



Unit 3: Nuclear Reactors/Energy Generation

Objectives

- To ensure students understand how nuclear energy is generated.
- To help students learn how a nuclear power plant works.
- To understand how the NRC regulates commercial nuclear energy.

At the conclusion of this unit the student should be able to --

- Describe the fission process.
- Identify the various kinds of nuclear power plants.
- Discuss the process of energy generation with nuclear power plants.
- Investigation and Building Background

1. Introduce term:

Students have little knowledge of nuclear reactors and limited understanding of the terminology used in nuclear power plants. Definitions found in dictionaries tend to be vague regarding this specialized language.

2. Resources:

Nuclear Power for Energy Generation "Nuclear Reactor Concepts" Workshop Manual, NRC
The Fission Process and Heat Production "Nuclear Reactor Concepts" Workshop Manual, NRC
Boiling Water Reactor Systems "Nuclear Reactor Concepts" Workshop Manual, NRC
Pressurized Water Reactor Systems "Nuclear Reactor Concepts" Workshop Manual, NRC

3. Generalizing:

The purpose of a nuclear power plant is to produce or release heat and boil water. It is designed to produce electricity. It should be noted that while there are significant differences, there are many similarities between nuclear power plants and other electrical generating facilities. Uranium is used for fuel in nuclear power plants to make electricity.

a. Vocabulary: Nuclear Power Plants

boiling water reactor (BWR)
pressurized water reactor (PWR)
uranium-235
sodium helium
uranium carbide
uranium-238

Questions

Is there a nuclear power plant near where you live? What type is it?

Why don't boiling water reactors have steam generators?

What is the purpose of a "cooling tower"?

What percentage of the electricity in the U.S. is produced in nuclear power plants?

Name the two types of reactor power plants in operation the U.S. What are the basic differences?

Lesson Plan

Greeting...

Increasingly, our country has become a nation of electricity users. We depend on an abundant affordable supply of energy to power the many machines we use in our complex society. Can you imagine what it would be like not having electricity in your home? About one-third of our energy resources are used to produce electricity.

Electricity can be produced in many ways -- most of which you already know about. Today, we're going to talk about one of those ways -- nuclear fission. In America, nuclear energy plants are the second largest source of electricity after coal -- producing approximately 21 percent of our electricity. There is something I want all of you to be aware of: The purpose of a nuclear power plant is to produce electricity.

