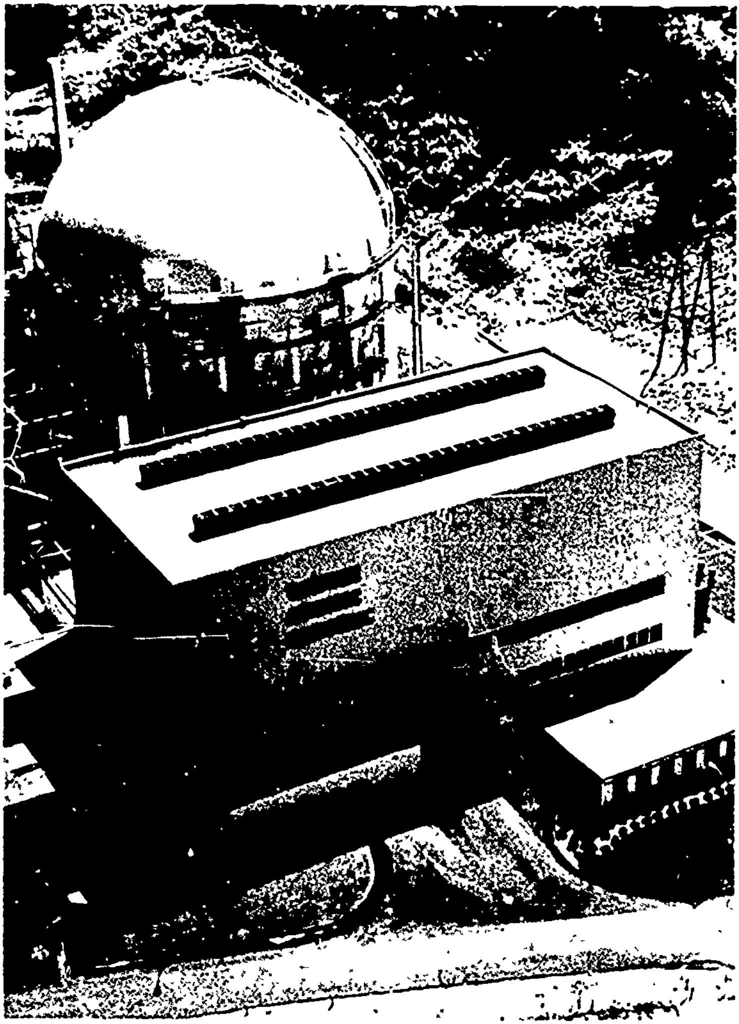
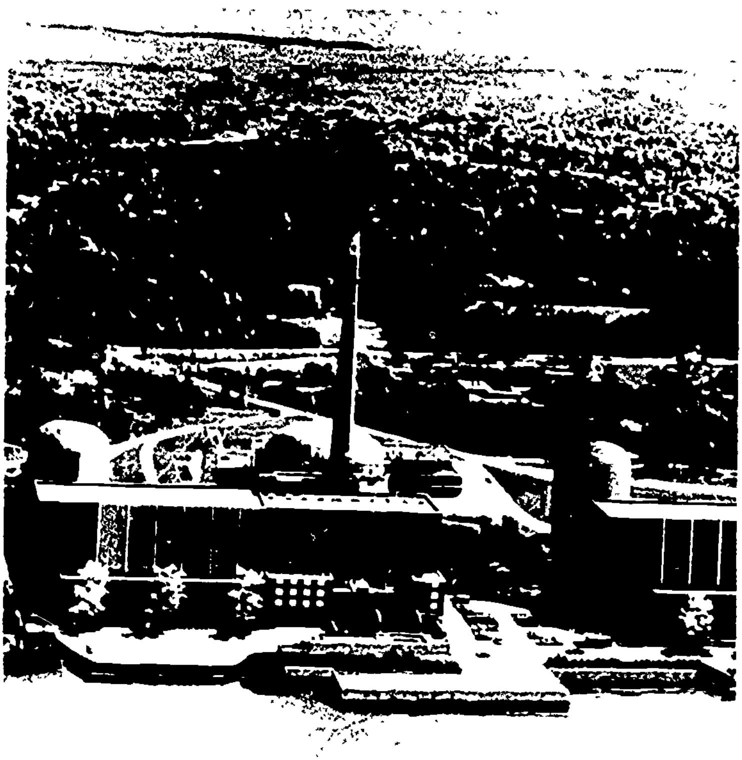


Figure 19 *YANKEE Nuclear Power Station. Located at Rowe, Massachusetts, about 45 miles east of Albany, New York. Pressurized-water reactor, 175,000-net-electrical-kilowatt capacity, designed by Westinghouse Electric Corporation. Started commercial operation in 1961. Owned and operated by Yankee Atomic Electric Company. Yankee was the third large nuclear power plant to be built in the U. S.*

Figure 20 *INDIAN POINT Station of Consolidated Edison Company of New York. Located on the Hudson River, about 35 miles north of New York City. The first unit of the station, located in front of the stack in the illustration, has a capacity of 265,000 kilowatts and was the fourth large nuclear power plant to be built in the United States. It uses a pressurized-water reactor, as do the other two units of the complex. Total projected capacity, with all three units operating, is more than two million kilowatts.*



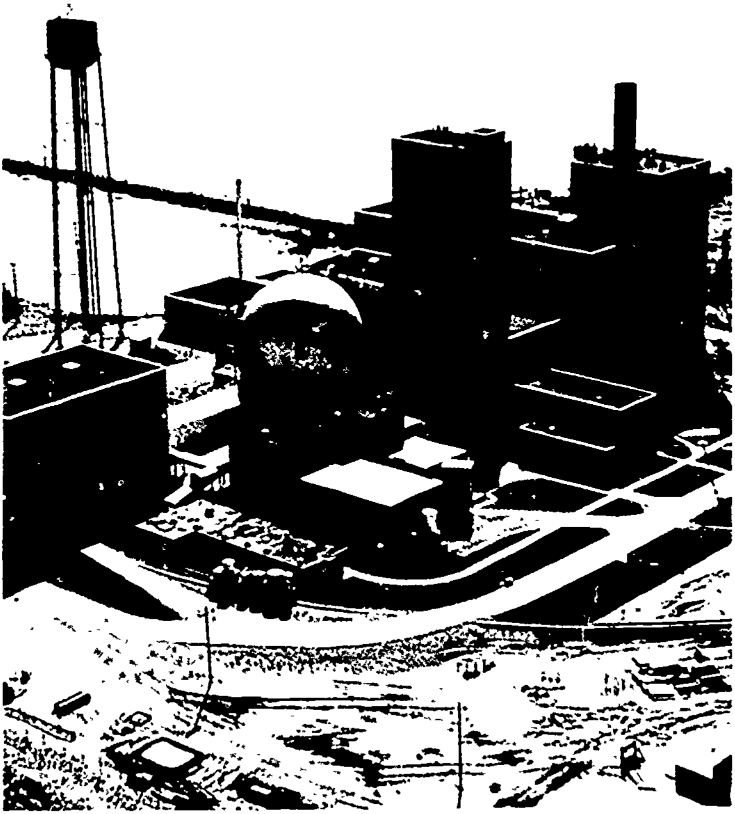
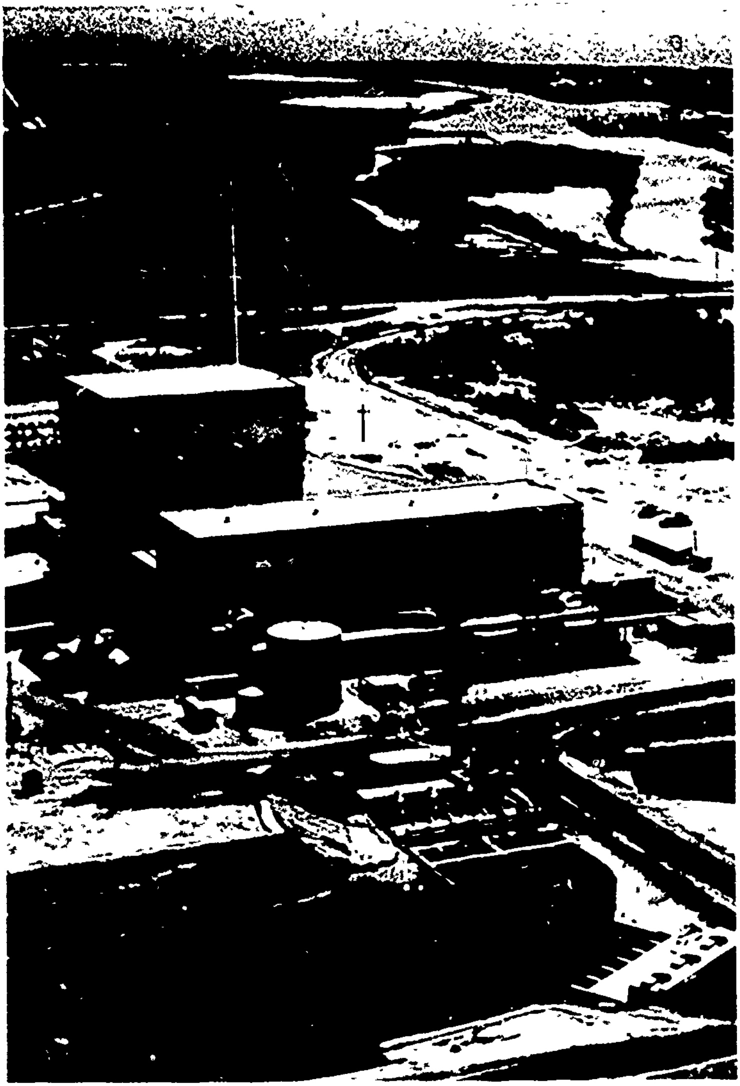


