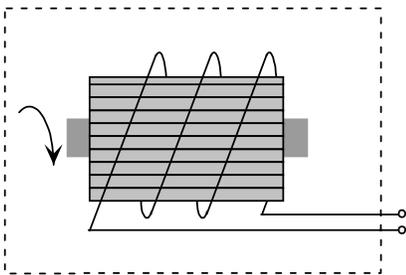
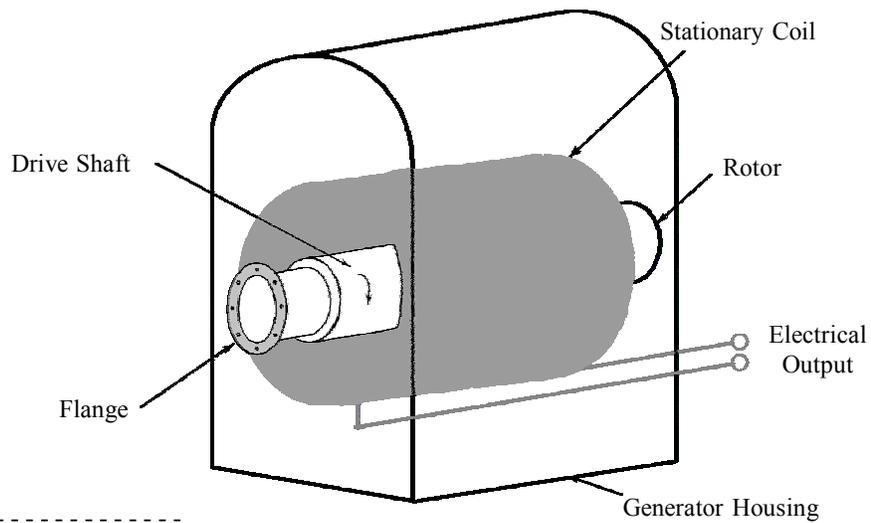
The background features a decorative graphic consisting of three overlapping circles in shades of blue, arranged in a triangular pattern. Two thin, light blue lines intersect at the top left, forming a large 'V' shape that frames the central text.

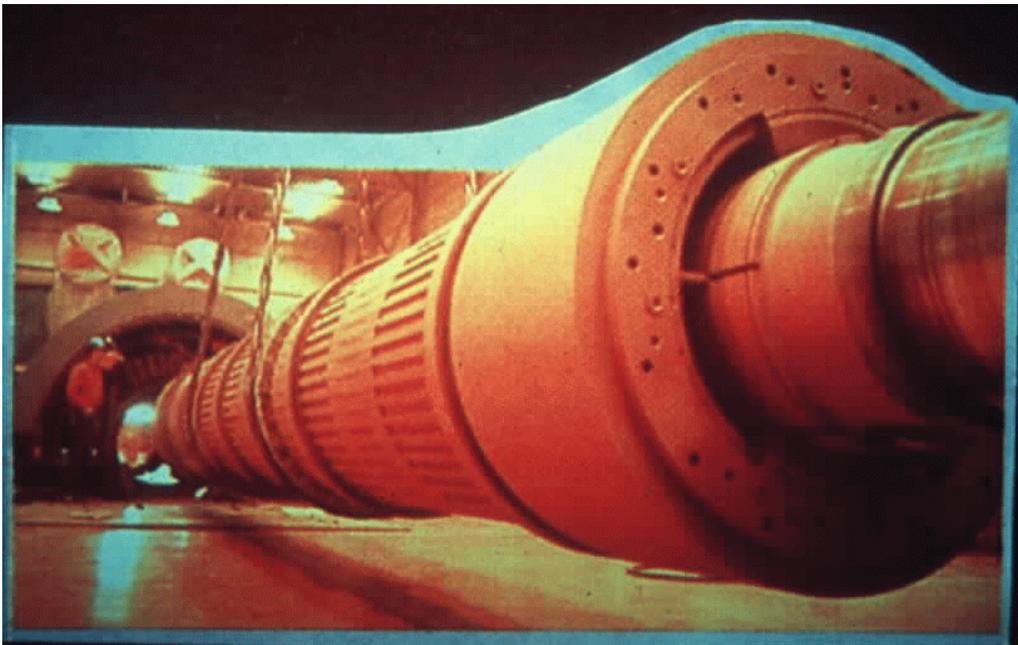
# Nuclear Power for Electrical Generation