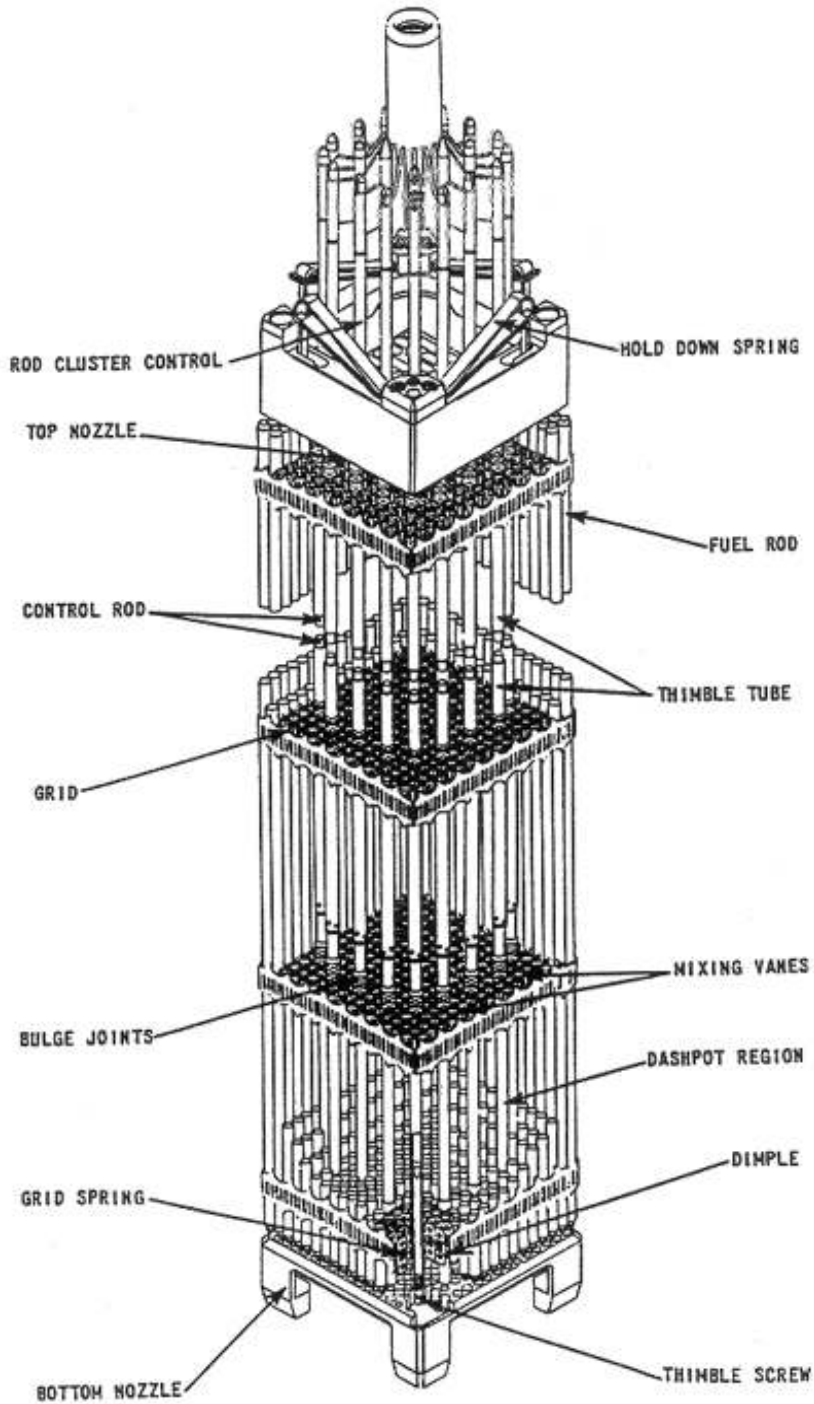
While nuclear power plants have many similarities to other types of electricity generating plants, there are some significant differences.

With the exception of solar, wind, and hydroelectric plants, all others including nuclear convert water to steam that spins the propeller-like blades of a turbine that spins the shaft of a generator. Inside the generator coils of wire and magnetic fields interact to create electricity.

The energy needed to boil water into steam is produced in one of two ways: by burning coal, oil, or gas (fossil fuels) in a furnace or by splitting certain atoms of uranium in a nuclear energy plant. Nothing is burned or exploded in a nuclear energy plant. Rather, the uranium fuel generates heat through a process called fission.

What Is Fission? Where Does It Take Place?

