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NUCLEAR POWER PLANTS AND NUCLER POWER

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Annotation: This article provides a number of information on the extraction of electricity from nuclear power plants and nuclear power plants, as well as on nuclear energy

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In nuclear power plants such as the one shown in Figure 1, a controlled nuclear reaction is used to make heat to produce steam needed to drive a steam turbine generator.

All nuclear plants in the United States must conform to the Nuclear Regulatory Commission's rules and regulations. Extensive documentation is required to establish that the proposed design can be operated safely without undue risk to the public. Once the Nuclear Regulatory Commission issues a license, the license holder must maintain the license and the reactor in accordance with strict rules, usually called Tech Specs. Compliance to these rules and regulations in conjunction with site inspections ensures that a safe nuclear power plant is in operation.

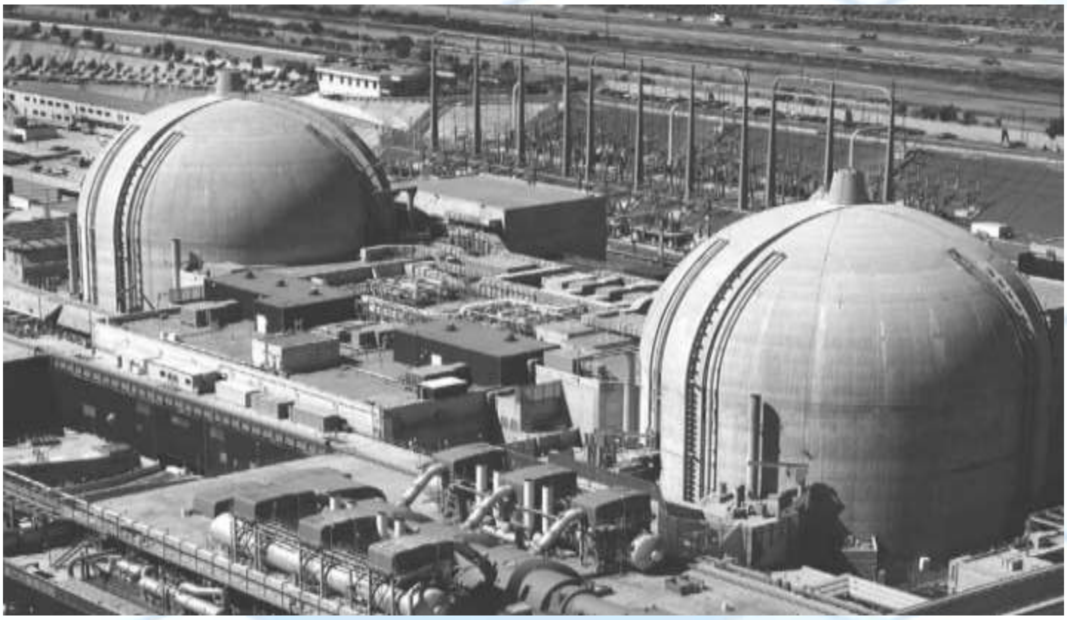

Figure 1. Nuclear power plant.

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Atoms are the building blocks from which all matter is formed. Everything is made up of atoms. Atoms are made up of a nucleus (with protons and neutrons) and orbiting electrons. The number of atomic particles (i.e., sum of neutrons, protons, and electrons) determines the atomic weight of the atom and type of element in the periodic table. Nuclear energy is contained within the center of atoms (i.e., nucleus) where the atom's protons and neutrons exist. Nature holds the particles within the atom's nucleus together by a very strong force. If a nucleus of a large element (such as uranium 235) is split apart into multiple nuclei of different element compositions, generous amounts of energy are released in the process. The heat emitted during this process (i.e., nuclear reaction) is used to produce steam energy to drive a turbine generator. This is the foundation of a nuclear power plant.

There are basically two methods used to produce nuclear energy in order to produce heat to make steam. The first process is called fission. Fission is the splitting of large nuclei atoms such as uranium inside a nuclear reactor to release energy in the form of heat to be used to produce steam to drive steam turbine electrical power generators. The second process is called fusion. Fusion is the combining of small nuclei atoms into larger ones, resulting in an accompanying release of energy. However, fusion reactors are not yet used to produce electrical power because it is difficult to overcome the natural mutual repulsion force of the positively charged protons in the nuclei of the atoms being combined.

In the fission process, certain heavy elements, such as uranium, are split when a neutron strikes them. When they split, they release energy in the form of kinetic energy (heat) and radiation. Radiation is subatomic particles or high-energy light waves emitted by unstable nuclei. The process not only produces energy and radiation, it also provides additional neutrons that can be used to fission other uranium nuclei and, in essence, start a chain reaction. The controlled release of this nuclear energy using commercial-grade fuels is the basis of electric power generation. The uncontrolled release of this nuclear energy using more highly enriched fuels is the basis for atomic bombs.