# Nuclear Power for Electrical Generation

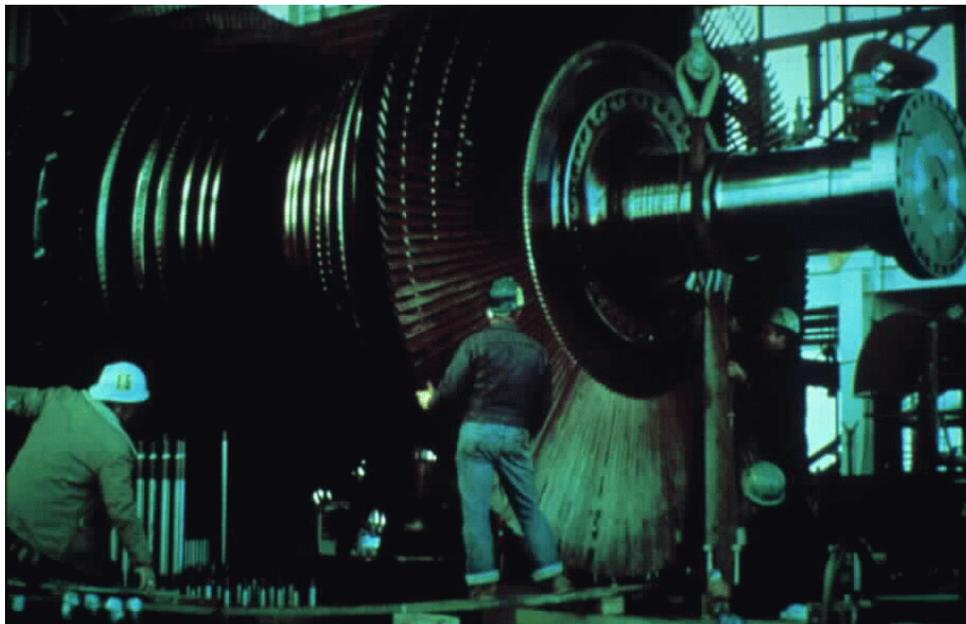
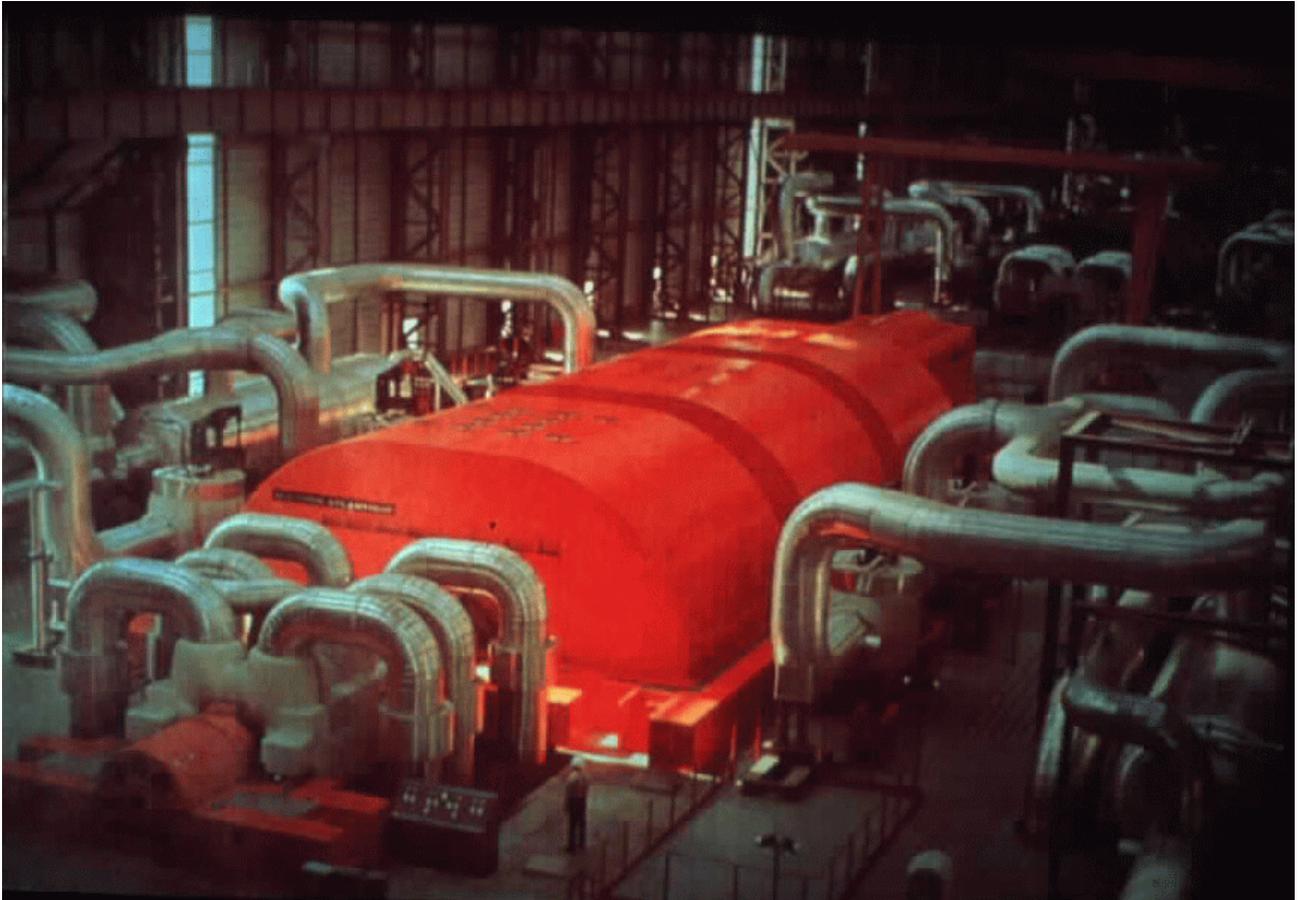
The purpose of a nuclear power plant is not to produce or release “Nuclear Power.” The purpose of a nuclear power plant is to produce electricity. It should not be surprising, then, that a nuclear power plant has many similarities to other electrical generating facilities. It should also be obvious that nuclear power plants have some significant differences from other plants.



