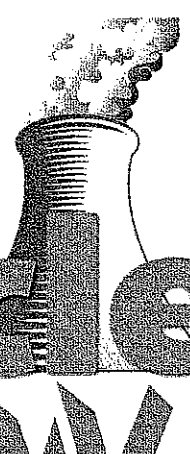


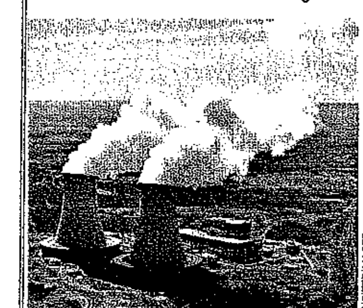
Nuclear POWER

A SAFE AND CLEAN SOURCE OF ENERGY?

By Douglas J. Shearer

When you flick on a switch, chances are that the electricity used to light up the room was produced from burning oil, natural gas, or coal. But these three sources of energy produce a lot of pollution. So, scientists and engineers are looking with renewed interest at a different source of energy called nuclear power.

Nuclear power comes from splitting atoms. Its main advantage is that it produces more energy per gram of fuel than any other known source of energy. Also, it does not pollute the air.



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Nuclear power is not new: It was generated for the first time in the United States in 1951. So, if nuclear power yields so much energy without polluting the air, why haven't we been using more of it?

The downside of nuclear power is that it leaves behind radioactive chemicals that can be very dangerous for human health and the environment if they are not safely stored. Also, you may have heard about two major safety events that occurred at two nuclear power plants.

In March 1979, human errors and component failures led to overheating in one of the units making up the Three Mile Island nuclear power plant near Harrisburg, Pa. The power plant became so hot that it melted. Fortunately, the building in which the power plant was contained prevented radioactivity from spreading.

In April 1986, an incident in Ukraine led to more tragic consequences. Poor training, poor deisgn of the power plant, and disregard for safety resulted in the destruction of a nuclear power plant called Chernobyl. Unlike the Three Mile Island incident, Chernobyl did not have a containment building, and at least 5% of the radioactive core was released by a steam explosion and fire, leading to the death of 31 people. An additional 47 emergency workers later died from acute radiation as a consequence of the cleanup efforts.

These two incidents have led to sweeping changes in the design and operation of nuclear power plants. Existing plants have been upgraded and strengthened, and the training of operators has improved. Thanks to these efforts, nuclear energy is now staging a comeback, as more utility companies are seeking permission to build additional nuclear power plants.

Nuclear energy

How is nuclear energy generated? It can happen in two ways, called nuclear fusion and nuclear fission. Nuclear fusion occurs when two atoms fuse together to create a different element. For example, atoms of hydrogen fuse together in the sun to make helium, releasing large amounts of energy. But back here on Earth, scientists haven't had much luck yet in generating energy from fusion.

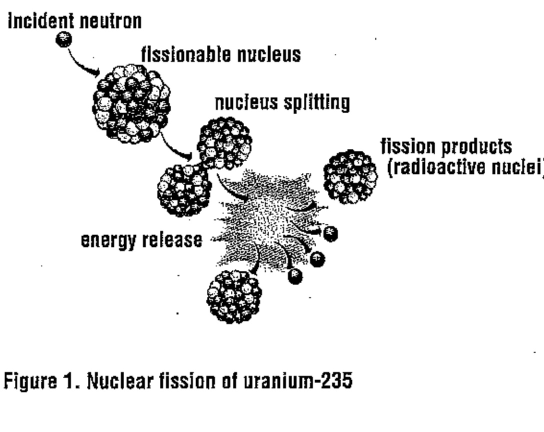

Figure 1. Nuclear fission of uranium-235

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The nuclear power plants that are currently operating are using nuclear fission: A nucleus breaks apart into two or more lighter nuclei. Nuclear plants use uranium-235.

When the nucleus of a uranium-235 atom is hit by neutrons, it breaks down into two smaller nuclei, releasing energy and very fast neutrons. For example, uranium-235 could fission into the elements krypton and barium, releasing energy and neutrons at very high speed.

These neutrons strike the nuclei of other uranium-235 atoms, generating more energy and more neutrons. The succession of such reactions is called a chain reaction (Fig. 1). In a nuclear power plant, the energy generated by this chain reaction is used to produce electricity.

Nuclear power plants

How do you produce electricity from nuclear fission? If you could weigh the uranium before it fissions and add up the weight of all the pieces after it splits, you would find that some of the mass is gone. This missing mass is converted to energy in the form of heat. This heat is used in two different ways, depending on the type of nuclear power plant.