The reactor is contained inside an obvious containment shell. It is made up of extremely heavy concrete and dense steel in order to minimize the possibility of a reactor breach due to an accidental. Nuclear power plants also have an emergency backup scheme of injecting boron into the reactor coolant. Boron is an element that absorbs neutrons very readily. By absorbing neutrons, the neutrons are not available to continue the nuclear reaction, and the reactor shuts down.

The most widely used design for nuclear reactors consists of a heavy steel pressure vessel surrounding the reactor core. The reactor core contains the uranium fuel. The fuel is formed into cylindrical ceramic pellets about one-half inch in diameter, which

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are sealed in long metal tubes called fuel tubes. The tubes are arranged in groups to make a fuel assembly. A group of fuel assemblies forms the reactor core.

Controlling the heat production in nuclear reactors is accomplished by using materials that absorb neutrons. These control materials or elements are placed among the fuel assemblies. When the control elements, or control rods as they are often called, are pulled out of the core, more neutrons are available and the chain reaction increases, producing more heat. When the control rods are inserted into the core, more neutrons are absorbed, and the chain reaction slows down or stops, producing no heat. The control rod drive system controls the actual output power of the electric power plant. Most commercial nuclear reactors use ordinary water to remove the heat created by the fission process. These are called light water reactors. the water also serves to slow down or moderate the neutrons in the fission process. In this type of reactor, control mechanisms are used such that the chain reaction will not occur without the water to serve as a moderator. In the United States, there are two different types of light-water reactor designs used, the pressurized water reactor (PWR) and the boiling water reactor (BWR).

PRESSURIZED WATER REACTOR (PWR). The basic design of a pressurized water reactor is shown in Figure 2. The reactor and the primary steam generator are housed inside a containment structure. The structure is designed to withstand accidental events such as small airplane crashes. The PWR steam generator separates the radioactive water that exists inside the reactor from the steam that is going to the turbine outside the shell.

In a PWR, the heat is removed from the reactor by water flowing in a closed, pressurized loop. The heat is transferred to a second water loop through a heat exchanger (or steam generator). The second loop is kept at a lower pressure, allowing the water to boil and create steam, which is used to turn the turbine generator and produce electricity. Afterward, the steam is condensed back into water and returned to the heat exchanger where it is recycled into useable steam.

The normal control of the reactor power output is by means of the control rod system. These control rods are normally inserted and controlled from the top of the reactor. Because the control rods are inserted and controlled from the top of the reactor, the design also includes special springs and re lease mechanisms so that if all power is lost, the control rod will be dropped into the reactor core by gravity to shut down the reactor.