## ELECTRICAL GENERATOR

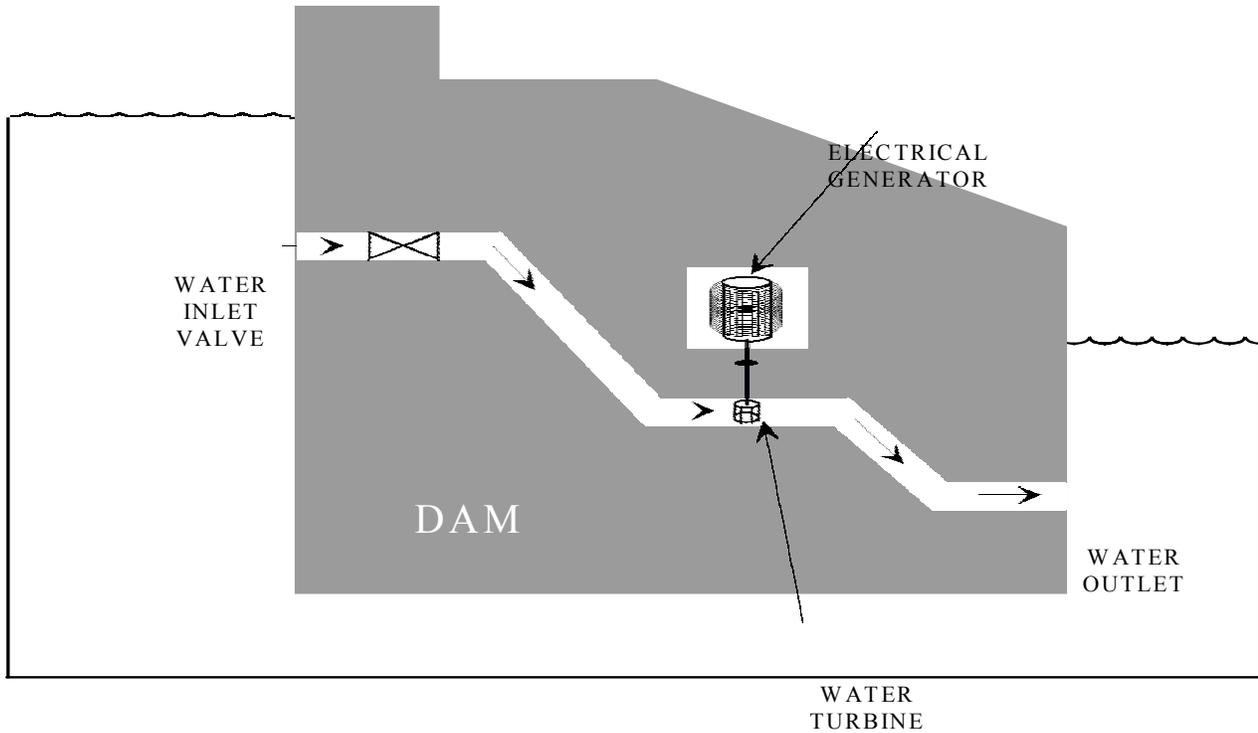


Of the several known methods to produce electricity, by far the most practical for large scale production and distribution involves the use of an “electrical generator.” In an electrical generator, a magnet (rotor) revolves inside a coil of wire (stator), creating a flow of electrons inside the wire. This flow of electrons is called electricity. Some mechanical device (wind turbine, water turbine, steam turbine, diesel engine, etc.) must be available to provide the motive force for the rotor.

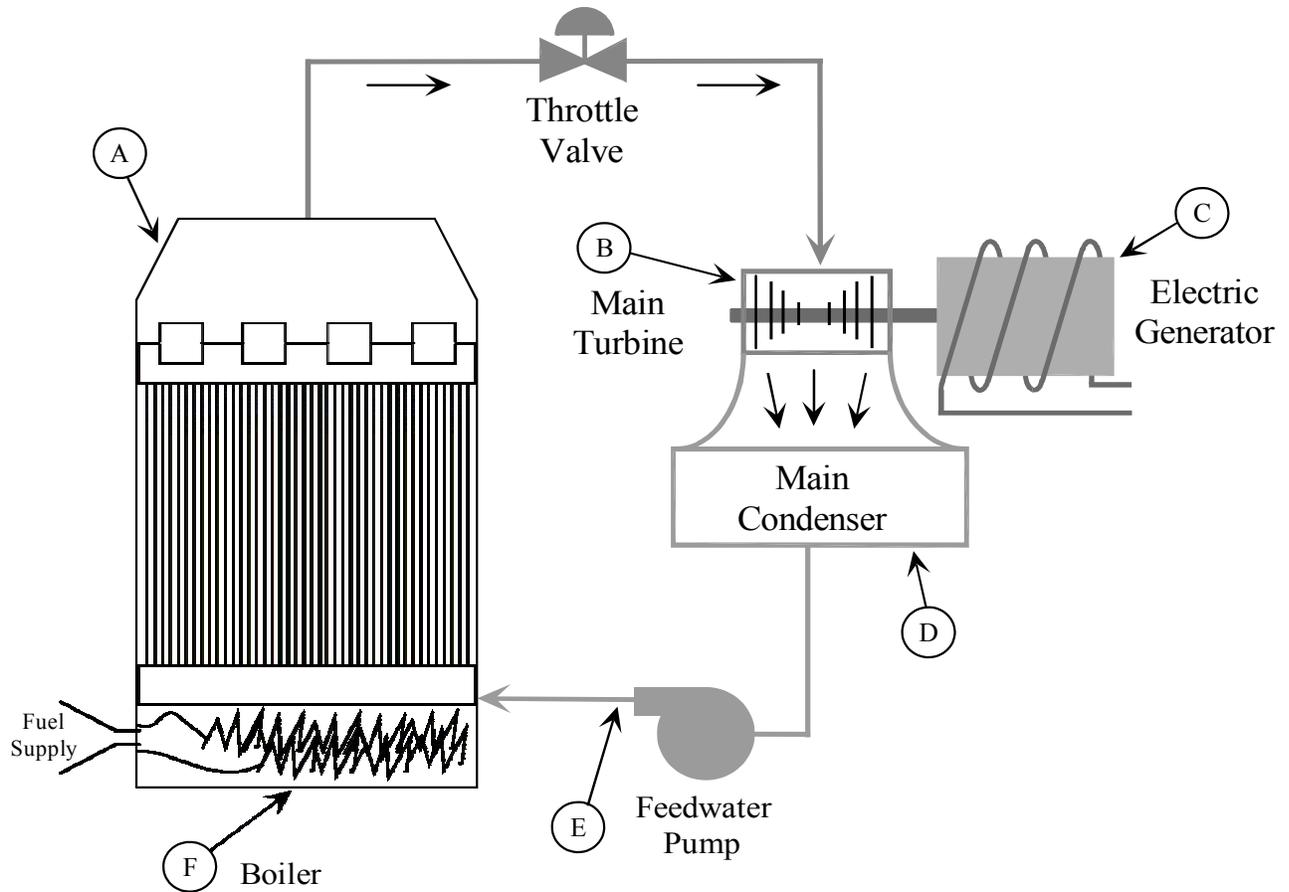


When a turbine is attached to the electrical generator, the kinetic energy (i.e., motion) of the wind, falling water, or steam pushes against the fan-type blades of the turbine, causing the turbine, and therefore, the attached rotor of the electrical generator, to spin and produce electricity.