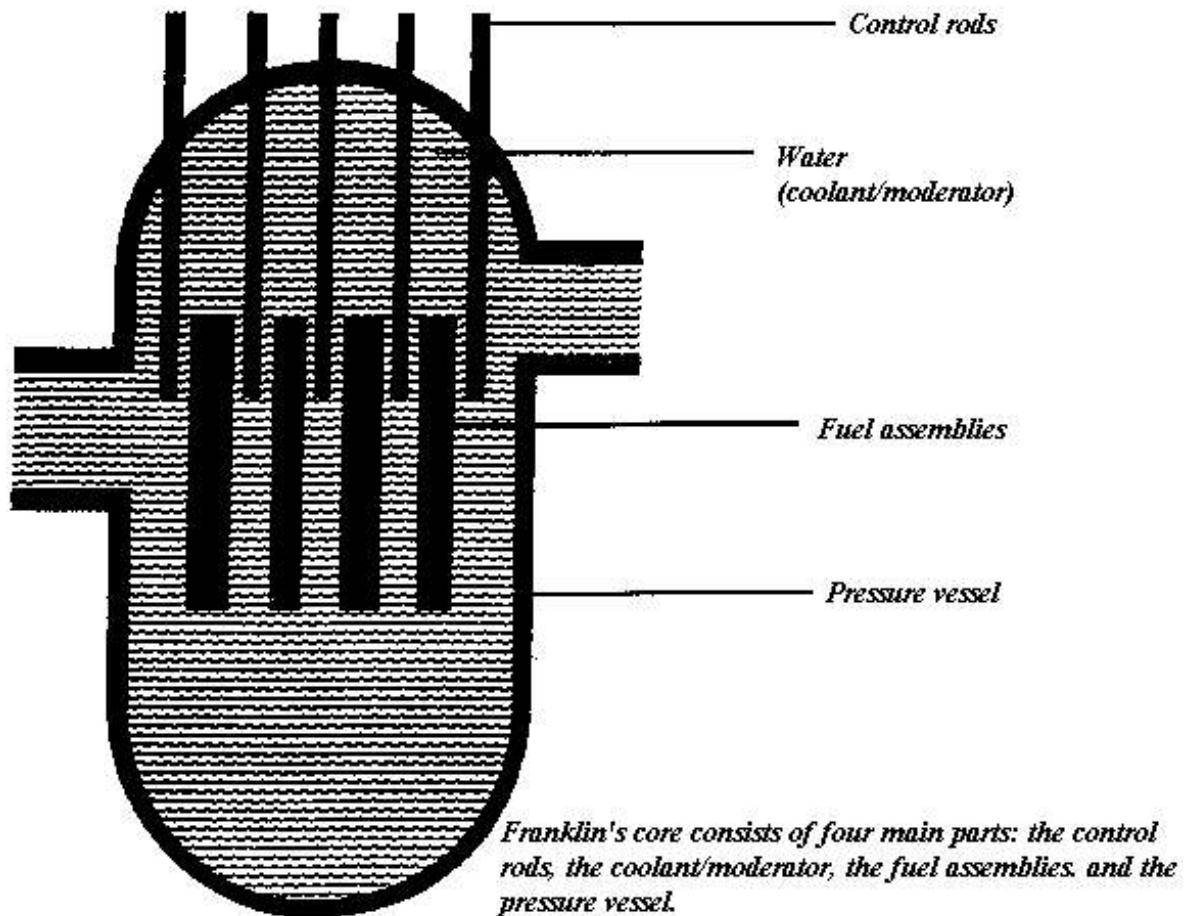
Uranium is an element that can be found in the crust of the Earth. This element, quite abundant in many areas of the world, is naturally radioactive. Certain isotopes of uranium can be used as fuel in a nuclear power plant. The uranium is formed into ceramic pellets about the size of the end of your finger. [Reactor Fuel Assembly]



Reactor Fuel Assembly

These pellets are inserted into long, vertical tubes (fuel rods) within the reactor. The reactor is the heart of the nuclear power plant. Basically, it is a machine that heats water.