In one type of nuclear plant, called a Boiling Water Reactor (BWR), the heat boils water, creating steam, which moves the blades of a machine called a

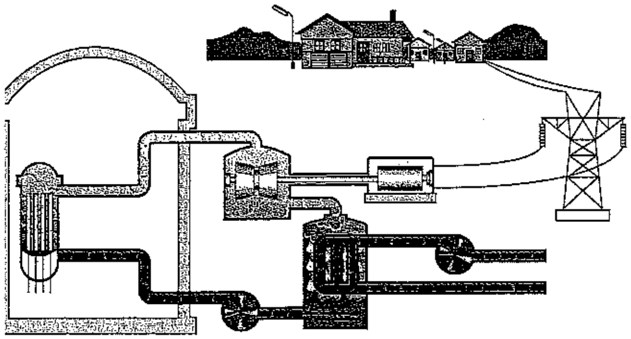


Figure 2. Boiling Water Reactor

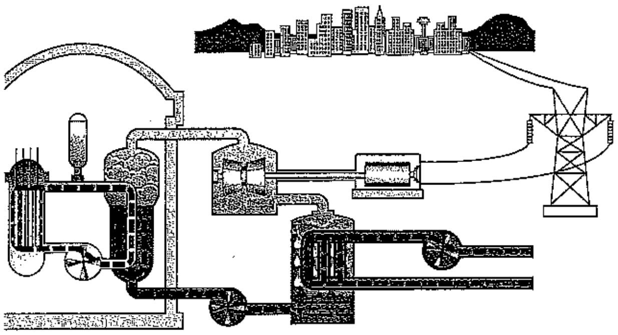


Figure 3. Pressurized Water Reactor

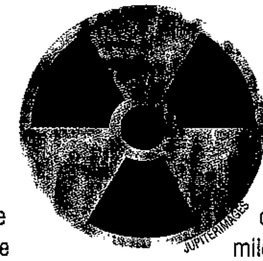
ANTHONY FERNANDEZ; ADAPTED FROM ILLUSTRATIONS BY THE U.S. NUCLEAR REGULATORY COMMISSION

turbine. This turbine is connected to a power generator, which produces electricity (Fig. 2). Also, a condenser cools down the boiling water, so it is recycled.

In the other type of nuclear plant, called a Pressurized Water Reactor (PWR), the hot water is under high pressure, so it is heated above its boiling temperature but does not boil. The heat is then transferred to a large vessel that contains water, which boils and releases steam (Fig. 3). The steam is then used to turn a turbine and power a generator, which produces electricity.

The neutrons that are produced during the nuclear reactions are so fast—their speed is about 10% of the speed of light—that they can escape and be lost. To slow them down, a nuclear power plant uses a material called a moderator. It consists of water or heavy water (water in which the hydrogen atoms are replaced with deuterium, a form of hydrogen with two neutrons instead of one neutron) or graphite (a form of carbon used to make pencil lead).

Also, sensors inside the plant measure how much fission is occurring and send this information to computers. If the reaction is too fast in one area, the computer slows it down by directing a control rod made of a neutron-absorbing material—such as cadmium, hafnium, or boron—inside the core of the power plant. If the reaction is too slow, control rods already inside the power plant are pulled out.



Safer nuclear power plants

The events at Three Mile Island and Chernobyl caused the nuclear industry to be stagnant from the late 1970s until 2002. Few new nuclear power plants were ordered, and many orders were cancelled.

Projected increases in electricity use worldwide, along with concerns about global warming, have led to a renewed interest in nuclear power. While existing nuclear power plants were being updated, future power plants were designed so that any abnormal increase in temperature would cause the nuclear reactions to decrease. Also, if, for some reason, the cooling water was removed, the nuclear reactions would slow down automatically.

These new plants generate the same amount of electricity or more as current plants but at less cost, and they use less uranium and produce less radioactive waste. Also, they have safety systems that do not require human intervention.

Radioactive waste

The uranium fuel stays in a nuclear power plant for 1–2 years, and then it is replaced, but not because all the fuel is used up. When the uranium splits, it leaves lighter chemical elements known as fission products. Some of these fission products absorb neutrons, so they tend to slow down the nuclear reactions.

After the fission products are removed from the reactor, they are stored in an underground water pond that cools them and shields their radiation. These stored fission products are called radioactive waste.

About 10 years later, when the radioactivity level has reduced substantially, the waste is enclosed in containers made of steel and concrete. But then what happens with it?

For the past two decades, the U.S. government has been considering plans to store this waste underground, particularly at a site in Nevada called Yucca Mountain, located 100 miles northwest of Las Vegas. But this project may not go forward because the U.S. government is now examining alternatives for the storage, processing, and disposal of nuclear waste.

Unlike the United States, Europe, Japan and Russia reprocess their nuclear waste, which still contains about 20% of the original uranium-235. This uranium is extracted from the waste and is fed back into a nuclear power plant.

Research is under way for even more advanced reactors that can extract more power from uranium. The objective is to generate 50–100 times more electricity from the same amount of uranium and to produce less radioactive waste. In fact, the waste from today's plants may be used as a fuel for next-generation plants, which would leave behind elements that lose their radioactivity faster, thus making disposal easier.

U.S. NUCLEAR REGULATORY COMMISSION

Fuel rods contain the uranium that is used to create energy in a nuclear power plant.

Studies by the International Energy Agency and the World Energy Council have shown that the world cannot cleanly satisfy its energy needs without a sharp expansion of nuclear energy. But the long-term disposal of radioactive waste will need to be addressed.

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