# HYDROELECTRIC PLANT

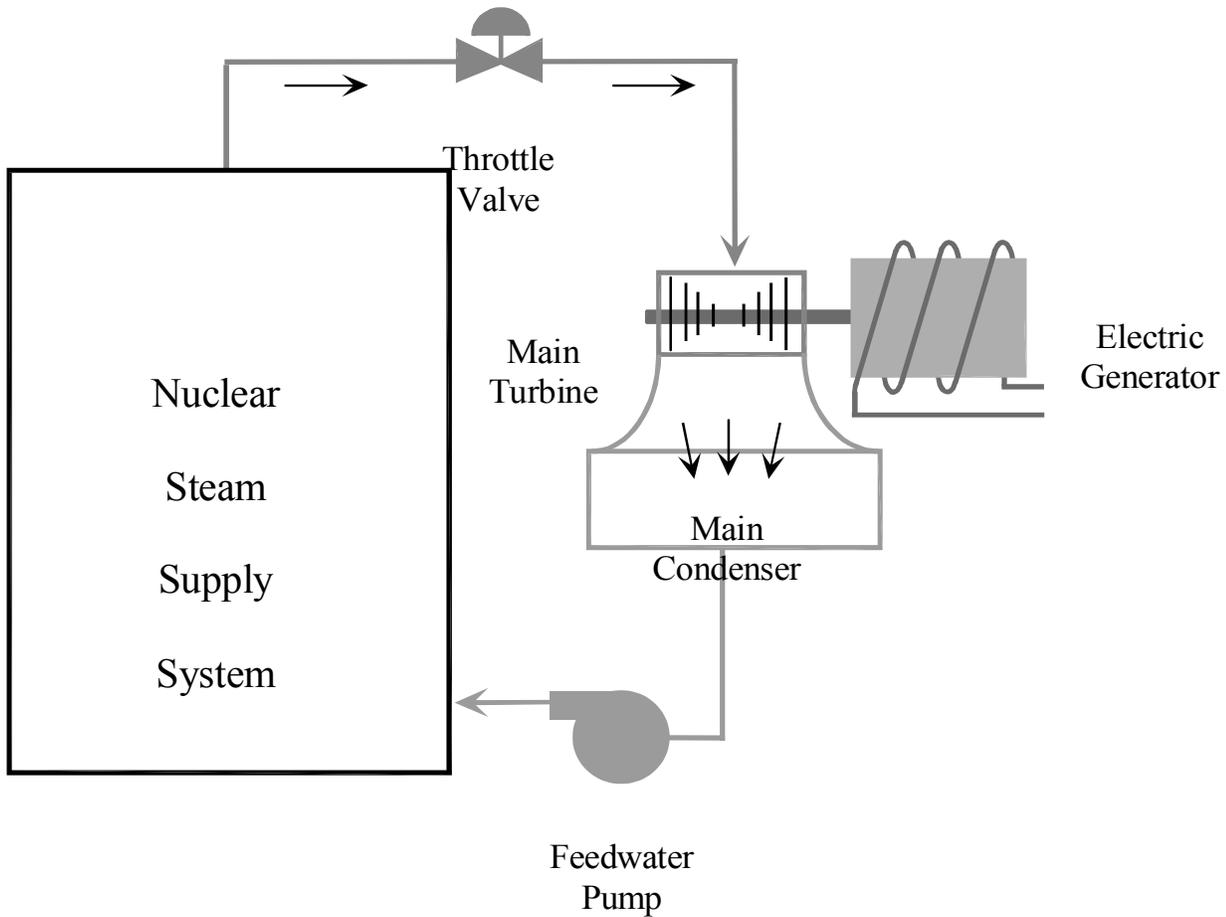


In a hydroelectric power plant, water, flowing from a higher level to a lower level, travels through the metal blades of a water turbine, causing the rotor of the electrical generator to spin and produce electricity.



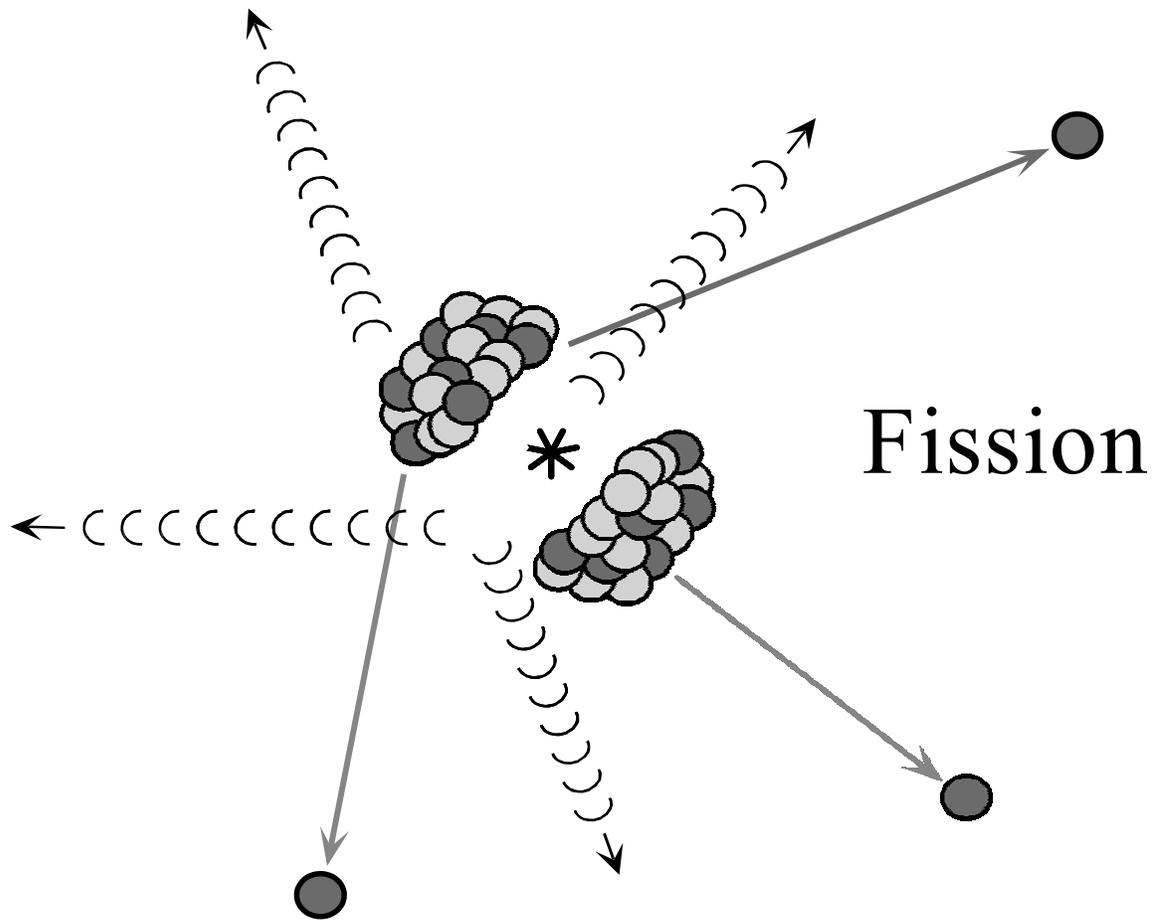
## FOSSIL FUEL STEAM PLANT

In a fossil-fueled power plant, heat, from the burning of coal, oil, or natural gas, converts (boils) water into steam (A), which is piped to the turbine (B). In the turbine, the steam passes through the blades, which spins the electrical generator (C), resulting in a flow of electricity. After leaving the turbine, the steam is converted (condensed) back into water in the condenser (D). The water is then pumped (E) back to the boiler (F) to be reheated and converted back into steam.



## Nuclear Fuel Steam Plant

In a nuclear power plant, many of the components are similar to those in a fossil-fueled plant, except that the steam boiler is replaced by a Nuclear Steam Supply System (NSSS). The NSSS consists of a nuclear reactor and all of the components necessary to produce high pressure steam, which will be used to turn the turbine for the electrical generator.