Figure 21 *ENRICO FERMI Atomic Power Plant. Located at Lagoona Beach on Lake Erie, near Monroe, Michigan, about 35 miles southwest of Detroit. Breeder reactor, cooled with liquid sodium, 60,900-net-electrical-kilowatt capacity, designed by Atomic Power Development Associates, Inc. Started power operation in 1965. Jointly owned and operated by Detroit Edison Company and Power Reactor Development Company. Enrico Fermi was the world's first large breeder nuclear power plant.*

Figure 22 *OYSTER CREEK Nuclear Power Plant, Unit #1. This 515,000-kilowatt plant of Jersey Central Power & Light Company is at Toms River, New Jersey. Boiling-water reactor, designed by the General Electric Company. Some of the canals and equipment which provide cooling water for the condenser can be seen in the photograph.*



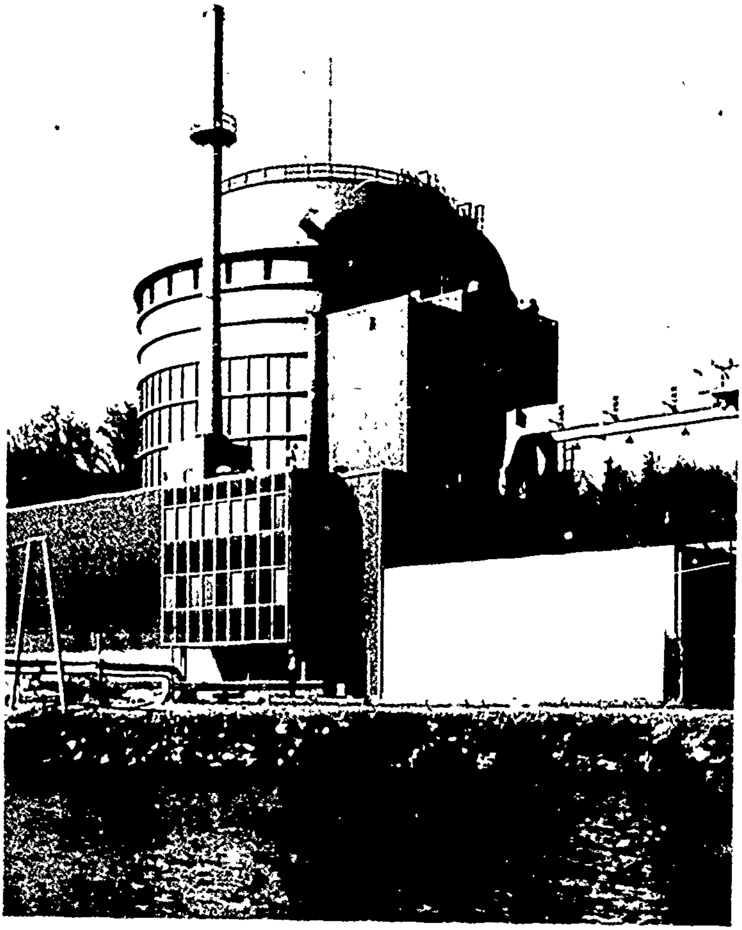
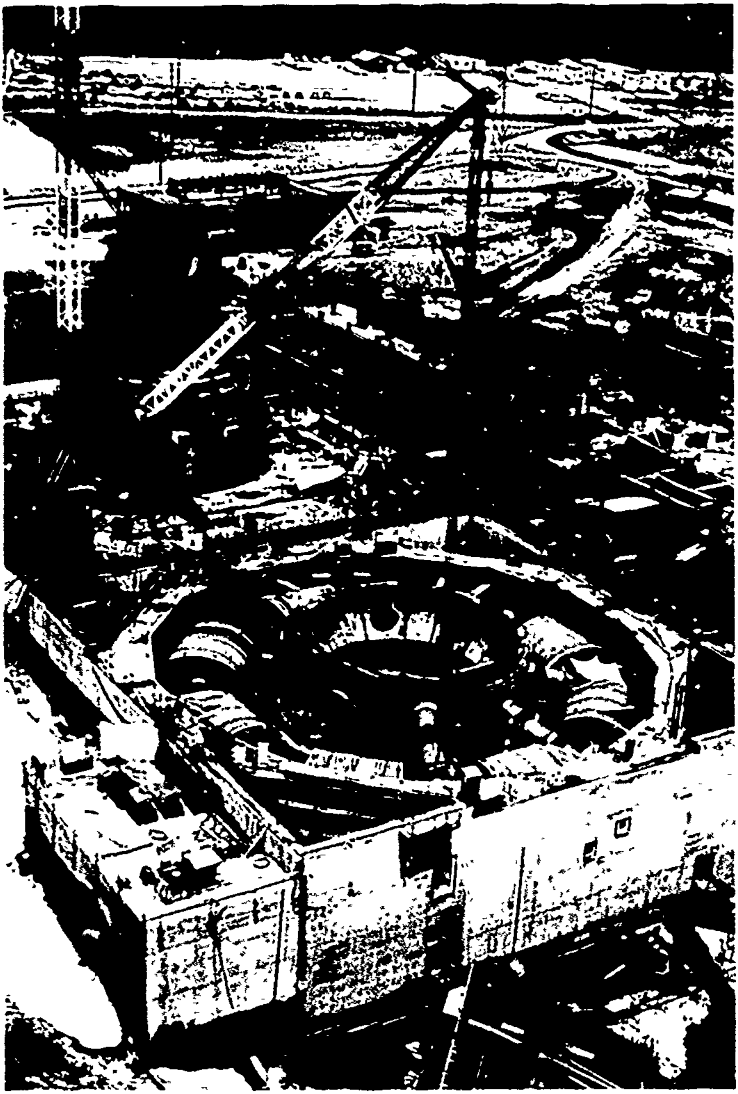