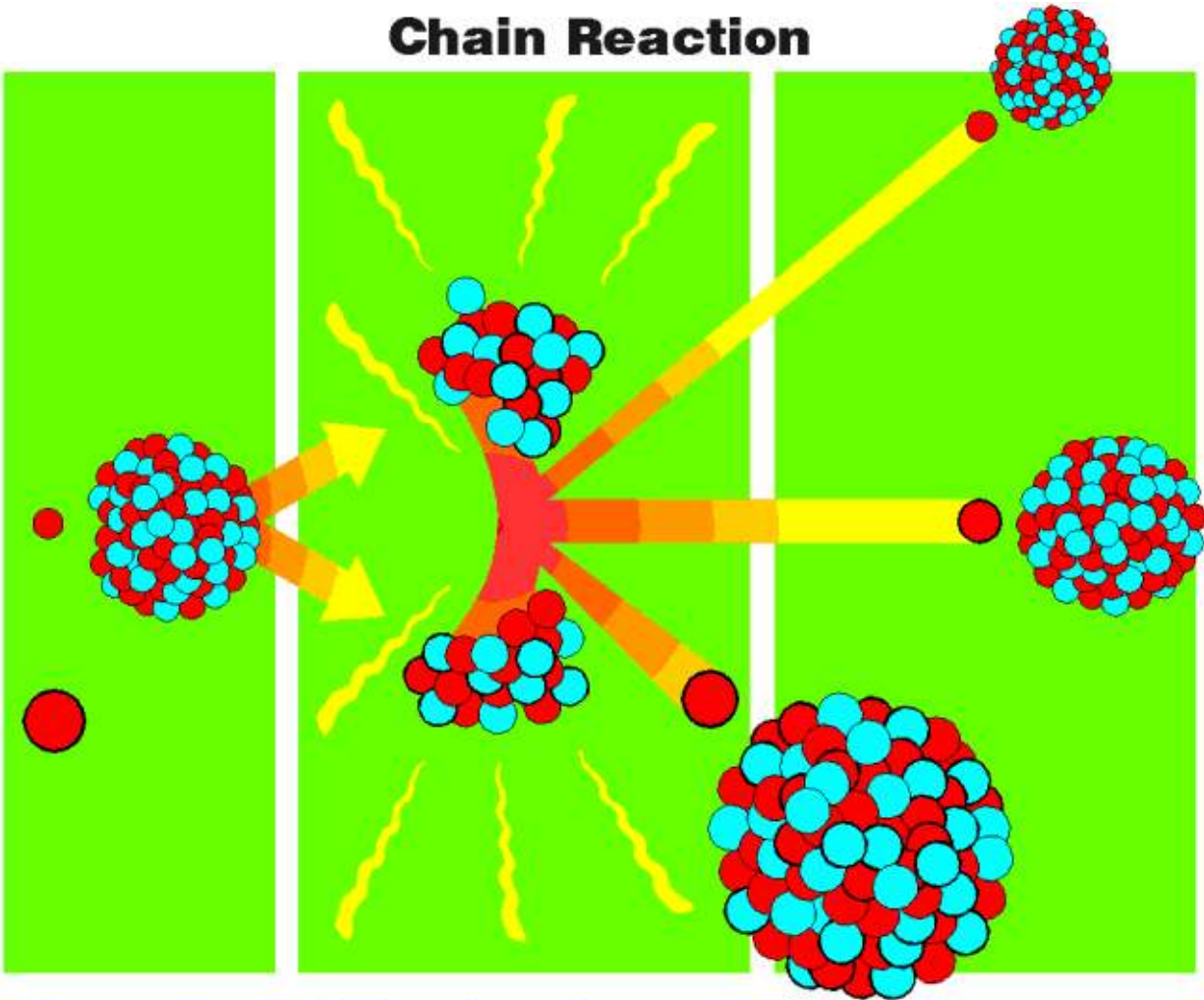
A reactor has four main parts: the uranium fuel assemblies, the control rods, the coolant/moderator, and the pressure vessel. The fuel assemblies, control rods, and coolant/moderator make up what is known as the reactor core. The core is surrounded by the pressure vessel. [Franklin's Core]



We also have to understand that uranium cannot just be thrown into a reactor the way we shovel coal into a furnace. The fuel rods, containing the uranium, are carefully bound together into fuel assemblies, each of which contains about 240 rods. The assemblies hold the rods apart so that when they are submerged into the reactor core, water can flow between them.

When the uranium atom splits, it releases energy and two or more neutrons from its nucleus. These neutrons can then hit the nuclei of other uranium atoms causing them to fission. The sequence of one fission triggering others, and those triggering still more, is called a chain reaction. When the atoms split, they release energy in the form of heat. The heat is transferred from the reactor core to the steam generator.