Like a fossil-fueled plant, a nuclear power plant boils water to produce electricity. Unlike a fossil-fueled plant, the nuclear plant's energy does not come from the combustion of fuel, but from the fissioning (splitting) of fuel atoms.

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# ENRICHMENT

(% U- $^{235}$ )

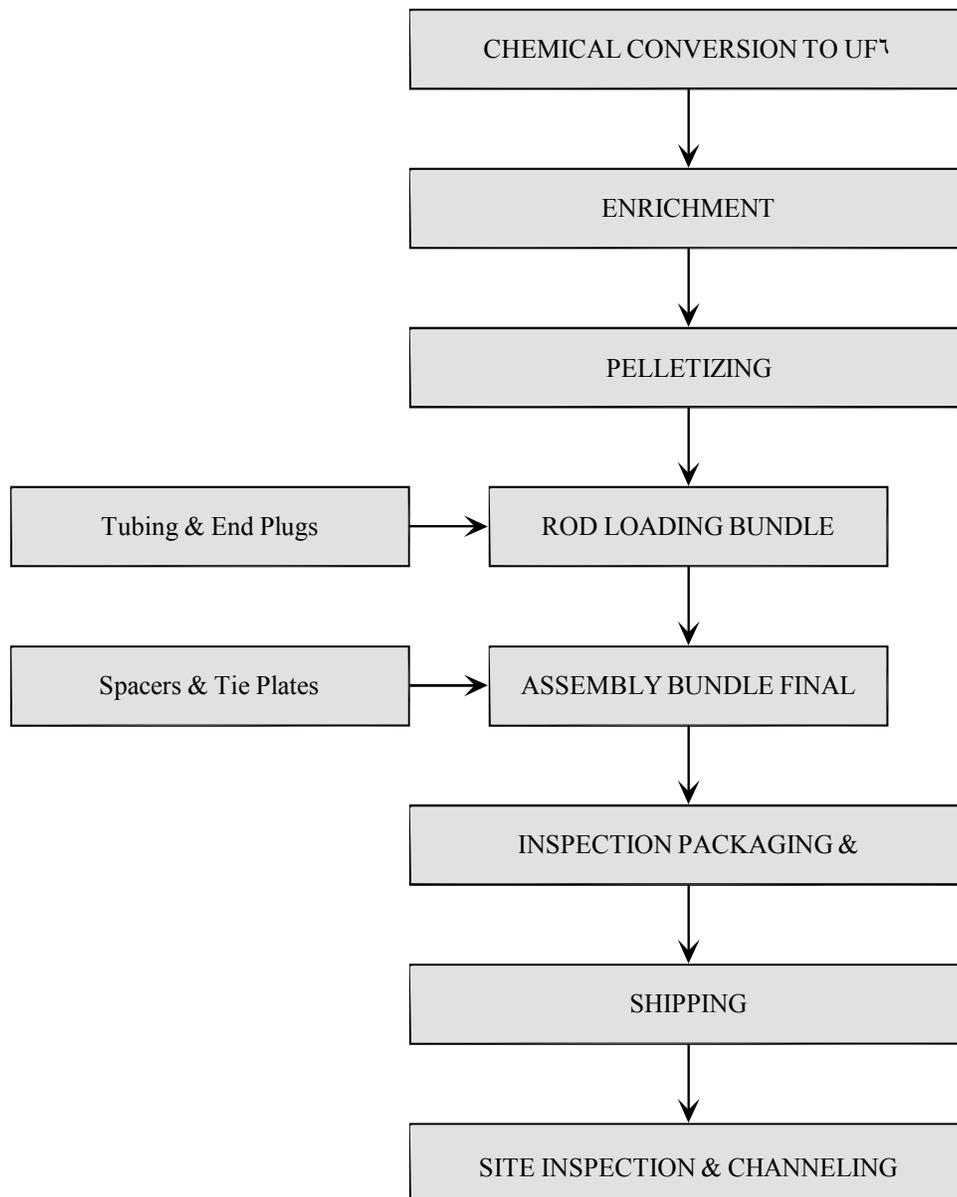


Uranium Ore (0.7%)



Fuel Pellet (3.5%)

The most common fuel for the electrical producing reactor plants in the United States is uranium. The uranium starts out as ore, and contains a very low percentage (or low enrichment) of the desired atoms (U- $^{235}$ ). The U- $^{235}$  is a more desirable atom for fuel, because it is easier to cause the U- $^{235}$  atoms to fission (split) than the much more abundant U- $^{238}$  atoms. Therefore, the fuel fabrication process includes steps to increase the number of U- $^{235}$  atoms in relation to the number of U- $^{238}$  atoms (enrichment process).



Once the fuel has been enriched, it is fabricated into ceramic pellets. The pellets are stacked into 12-foot long, slender metal tubes, generally made of a zirconium alloy. The tube is called the “fuel cladding.” When a tube is filled with the uranium pellets, it is pressurized with helium gas, and plugs are installed and welded to seal the tube. The filled rod is called a “fuel rod.” The fuel rods are bundled together into “fuel assemblies” or “fuel elements.” The completed assemblies are now ready to be shipped to the plant for installation into the reactor vessel.

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# REACTOR FUEL ASSEMBLIES

Both boiling water reactor and pressurized water reactor fuel assemblies consist of the same major components. These major components are the fuel rods, the spacer grids, and the upper and lower end fittings. The fuel assembly drawing on page 1-11 shows these major components (pressurized water reactor fuel assembly).