Figure 23 *PEACH BOTTOM Atomic Power Station Unit #1. Located on the Susquehanna River near Peach Bottom, Pennsylvania, about 65 miles southwest of Philadelphia. Helium-cooled reactor, 40,000-net-electrical-kilowatt capacity, designed by Gulf General Atomic. Started commercial operation in 1967. Operated by Philadelphia Electric Company, Peach Bottom is a demonstration reactor featuring high temperatures and a gaseous coolant. Units #2 and #3 are located at the same site.*

Figure 24 *BROWNS FERRY Nuclear Power Plant under construction. This view shows two of the three boiling-water reactors. Total generating capacity, all units operating, over three million kilowatts. Located about 10 miles northwest of Decatur, Alabama, the Browns Ferry station is part of the Tennessee Valley Authority system.*



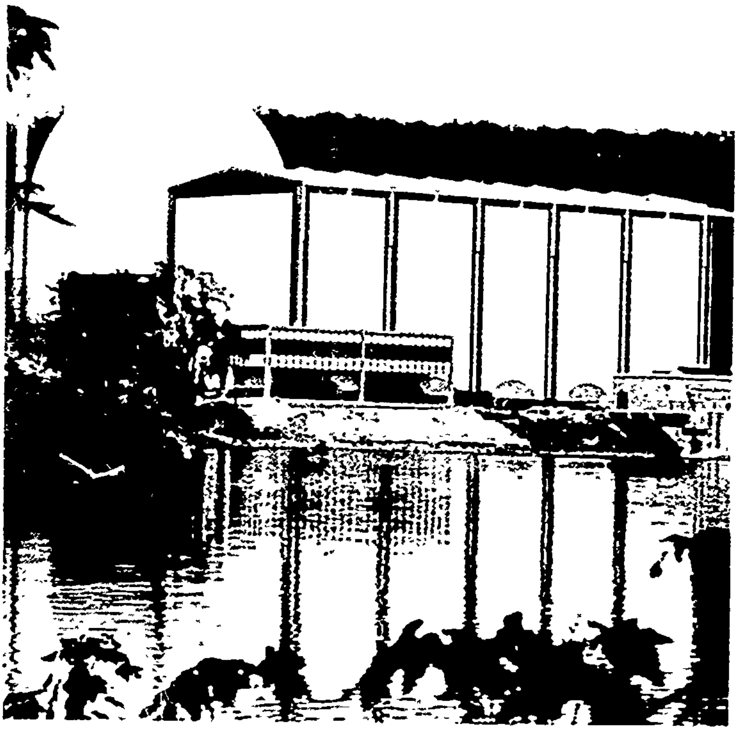
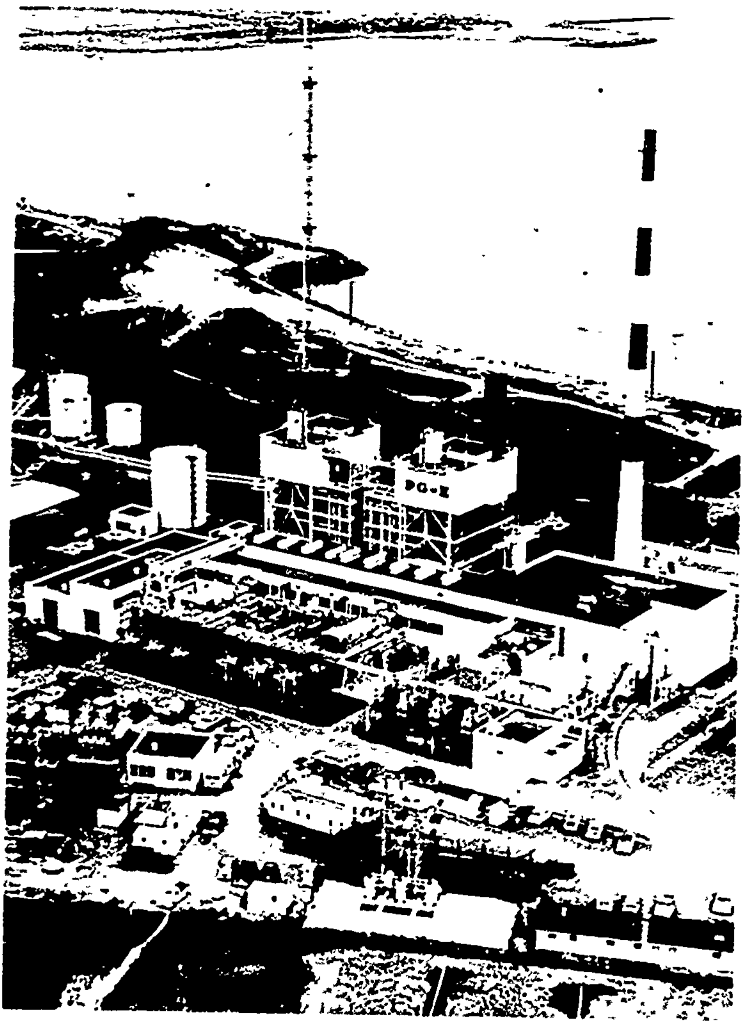


Figure 25 *CONNECTICUT YANKEE Atomic Power Plant. Located at Haddam Neck on the east bank of the Connecticut River, about 20 miles southeast of Hartford. Pressurized-water reactor, 462,000-kilowatt capacity, designed by Westinghouse Electric Corporation. Operation of the plant, owned by Connecticut Yankee Atomic Power Company, began in 1967.*

Figure 26 *HUMBOLDT BAY Power Plant. Located on Humboldt Bay near Eureka, California, about 200 miles north of San Francisco. Boiling-water reactor, 68,500-net-electrical-kilowatt capacity, designed by General Electric Company. Started commercial operation in 1963. Owned and operated by Pacific Gas and Electric Company. The picture shows the reactor building on the right; to the left are two oil-fired generating units.*