Chain Reaction

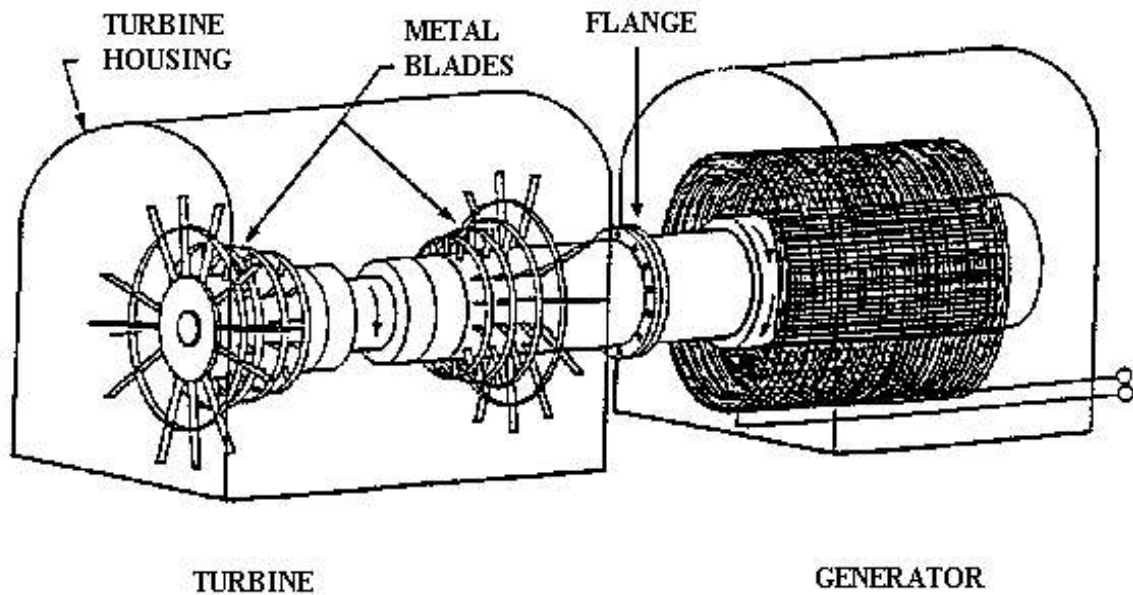


1 A neutron is about to hit the nucleus of a uranium atom.

2 The uranium nucleus splits (fissions) into several smaller atoms, releasing heat and several more neutrons.

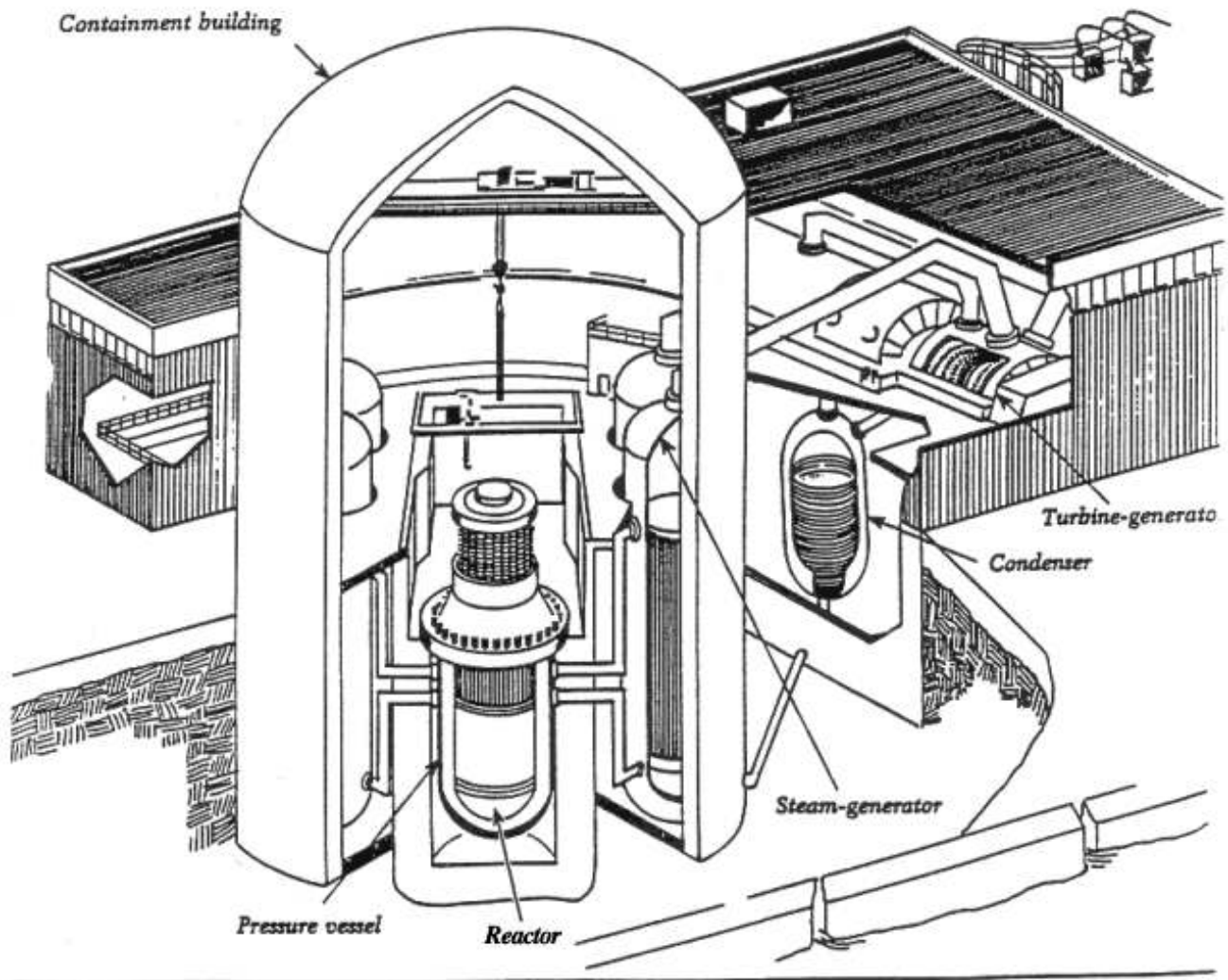
3 The chain reaction begins: those neutrons hit other nuclei, causing them to fission. And so on.