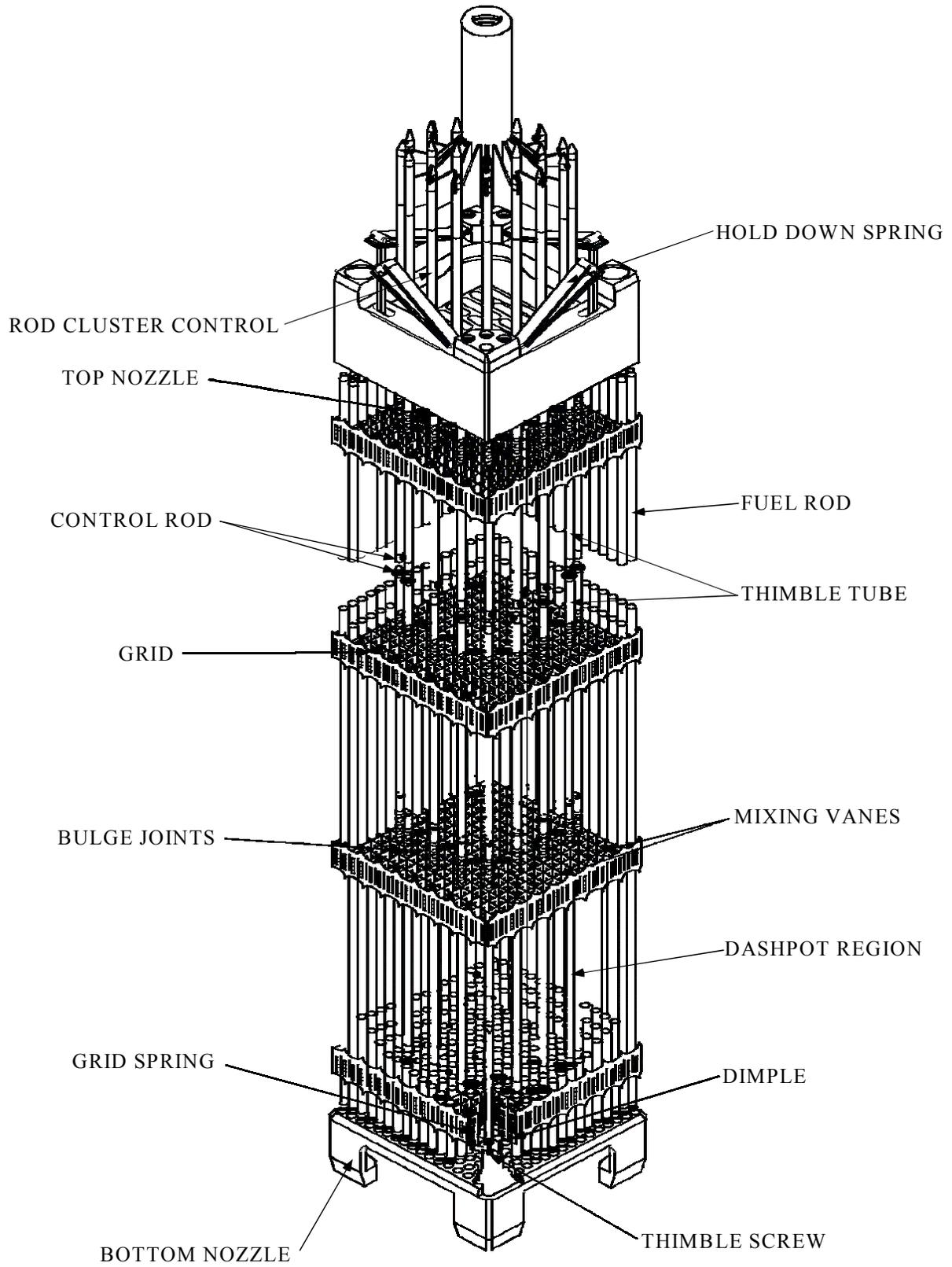
The fuel rods contain the ceramic fuel pellets. The fuel rods are approximately 12 feet long and contain a space at the top for the collection of any gases that are produced by the fission process. These rods are arranged in a square matrix ranging from 12 x 12 for pressurized water reactors to 8 x 8 for boiling water reactors.

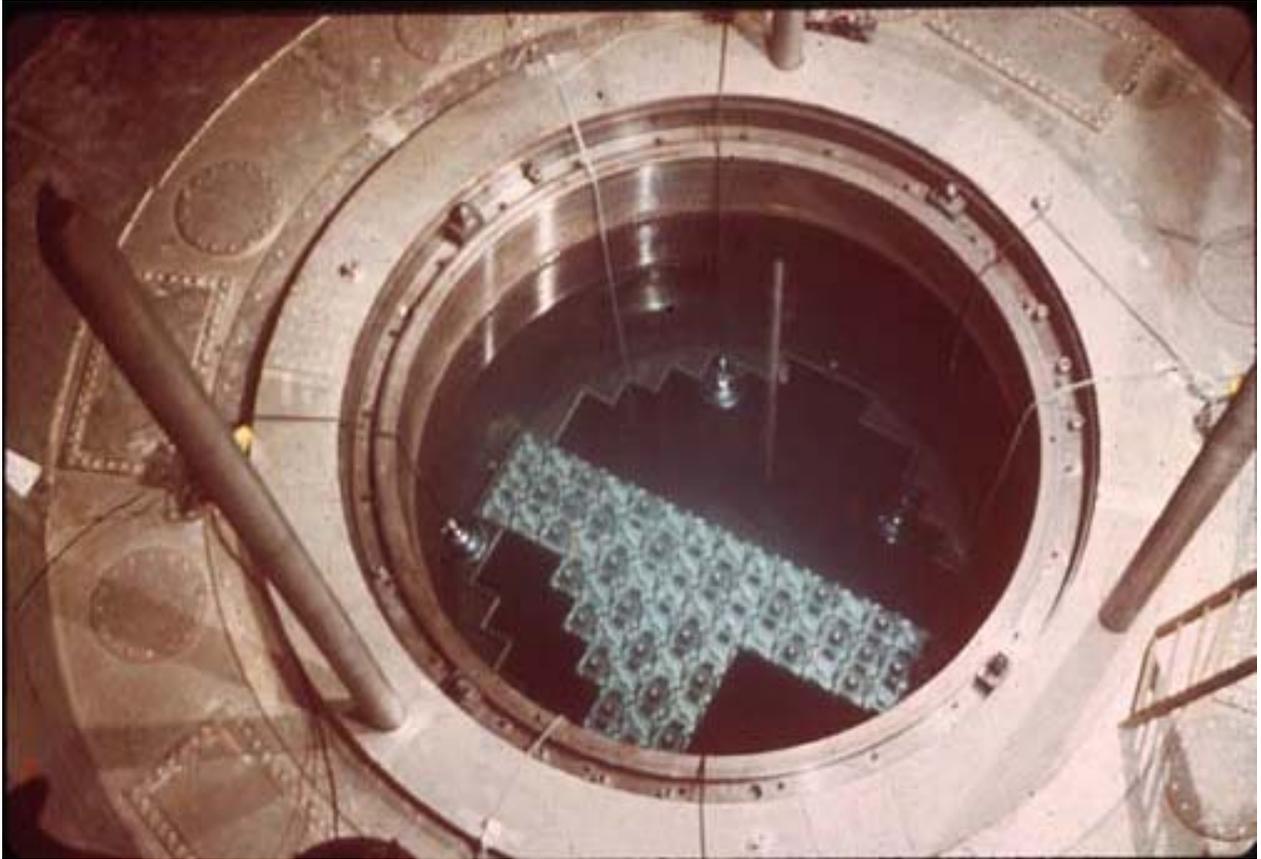
The spacer grids separate the individual rods with pieces of sprung metal. This provides the rigidity of the assemblies and allows the coolant to flow freely up through the assemblies and around the fuel rods. Some spacer grids may have flow mixing vanes that are used to promote mixing of the coolant as it flows around and through the fuel assembly.