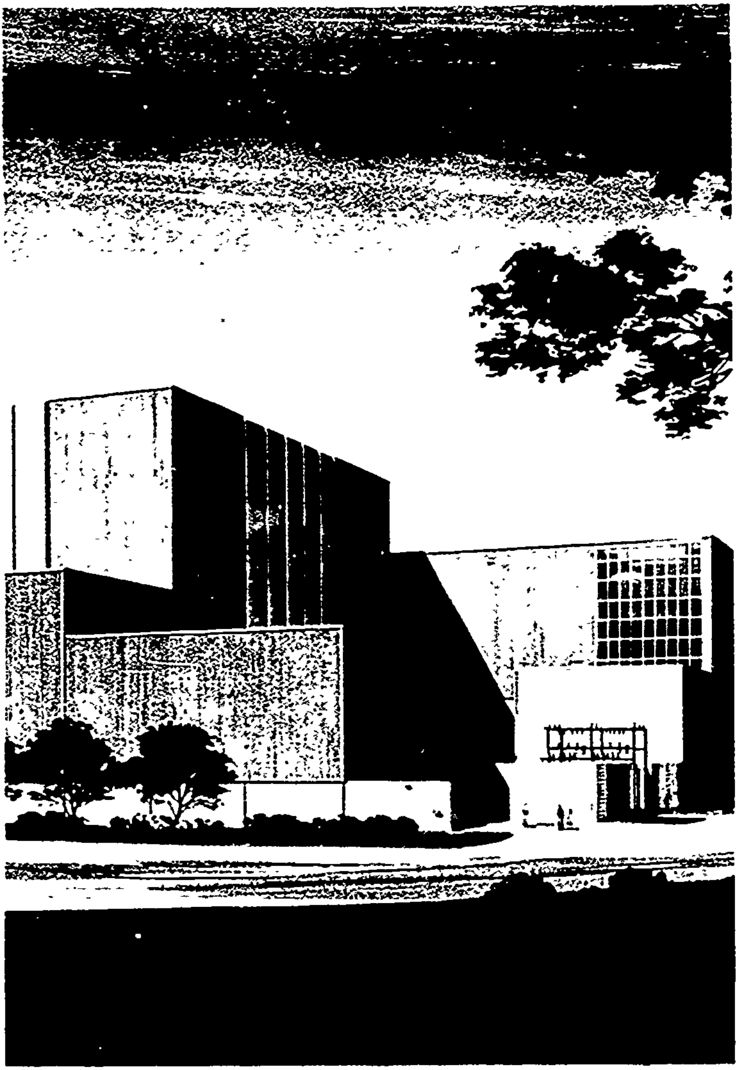


Figure 27 *ROBERT EMMETT GINNA Nuclear Power Plant. Located on the south shore of Lake Ontario, about 15 miles east of Rochester, New York. Pressurized-water reactor, net electrical capacity 420,000 kilowatts, designed by Westinghouse Electric Corporation. The Ginna plant was formerly known as Brookwood and is owned by Rochester Gas and Electric Corporation.*

Figure 28 *BIG ROCK POINT Nuclear Plant. Located on Lake Michigan at Big Rock Point near Charlevoix, Michigan, about 200 miles northwest of Detroit. Boiling-water reactor, 70,400-net-electrical-kilowatt capacity, designed by General Electric Company. Started commercial operation in 1963. Owned and operated by Consumers Power Company.*

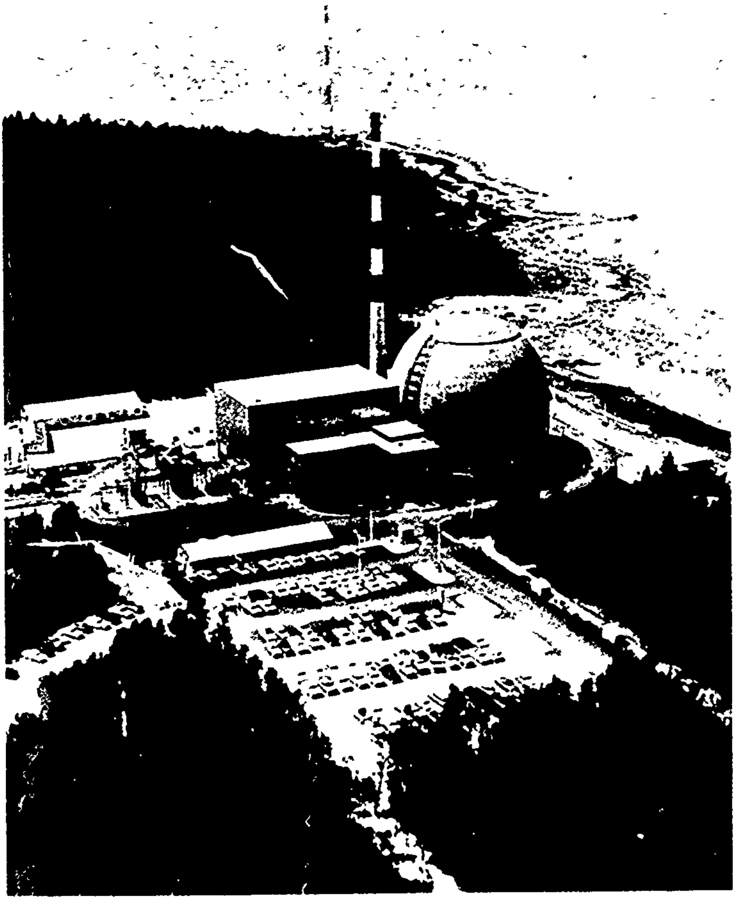
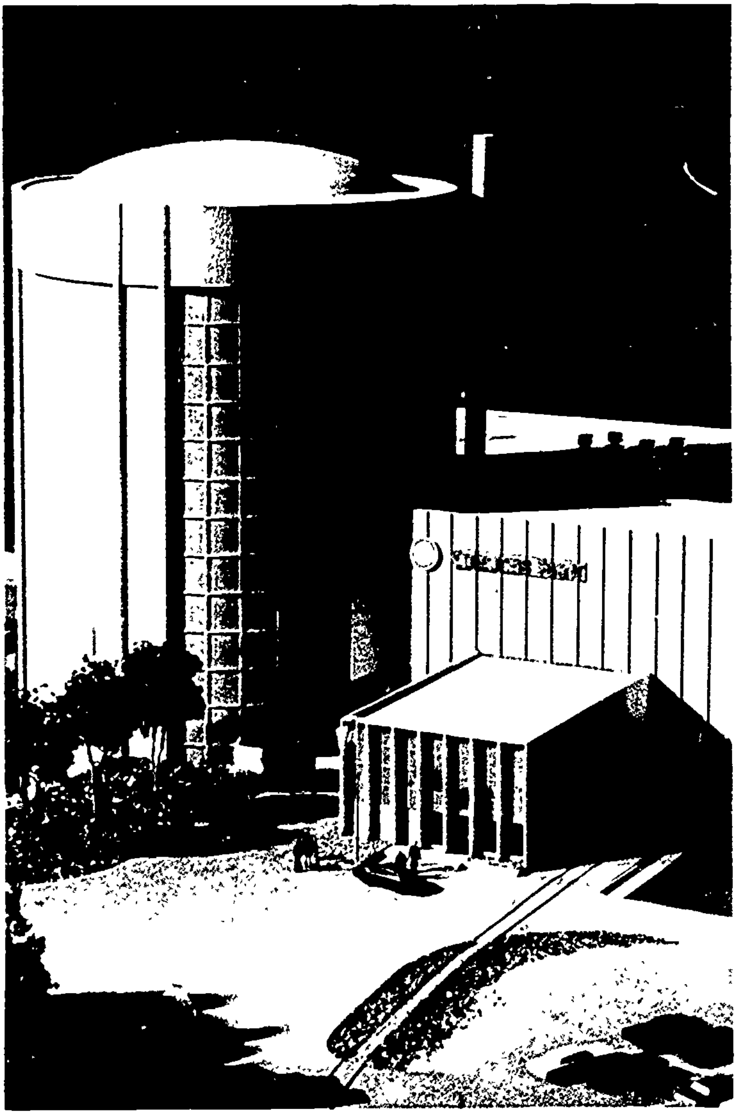


Figure 29 *SAN ONOFRE Nuclear Generating Station. Located on the Pacific Ocean near San Clemente, California. Pressurized-water reactor, 430,000-kilowatt capacity, commenced operation in 1967. Owned jointly by Southern California Edison Company and San Diego Gas & Electric Company.*

Figure 30 *PALISADES Nuclear Power Station. Located at South Haven, Michigan, about 35 miles west of Kalamazoo. Pressurized-water reactor, net capacity 700,000 kilowatts, designed by Combustion Engineering, Inc. Owned by Consumers Power Company, whose Big Rock Point plant is shown in Figure 28.*