Here, it's converted to high pressure steam which turns the turbine in the electric generator.
[Turbine/Generator]



When a turbine is attached to the electrical generator, the kinetic energy (i.e., motion) of steam pushes against the fan-type blades of the turbine, causing the turbine, and therefore the attached rotor of the electrical generator, to spin and produce electricity.

This image shows the basic design of the nuclear fuel steam plant and its various components. [Nuclear Power Plant]



2 major parts of a nuclear powerplant work together to produce electricity.

In the past few minutes I've introduced several new terms. Let me explain what each means in the energy generating process. First, control rods. What are they? How are they used?

The control rods slide up and down in between the fuel assemblies in the reactor core. They control or regulate the speed of the nuclear reaction by absorbing neutrons. Here's how it works: When the control rods absorb neutrons, fewer neutrons hit the uranium atoms thus slowing down the chain reaction.

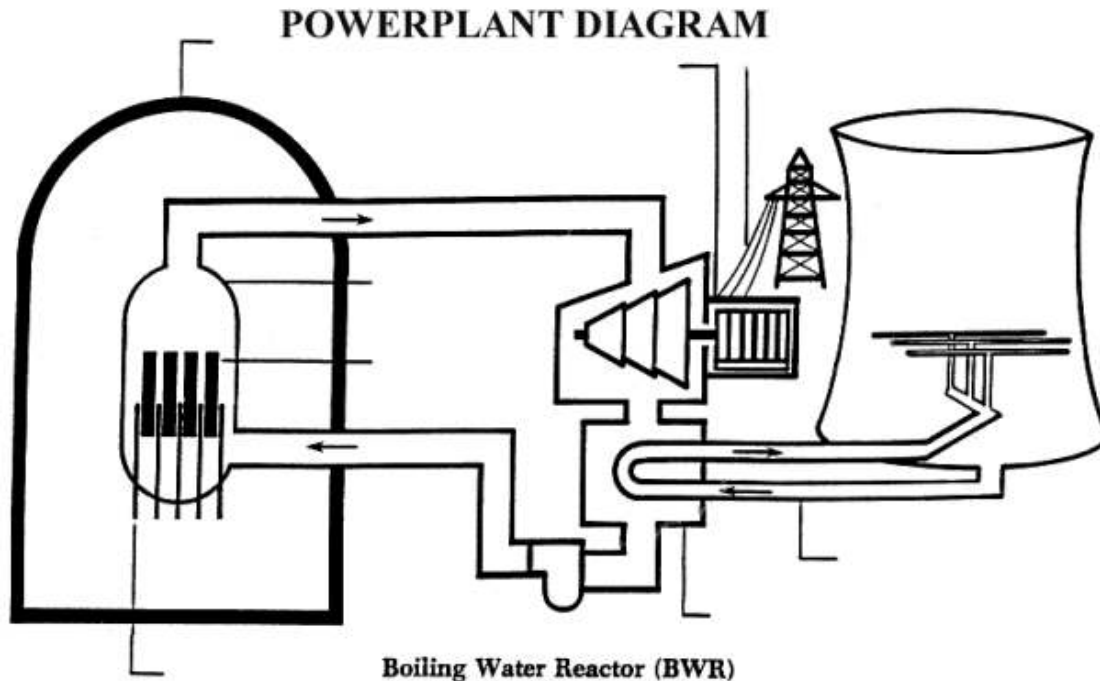
On the other hand, when the core temperature goes down, the control rods are slowly lifted out of the core, and fewer neutrons are absorbed. Therefore, more neutrons are available to cause fission. This releases more heat energy.