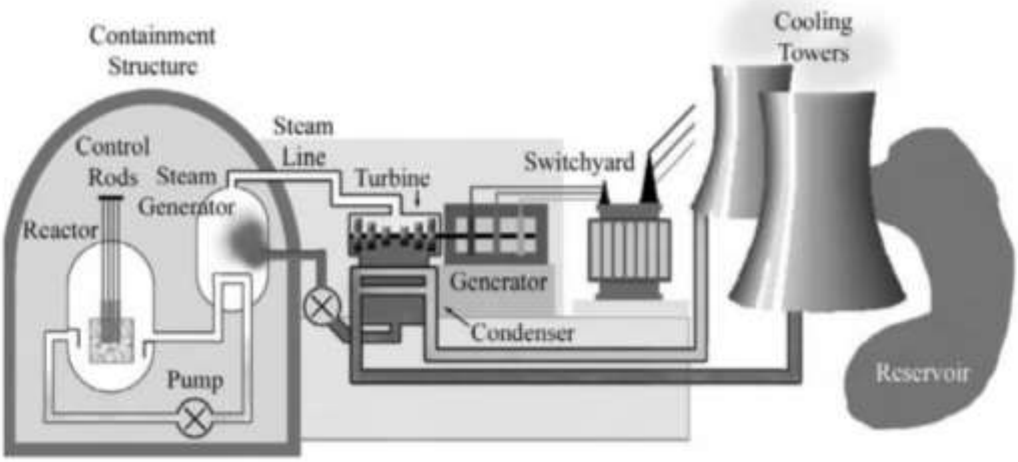

Figure 2. Pressurized water reactor

Advantages and Disadvantages of PWR. As with any design, there are advantages and disadvantages of pressurized water reactors. A major design advantage is the fact that fuel leaks, such as ruptured fuel rods, are isolated in the core and primary loop. That is, radioactive material contained inside the fuel is not allowed to go outside of the containment shell. The pressurized water reactor can be operated at higher temperature/pressure combinations, and this allows an increase in the efficiency of the turbine generator system. Another advantage is that it is believed that a pressurized water reactor is more stable than other designs. This is because boiling is not allowed to take place inside the reactor vessel and, therefore, the density of the water in the reactor core is more constant. By reducing the variability of the water density, controls are somewhat simplified. The biggest disadvantage appears to be the fact that the reactor design is more complicated. It is necessary to design for extremely high pressures and temperatures in order to ensure that boiling does not take place inside the reactor core. The use of high-pressure vessels makes the overall reactor somewhat more costly to build. Finally, under certain circumstances, the pressurized water reactor can produce power at a faster rate than the cooling water can remove heat. If this event takes place, there is a high probability of fuel rod damage. BOILING WATER REACTOR (BWR). Figure 3. shows a boiling water reactor (BWR). Again, there is a reactor building or containment shell where the nuclear reactor and some of its complement equipment are located. The reactor housing of the BWR tends to be larger than the PWR and looks almost like an inverted lightbulb. In a BWR, water boils inside the reactor itself, and the steam goes directly to the turbine generator to produce electricity. Similar to other steam power plants, the steam is condensed and reused. Note that the turbine building is closely coupled to the reactor building, and special constraints exist in entering the turbine building because the water can pick up radioactivity. Note the torus at the bottom of the reactor. If there should be a reactor rupture, the water inside the reactor will flash into steam and create a very high pressure surge in the reactor building. The reactor torus is filled with cold water, which will instantly condense the steam. The torus system ensures that the pressure inside the containment dome never exceeds an acceptable level.

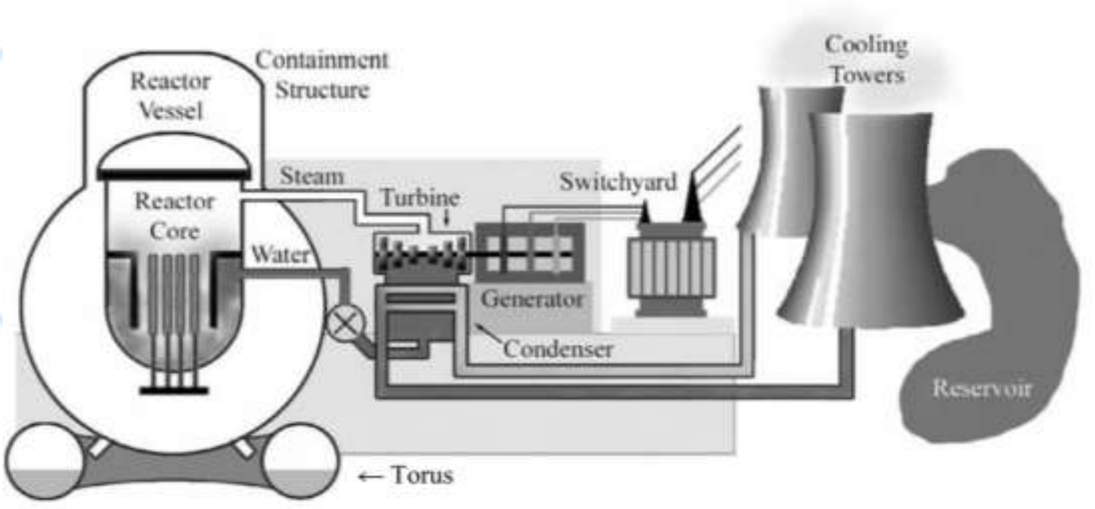

Figure 3. Boiling water reactor

As with the pressurized water reactor, the reactor housing contains the fuel core and water supply flow paths. The reactor recirculation system consists of the pumps and pipes that circulate the water through the reactor. The water circulating through the reactor actually goes into the turbine itself and then condensed water goes back into the reactor. The steam separator in the reactor shell separates the water from the steam and allows the steam to pass to the steam generator. The separated water is returned to the reactor for recirculation. The boiling water reactor utilizes one cooling loop. Both water and steam exist in the reactor core (i.e., a definition of boiling). Reactor power is controlled by positioning the control rods from start-up to approximately 70% of rated power. From 70% to 100% of rated power, the reactor power is controlled by changing the flow of water through the core. As more water is pumped through the core and more steam generated, more power is produced. In the boiling water reactor, control rods are normally inserted from the bottom. The top of the reactor vessel is used to separate water and steam. Advantages and Disadvantages of BWR. A major advantage of the BWR is that the overall thermal efficiency is greater than that of a pressurized water reactor because there is no separate steam generator or heat exchanger. Controlling the reactor is a little easier than in a PWR because it is accomplished by controlling the flow of water through the core. Increasing the water flow increases the power generated. Because of the nature of the design, the reactor vessel is subjected to less radiation, and this is considered to be an advantage because some steels become brittle with exposure to excessive radiation. The greatest disadvantage of the BWR is that the design is much more complex. It requires a larger pressure vessel than the PWR because of the amount of steam that can be released during an accident. This larger pressure vessel also increases the cost of the BWR.

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Finally, the design does allow a small amount of radioactive contamination to get into the turbine system. This modest radioactivity requires that anybody working on the turbine must wear appropriate protective clothing and use the proper equipment.

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