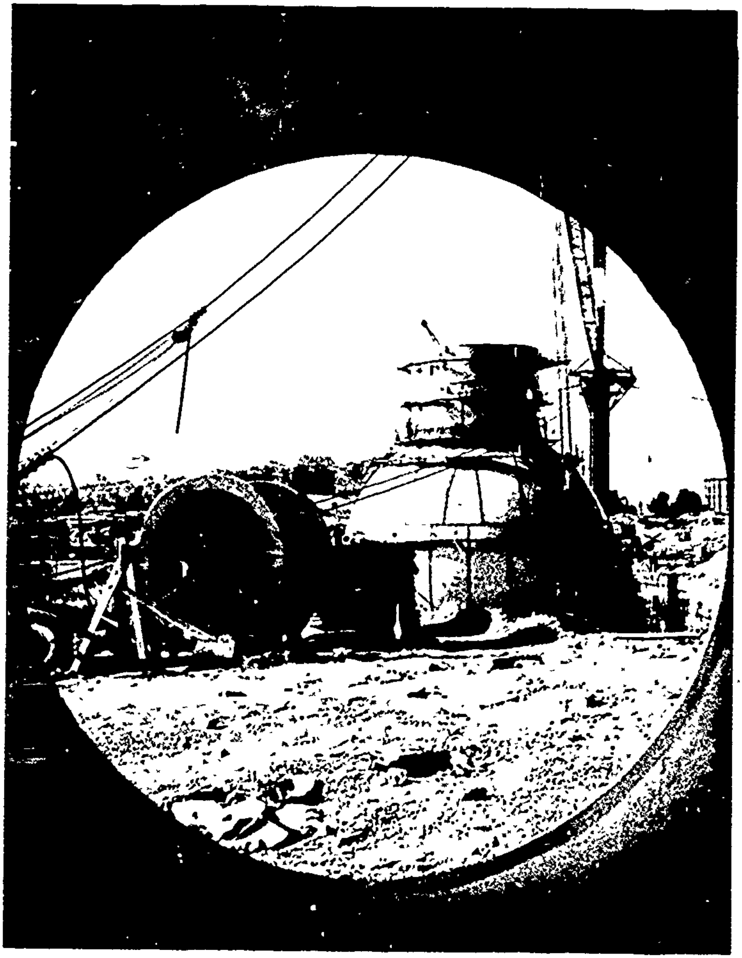


Figure 31 *NINE MILE POINT Nuclear Station, under construction. It takes several years time, a lot of material, and many hours of labor to erect a large power plant. In taking this picture, the photographer stood inside a large pipe that carries cooling water from Lake Ontario onto the steam condenser. The huge, light-bulb-shaped steel shell in the foreground houses the reactor. A view of the finished plant is shown in Figure 32.*

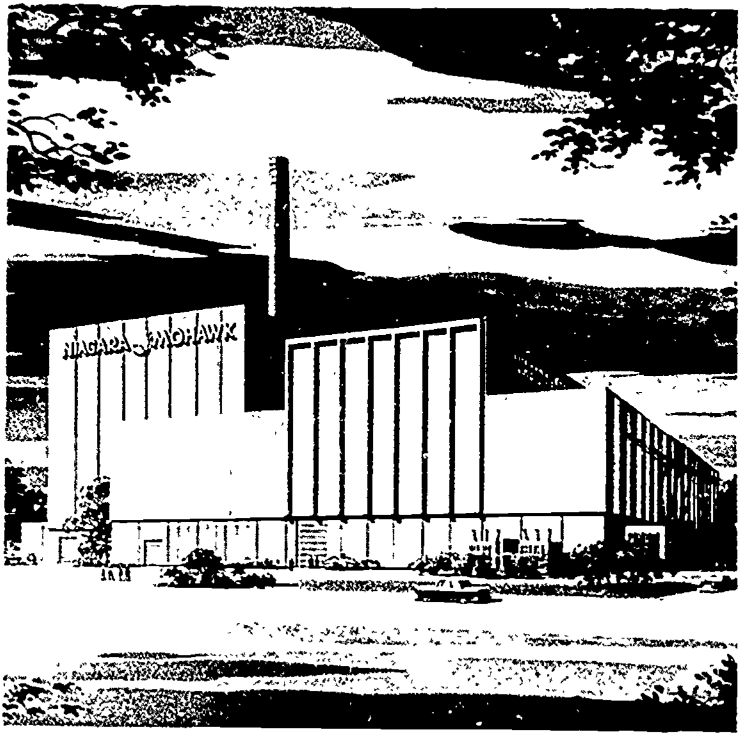


Figure 32 *NINE MILE POINT Nuclear Station. Located on Lake Ontario near Oswego, New York, about 35 miles north of Syracuse. Boiling-water reactor, 500,000-net-electrical-kilowatt capacity, designed by General Electric Company. Owned and operated by Niagara Mohawk Power Corporation.*

DEVELOPMENTS IN FOREIGN COUNTRIES

Many countries use nuclear energy to produce electric power. Some of these countries have large reactor development programs of their own, like the one in the United States, while others undertake little development, preferring to buy their nuclear power plants from a country that sells them for export. Among the countries whose programs we will discuss, our neighbor to the north comes first.

Canada

With large reserves of uranium, with a pool of scientists who participated in the early atomic energy work, and with inconveniently located fossil-fuel resources, Canada is "a natural" for the utilization of nuclear energy. The Canadians, in fact, for years have had a vigorous nuclear development program, oriented strongly toward heavy-water reactors.

In 1962, the Nuclear Power Demonstration (NPD) Station at Rolphton, Ontario, became Canada's first operating

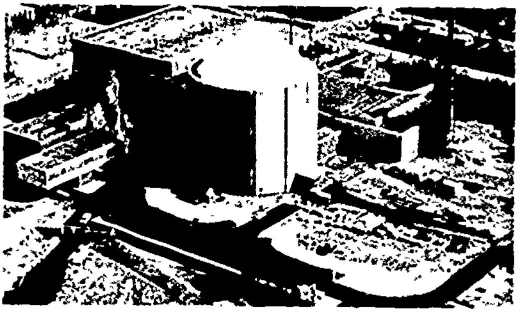


Figure 33 *The DOUGLAS POINT Nuclear Power Station located on the eastern shore of Lake Huron near Kincardine, Ontario.*

nuclear power plant and the first in the world to use a heavy-water reactor. The station, with a power output of 22,500 kilowatts, was designed as a prototype for larger plants. The first full-scale nuclear electric generating plant, the Douglas Point Nuclear Power Station, has a capacity of 203,000 kilowatts. It was built by Atomic Energy of Canada, Ltd. (which corresponds to our Atomic Energy Commission) in partnership with the Hydro Electric Power Commission of Ontario.

The dominance of the heavy-water reactor in Canadian efforts is illustrated by several additional large plants in Canada, and by the export sale of power plants of this type to India and Pakistan.

Great Britain

The British have been in the nuclear energy business for a long time, and they have the nuclear power plants to prove it. In 1956, when the British began operating their first nuclear plant at Calder Hall, shown in Figure 34, they chose a gas-cooled reactor. More than two dozen plants later, the English still prefer gas-cooled reactors. Many technical improvements have been incorporated in the newer plants. The outside appearance has changed, too, as can be seen by comparing a photo of a newer plant (Figure 35) with that of the original station.

Figure 34 *England's CALDER HALL Nuclear Power Station. The tall structures are cooling towers, which are employed in locations where a large body of water is not accessible. These towers cool the condenser cooling water so that it can be used again, and they emit steam, not smoke. Four reactors supply steam to two turbines. Total capacity of the station is 198,000 electrical kilowatts.*

Great Britain offers plants for export and competes for contracts in other countries. British-designed gas-cooled reactors have been built in Italy and Japan.