Just as there are different types of houses and cars, there are different types of nuclear power plants that generate electricity. The two basic types being used in the United States are the boiling water reactor (BWR) and the pressurized water reactor (PWR). These power plants are often referred to as light water reactors.

Pass out Activities 4 - Boiling Water Reactor (BWR) and 5 - Pressurized Water Reactor (PWR). Students can label components of each type reactor during the discussion.]

Boiling Water Reactor (BWR)

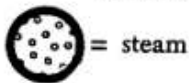
The boiling water reactor operates in essentially the same way as a fossil fuel generating plant. Neither of these types of power plants have a steam generator. Instead, water in the BWR boils inside the pressure vessel and the steam water mixture is produced when very pure water (reactor coolant) moves upward through the core absorbing heat. The water boils and produces steam. When the steam rises to the top of the pressure vessel, water droplets are removed, the steam is sent to the turbine generator to turn the turbine. [BWR schematic]



A. Identify the powerplant parts by writing the number of the correct powerplant part on the blank.

- | | | |
|-------------------------|-----------------------|-----------------|
| 1. containment building | 4. cooling water loop | 7. condenser |
| 2. turbine-generator | 5. transmission lines | 8. nuclear fuel |
| 3. control rods | 6. reactor | |

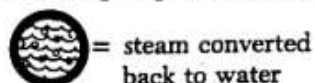
B. Color the separate loops using a different color for each loop. Then use the following symbols to show what is in each loop or part of a loop.