The upper and lower end fittings serve as the upper and lower structural elements of the assemblies. The lower fitting (or bottom nozzle) will direct the coolant flow to the assembly through several small holes machined into the fitting. There are also holes drilled in the upper fitting to allow the coolant flow to exit the fuel assembly. The upper end fitting will also have a connecting point for the refueling equipment to attach for the moving of the fuel with a crane.

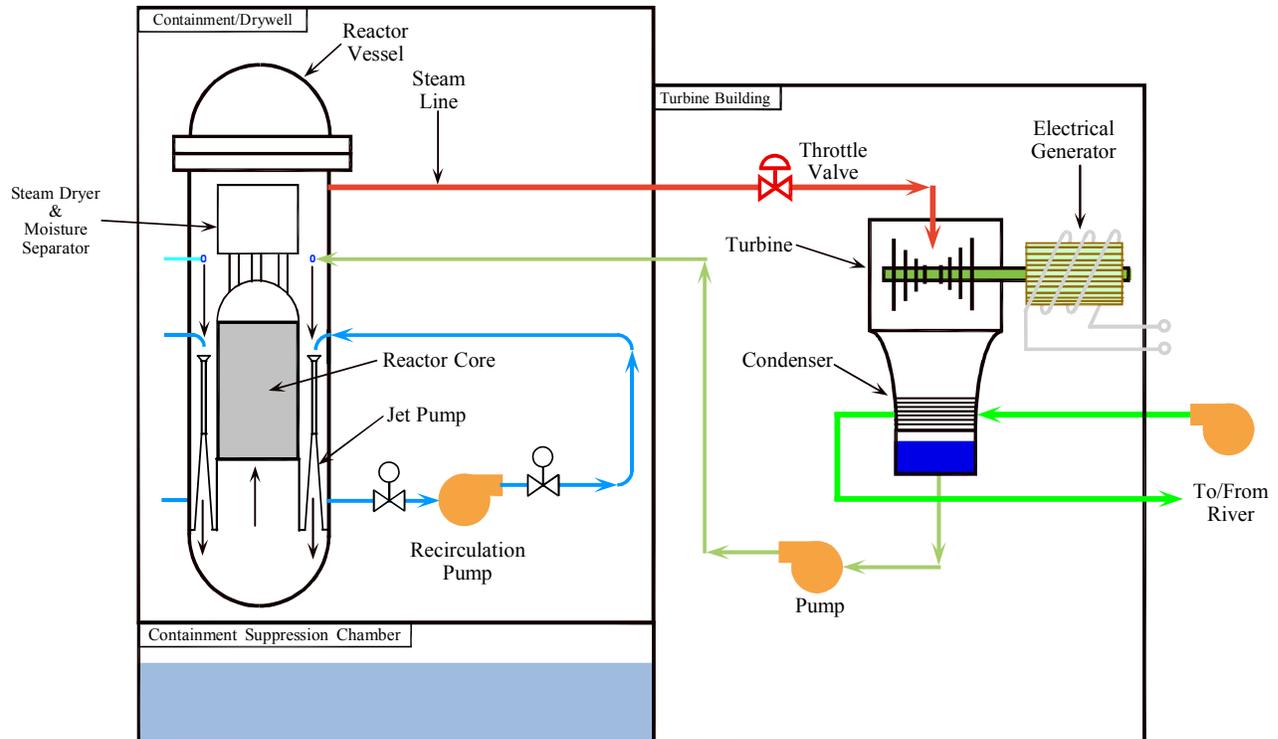
For pressurized water reactor fuel, there will also be guide tubes in which the control rods travel. The guide tubes will be welded to the spacer grids and attached to the upper and lower end fittings. The guide tubes provide a channel for the movement of the control rods and provide for support of the rods. The upper end of the control rod will be attached to a drive shaft, which will be used to position the rod during operations.

A brief description and a picture of boiling water reactor fuel can be found in Chapter 3 (pages 3-3 and 3-4).