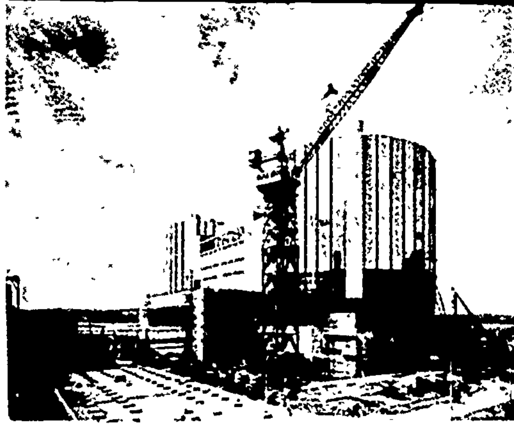


Figure 35 *The OLDBURY Nuclear Power Station went into operation in Great Britain in 1967. Generating capacity of the two plants at the station is 600,000 electrical kilowatts.*

Figure 36 *The DOUNREAY Fast Reactor located in Scotland.*

In addition to their work on gas-cooled reactors, the British are investigating other systems, including steam-generating heavy-water and liquid-metal-cooled breeder reactors. The Dounreay Fast Reactor, shown in Figure 36, is a 12,700-kilowatt experimental plant that has been in use since 1959. A new, 250,000-kilowatt prototype breeder reactor is located at the same site.

France

The emphasis in the French program, as in the British, has been on gas-cooled reactors. Although the two countries have developed nuclear plants that are very similar in principle and in major features, the development programs have been independent.

The first French plant went into operation at Marcoule in 1956, and since that time a new unit has come "on the line" about every 2 years with progressive improvements in the later designs. This should not be taken as an indication that progress has been slow, however, for the latest French plants show important improvements over the early designs.

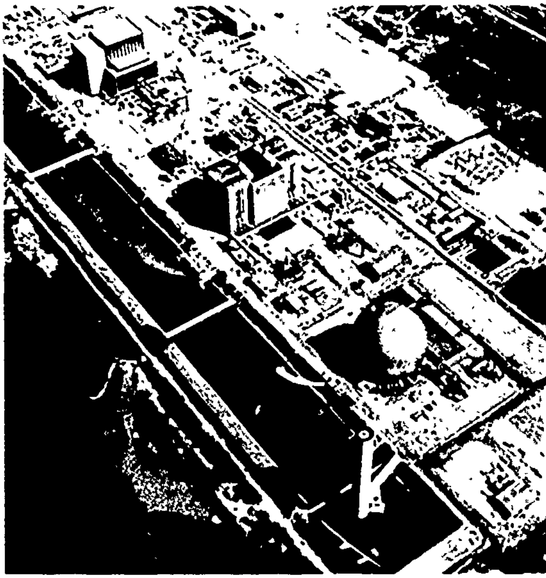


Figure 37 *Aerial view of the 735,000-kilowatt nuclear power station at Chinon, France. CHINON 1 is at the bottom, and the newer plants, CHINON 2 and 3, are above.*

The nuclear research and development work in France is considered to be good, and the French scientists are respected by their counterparts in other countries. In addition to contemporary gas-cooled reactors, the French have an active fast breeder program underway, including a 250,000-kilowatt prototype at Marcoule.

Japan

The Japanese have undertaken an ambitious nuclear power construction program, and the supporting industries necessary for such a program are developing rapidly. Although most of the current nuclear power plants are based on American designs, the Japanese have been operating reactors for over a decade.

The large nuclear plants that are becoming operational use boiling-water or pressurized-water reactors, but the Japanese are also looking well into the future as they develop a native capability. In addition to work on the kinds of reactors that are currently operating or under construction, research centers and industrial organizations are involved in the development of heavy-water and breeder reactors.

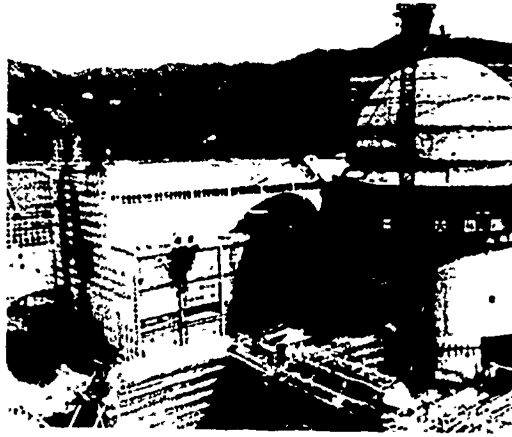


Figure 38 *Japan's TSURUGA Nuclear Power Plant. This 322,000-kilowatt plant is located near Kyoto.*

Figure 38 shows one of Japan's nuclear power plants, which uses a boiling-water reactor.

Soviet Union

The Russians have been operating nuclear reactors for over 25 years—nearly as long as scientists in the United States have. Their earliest reactors, like ours, were designed to produce materials for nuclear weapons. The Soviet program on peaceful uses of atomic energy also is like ours. It is diversified and, in the nuclear power plant area, it is not concentrated strongly on any particular type of plant.

A nuclear power plant called AM-1 went into operation near Moscow in 1954, preceding the first operation of our Shippingport station. We do not consider AM-1 to be a true nuclear power plant, however, because of its small size (5000 kilowatts) and experimental use. (A U. S. facility, the Experimental Breeder Reactor in Idaho, was producing electric power in 1951.)

Russia has built several types of nuclear power plants, but not many of any one type. Figure 39 shows an interior view of one of their larger plants, a pressurized-water type. The level of their technology is about equal to ours for the kinds of plants being constructed in fairly large numbers here. The U.S.S.R. is also pushing ahead with a large breeder-reactor construction program.

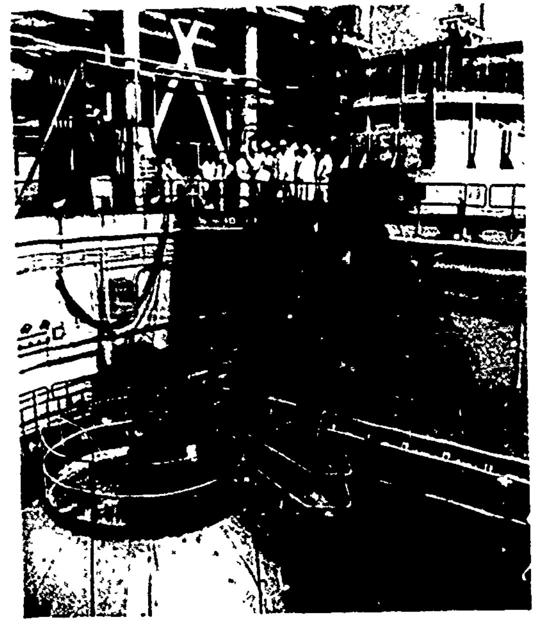


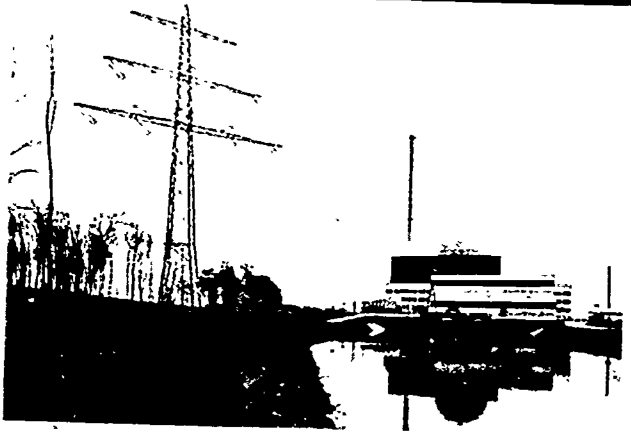
Figure 39 *The reactor pit in the NOVOVORONEZH Nuclear Power Station located on the Don River in the Soviet Union. The dome at the bottom is a cover for the reactor vessel. This plant produces 196,000 kilowatts; a second, larger plant is at the same site.*

West Germany

A vigorous development program promises to place West Germany among the foremost builders of nuclear power plants. Since their 15,000-kilowatt Kahl station began power operation in 1961, the Germans have proceeded with research and construction plans encompassing a variety of nuclear plants and facilities.