= steam



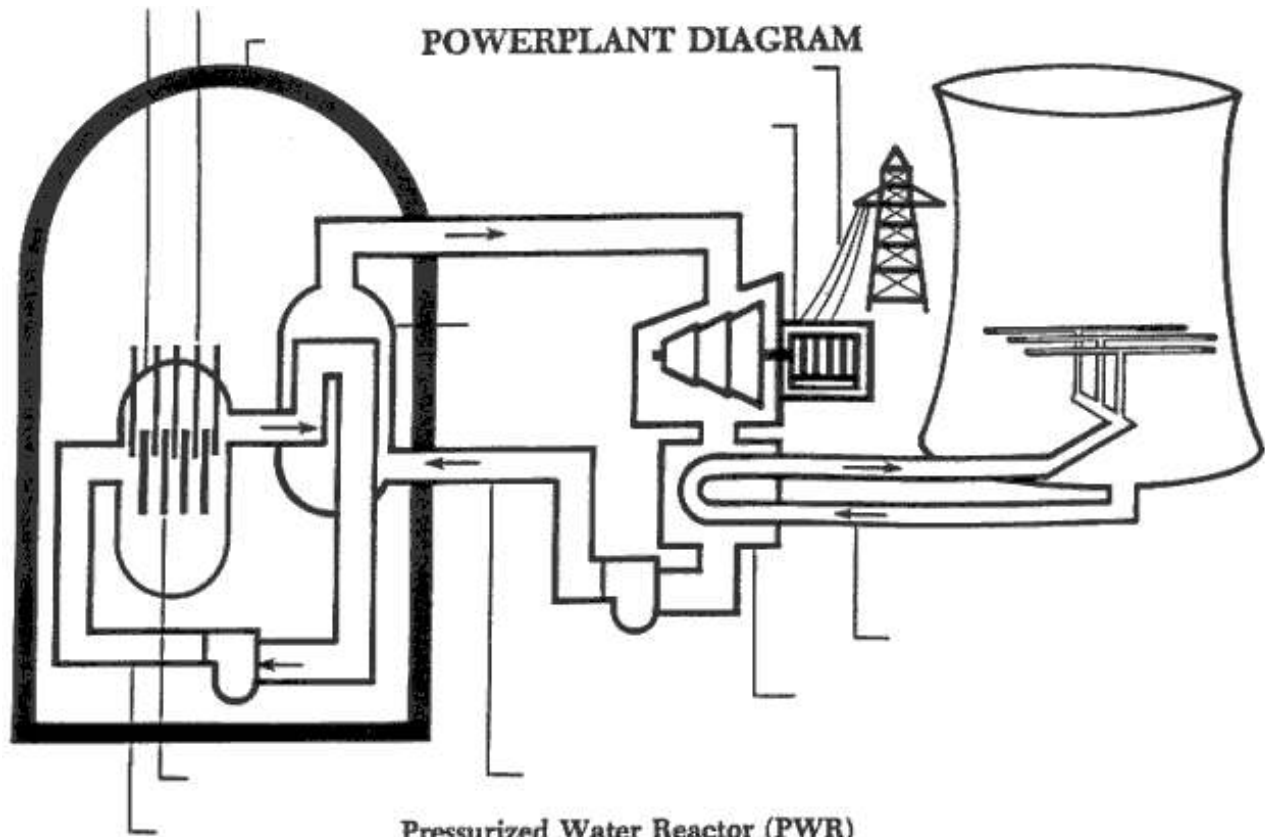
= water



= steam converted
back to water

Pressurized Water Reactor (PWR)

The pressurized water reactor differs from the BWR in that the steam to run the turbine is produced in a steam generator. Water boils at 212°F or 100°C. If a lid is tightly placed over a pot of boiling water (a pressure cooker), the pressure inside the pot will increase because the steam cannot escape. As the pressure increases, so does the temperature of the water in the pot. In the PWR plant, a pressurizer unit keeps the water that is flowing through the reactor vessel under very high pressure to prevent it from boiling. The hot water then flows into the steam generator where it is converted to steam. The steam passes through the turbine which produces electricity. About two-thirds of the reactor power plants in the U.S. are of the PWR type. [PWR schematic]



A. Identify the powerplant parts by writing the number of the correct powerplant part on the blank.

- | | | |
|-------------------------|-----------------------|-----------------------|
| 1. reactor | 5. steam-generator | 9. first water loop |
| 2. control rods | 6. turbine-generator | 10. second water loop |
| 3. cooling water loop | 7. transmission lines | 11. nuclear fuel |
| 4. containment building | 8. condenser | |

B. Color the separate loops using a different color for each loop. Use the following symbols to show what is in the loop or part of the loop.



= steam



= steam converted
back to water



= cooling water



= water in first
loop

Answers to Questions from "Nuclear Reactors/Energy Generation" Unit Outline:

1. Q: Is there a nuclear power plant near where you live? What type is it?

A: Example: 40 miles south of Annapolis, MD -- Calvert Cliffs 1 & 2 (PWR).

2. Q: Why don't boiling water reactors have steam generators?

A: Because the water is boiled inside the pressure vessel and the steam is used directly to turn the turbine.

3. Q: What is the purpose of a "cooling tower"?

A: To remove excess heat from the reactor circulating water system.

4. Q: What percentage of our electricity in the U.S. is produced in nuclear power plants?

A: Approximately 20 percent.

5. Q: Name the two types of reactor power plants in operation the U.S. What are the basic differences?

A: a. Boiling water reactor (BWR) -- water is boiled in the pressure vessel and the steam is used directly to turn the turbine.

b. Pressurized water reactor (PWR) -- water flows through a steam generator where it is heated to produce steam that then flows to the turbine to generate electricity.