Some of the German plants are experimental in nature and serve as steps in a large, breeder-reactor program, but others have been built to furnish electric power to meet today's requirements. One such plant is shown in Figure 40, while Figure 41 shows the reactor vessel of another. Although the two photos illustrate boiling-water reactors, other German plants use pressurized-water, heavy-water, and gas-cooled reactors.

The German program is not limited to the development and construction of nuclear power plants for domestic use only. German industry is active in the competition for contracts to build plants in other countries, and a 317,000-kilowatt heavy-water reactor was sold to Argentina in 1968.



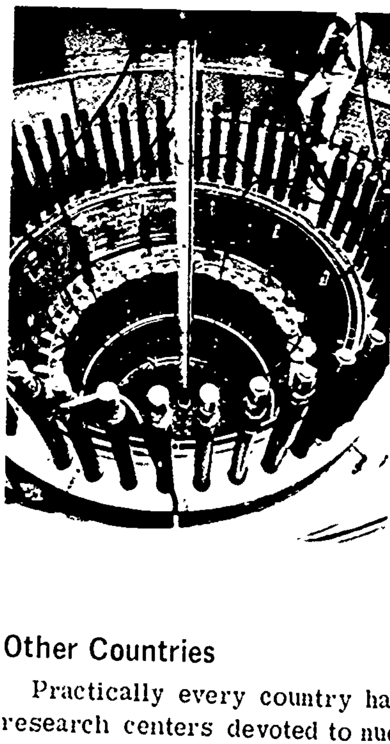
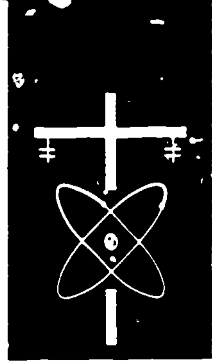


Figure 40 *West Germany's GUNDREMMINGEN Nuclear Power Station. This 237,000-kilowatt plant was Germany's first large-scale nuclear power station. It uses a boiling-water reactor and has been in operation since 1966.*

Figure 41 *The interior of the reactor vessel of the LINGEN Nuclear Power Station in West Germany. The inside diameter of the vessel is about 12 ft. This boiling-water reactor has been in operation since 1968.*

Other Countries

Practically every country has a government agency and research centers devoted to nuclear energy. Even some of the nations that are small in size have substantial programs under way and have actually built a nuclear power plant or two. Others have preferred—at least at first—to buy their plants from another country. In addition to the countries mentioned in the preceding paragraphs, the following have built or bought nuclear power plants: Belgium, Czechoslovakia, East Germany, the Netherlands, Spain, Sweden, Switzerland, and, reportedly, Bulgaria and Hungary.



THE LAST WORD

In the near future, a substantial amount of electric power may come from a kind of nuclear plant that we have not mentioned yet. This is called a *dual-purpose* plant because it has two products: Electricity and fresh water. The reactor in a dual-purpose plant serves the usual purpose—it produces heat. However, it produces enough heat to make more steam than the power-generating section of the plant needs. The extra steam is used in a desalting plant, or process, that makes fresh water from salt water. Thus, the dual-purpose plant is much like a regular nuclear power plant except that it has an extra section—and a big one, at that—which produces large amounts of fresh water.*

We have discussed some aspects of nuclear power plants, how reactors work, and why atomic energy is important in meeting the demand for electric power today and in the future. For those who want more information, the following pages give lists of suggested books, reports, articles, and motion pictures.

*See *Nuclear Energy for Desalting*, a companion booklet in this series.

SUGGESTED REFERENCES

Books

Nuclear Power Plants: Design, Operating Experience, and Economics, Robert L. Loftness, D. Van Nostrand Company, Inc., Princeton, New Jersey 08541, 1964, 548 pp., $12.50.

Sourcebook on Atomic Energy, (third edition), Samuel Glasstone, D. Van Nostrand Company, Inc., Princeton, New Jersey 08541, 1967, 883 pp., $9.25.

Directory of Nuclear Reactors, Volume IV—*Power Reactors*, International Atomic Energy Agency, National Agency for International Publications, Inc., 317 East 34th Street, New York 10016, 1962, 324 pp., $5.00.

Directory of Nuclear Reactors, Volume VII—*Power Reactors*, International Atomic Energy Agency, National Agency for International Publications, Inc., 317 East 34th Street, New York 10016, 1965, 341 pp., $9.00.

Fact Book on U. S. Nuclear Power Projects, revised periodically, Electric Companies Public Information Program, 230 Park Avenue, New York 10017, price varies with each edition.

Reports

Nuclear Reactors Built, Being Built, or Planned in the United States (TID-8200), revised semiannually, U. S. Atomic Energy Commission, Clearinghouse for Federal Scientific and Technical Information, 5285 Port Royal Road, Springfield, Virginia 22151, $3.00.

The following reports are available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402:

Major Activities in the Atomic Energy Programs, January–December, issued annually, U. S. Atomic Energy Commission, about 400 pp., $1.75.

The Nuclear Industry, revised annually, Division of Industrial Participation, U. S. Atomic Energy Commission, price varies with each issue.

Forecast of Growth of Nuclear Power (WASH-1084), Division of Operations Analysis and Forecasting, U. S. Atomic Energy Commission, December 1967, 50 pp., $0.35.

Civilian Nuclear Power The 1967 Supplement to the 1962 Report to the President, U. S. Atomic Energy Commission, February 1967, 56 pp., $0.40.

Articles

Annual Report on Nuclear Power, *Electrical World*. Reprints are $1.00 a copy from Reprint Editor, *Electrical World*, 330 West 42nd Street, New York 10036.

The Arrival of Nuclear Power, John F. Hogerton, *Scientific American*, 218: 21 (February 1968).

Numerous articles on nuclear power plants appear in the regular monthly issues of the following periodicals: *Power*, *Electrical World*. *Power Engineering*, *Nuclear News*, and *Nuclear Engineering International*.

Motion Pictures

Available for loan without charge from the AEC Headquarters Film Library, Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545 and from other AEC film libraries.

Atomic Power Today. Service with Safety, 28½ minutes, color, 1966. Produced for the Atomic Industrial Forum, Inc. This film tells the story of central station nuclear power plants and how they serve the country now and will continue to do so in the future. Starting with basic information on how electricity is produced from water power and fossil fuels, the film introduces nuclear fuel as a new energy resource that helps keep down the cost of electricity. Nuclear fuel is shown being fabricated, and its use in a reactor is illustrated through animation. The film shows the components and construction of a nuclear power plant, and deals with the safety of the plant. The film concludes by showing several of the nuclear power plants across the country, which serve our needs for electric power.

Tomorrow's Power — Today, 5½ minutes, color, 1964. Produced for the AEC by the Argonne National Laboratory. This film explains why energy from the atom is needed to supplement that of conventional fossil fuels. It shows how heat from nuclear fission is converted to electrical power and gives a brief survey of representative atomic power plants in the U.S.

The New Power, 45 minutes, color, 1965. Produced for the AEC's Idaho Operations Office by the Lookout Mountain Air Force Station. This film tells how the National Reactor Testing Station in Idaho is furthering the AEC's quest for economic nuclear power. Most of the many experimental nuclear reactors located at the Testing Station are described. The film also explains the basic principles of power reactor construction and operation.

Atomic Power Production, 14 minutes, color or black and white, 1964. This film in the Magic of the Atom Series was produced by the Handel Film Corporation. An explanation is given of how the heat created by the controlled chain reaction of atomic fuel in a reactor is converted to electrical power. The basic differences in these power reactors are discussed: the boiling-water reactor, the pressurized-water reactor, the liquid-metal-cooled reactor, and the organic-cooled reactor. The principle of the breeder reactor is explained and its importance stressed.

Atomic Venture, 23½ minutes, color, 1961. Produced by the General Electric Company. This film covers the design and development of a large dual-cycle boiling-water reactor — the 180,000-kilowatt Dresden Nuclear Power Station — built by the General

Electric Company for the Commonwealth Edison Company in Chicago and the Nuclear Power Group, Inc., from its beginning in 1955 to its completion in 1959.

Power and Promise, 29 minutes, color, 1959. Produced by the AEC This film describes the Shippingport Atomic Power Station in Pennsylvania, which was built to advance power reactor technology and demonstrate the practicability of operating a central station nuclear power plant in a utility network.

The Day Tomorrow Began, 30 minutes, color, 1967. Produced by Argonne National Laboratory for the AEC. This film tells the story of the building and testing of the world's first reactor. By interview, historical film footage, and paintings, the motion picture re-enacts the historic events that led to the dramatic moment when the first sustained chain reaction was achieved. This milestone in man's quest for knowledge occurred under the stands of Stagg Field, Chicago, on December 2, 1942.

PHOTO CREDITS

Cover courtesy Southern California Edison Company

Figure 10	Connecticut Light & Power Company
Figure 11	Babcock & Wilcox Company
Figure 12	Rural Cooperative Power Association
Figure 13	Combustion Engineering, Inc.
Figure 14	Power Reactor Development Company
Figure 18	General Electric Company
Figure 19	Yankee Atomic Electric Company
Figure 20	Consolidated Edison Company of New York, Inc.
Figure 21	Power Reactor Development Company
Figure 22	General Electric Company-APED and J. A. Jones Construction Company
Figure 23	Philadelphia Electric Company
Figure 24	Tennessee Valley Authority
Figure 25	Connecticut Light & Power Company
Figure 26	Pacific Gas and Electric Company
Figure 27	Rochester Gas and Electric Corporation
Figure 28	Consumers Power Company
Figure 29	Southern California Edison Company
Figure 30	Consumers Power Company
Figure 31	Niagara Mohawk Power Corporation
Figure 32	Niagara Mohawk Power Corporation
Figure 33	Atomic Energy of Canada, Ltd.
Figure 34	United Kingdom Atomic Energy Authority (UKAEA)
Figure 35	UKAEA
Figure 36	UKAEA
Figure 37	Electricite de France, photography by M. Brigaud
Figure 38	General Electric Company
Figure 39	Soviet Delegation to the Third International Conference on the Peaceful Uses of Atomic Energy
Figure 40	Deutsches Atomforum e.V.
Figure 41	Deutsches Atomforum e.V.

THE AUTHORS

RAY L. LYERLY is a consulting engineer who works with electric utility firms. He received a B.S. degree in mechanical engineering from North Carolina State University and an M.S. degree from Columbia University. A registered professional engineer, Mr. Lyerly has broad experience in the power generation field, both with fossil-fuel and nuclear power plants. In recent years, his work has been heavily oriented toward the investigation and resolution of power plant air and water environmental concerns. He is the principal member of Ray L. Lyerly and Associates of Dunedin, Florida, consultants in power plant engineering.

WALTER MITCHELL, III, is a nuclear engineer. Mr. Mitchell, a graduate of the Georgia Institute of Technology, began his career in the nuclear industry in the 1950s with design work on prototype ship-propulsion reactors. During the period since that early work, he has been active in the design, analysis, and evaluation of essentially all types of nuclear plants. He has written scores of technical reports and articles, many of which have appeared in national and international journals, and is coauthor of *Nuclear Power Plants* and *Breeder Reactors*, other booklets in this series. A founder and Vice President of Southern Nuclear Engineering, Inc., Mr. Mitchell is now a Senior Staff Consultant for NUS Corporation.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1974 — 747-552/5

The U S Atomic Energy Commission publishes this series of information booklets for the general public. The booklets are listed below by subject category.

If you would like to have copies of these booklets, please write to the following address for a booklet price list:

USAEC–Technical Information Center
P. O. Box 62
Oak Ridge, Tennessee 37830

School and public libraries may obtain a complete set of the booklets without charge. These requests must be made on school or library stationery.

Chemistry

IB-303 The Atomic Fingerprint. Neutron Activation Analysis
IB-301 The Chemistry of the Noble Gases
IB-302 Cryogenics. The Uncommon Cold
IB-304 Nuclear Clocks
IB-306 Radioisotopes in Industry
IB-307 Rare Earths The Fraternal Fifteen
IB-308 Synthetic Transuranium Elements

Biology

IB-101 Animals in Atomic Research
IB-102 Atoms in Agriculture
IB-105 The Genetic Effects of Radiation
IB-110 Preserving Food with Atomic Energy
IB-106 Radioisotopes and Life Processes
IB-107 Radioisotopes in Medicine
IB-109 Your Body and Radiation

The Environment

IB-201 The Atom and the Ocean
IB-202 Atoms, Nature, and Man
IB-414 Nature's Invisible Rays

General Interest

IB-009 Atomic Energy and Your World
IB-010 Atomic Pioneers–Book 1: From Ancient Greece to the 19th Century
IB-011 Atomic Pioneers–Book 2: From the Mid-19th to the Early 20th Century
IB-012 Atomic Pioneers–Book 3: From the Late 19th to the Mid-20th Century
IB-002 A Bibliography of Basic Books on Atomic Energy
IB-004 Computers
IB-008 Electricity and Man
IB-005 Index to AEC Information Booklets
IB-310 Lost Worlds. Nuclear Science and Archeology
IB-309 The Mysterious Box: Nuclear Science and Art
IB-006 Nuclear Terms: A Glossary
IB-013 Secrets of the Past. Nuclear Energy Applications in Art and Archaeology
IB-017 Teleoperators. Man's Machine Partners
IB-014, 015, & 016 Worlds Within Worlds: The Story of Nuclear Energy Volumes 1, 2, and 3

Physics

IB-401 Accelerators
IB-402 Atomic Particle Detection
IB-403 Controlled Nuclear Fusion
IB-404 Direct Conversion of Energy
IB-410 The Electron
IB-405 The Elusive Neutrino
IB-416 Inner Space: The Structure of the Atom
IB-406 Lasers
IB-407 Microstructure of Matter
IB-415 The Mystery of Matter
IB-411 Power from Radioisotopes
IB-413 Spectroscopy
IB-412 Space Radiation

Nuclear Reactors

IB-501 Atomic Fuel
IB-502 Atomic Power Safety
IB-513 Breeder Reactors
IB-503 The First Reactor
IB-505 Nuclear Power Plants
IB-507 Nuclear Reactors
IB-510 Nuclear Reactors for Space Power
IB-508 Radioactive Wastes
IB-511 Sources of Nuclear Fuel
IB-512 Thorium and the Third Fuel