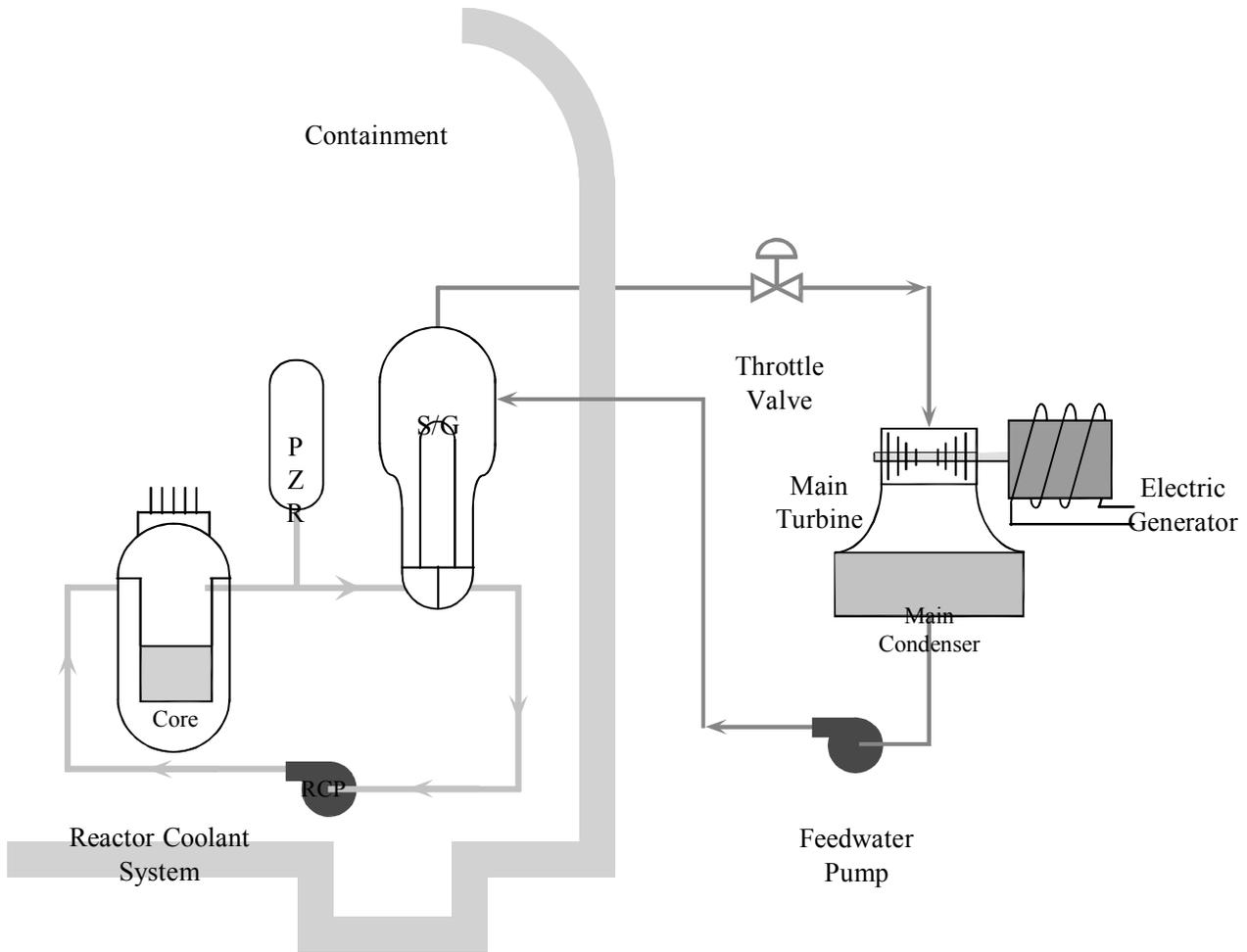


At the nuclear power plant, the fuel assemblies are inserted vertically into the reactor vessel (a large steel tank filled with water with a removable top). The fuel is placed in a precise grid pattern known as the “reactor core.”



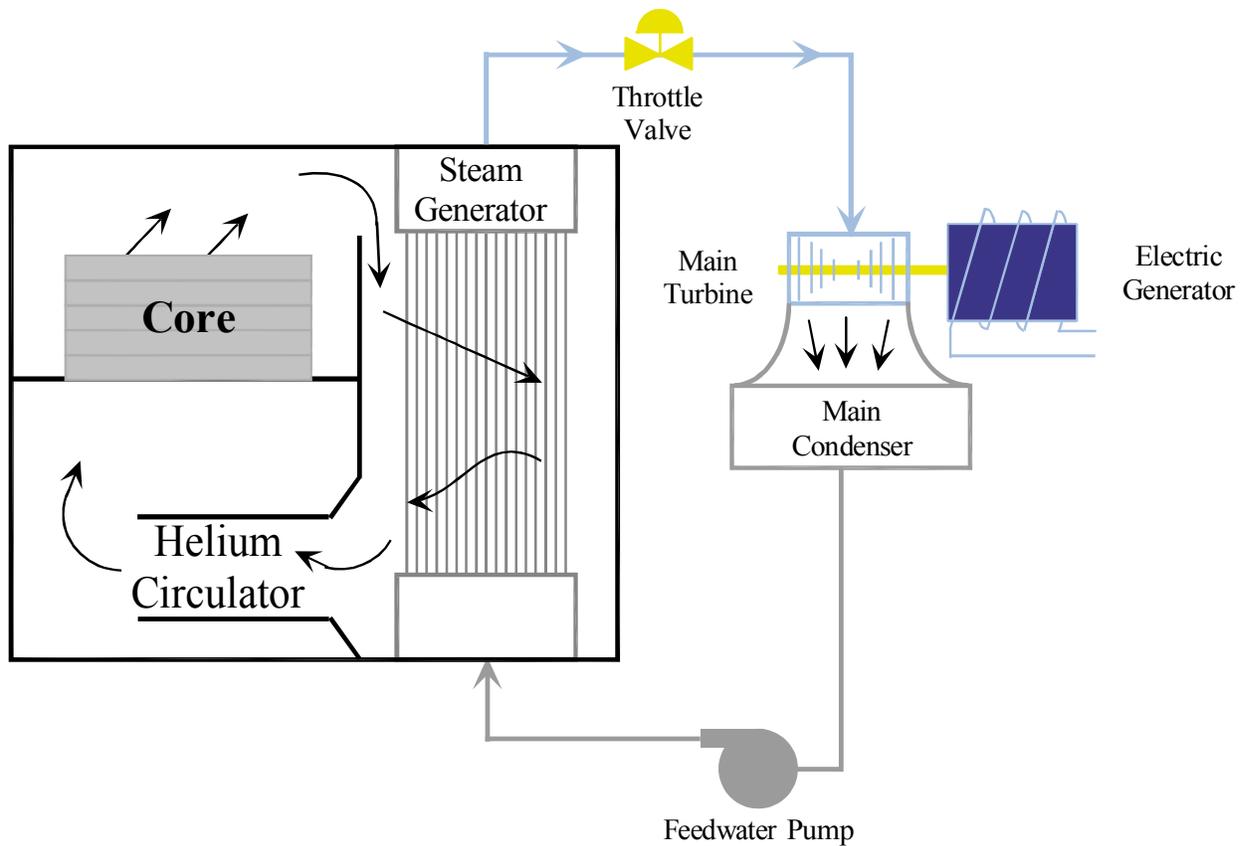
There are two basic types of reactor plants being used in the United States to produce electricity, the boiling water reactor (BWR) and the pressurized water reactor (PWR). The boiling water reactor operates in essentially the same way as a fossil-fueled generating plant. Inside the reactor vessel, a steam/water mixture is produced when very pure water (reactor coolant) moves upward through the core absorbing heat. The major difference in the operation of a boiling water reactor as compared to other nuclear systems is the steam void formation in the core. The steam/water mixture leaves the top of the core and enters two stages of moisture separation, where water droplets are removed before the steam is allowed to enter the steam line. The steam line, in turn, directs the steam to the main turbine, causing it to turn the turbine and the attached electrical generator. The unused steam is exhausted to the condenser where it is condensed into water. The resulting water (condensate) is pumped out of the condenser with a series of pumps and back to the reactor vessel. The recirculation pumps and the jet pumps allow the operator to vary coolant flow through the core and to change reactor power.

Boiling water reactors are manufactured in the United States by the General Electric Company, San Jose, California. Boiling water reactors comprise about one-third of the power reactors in the United States.



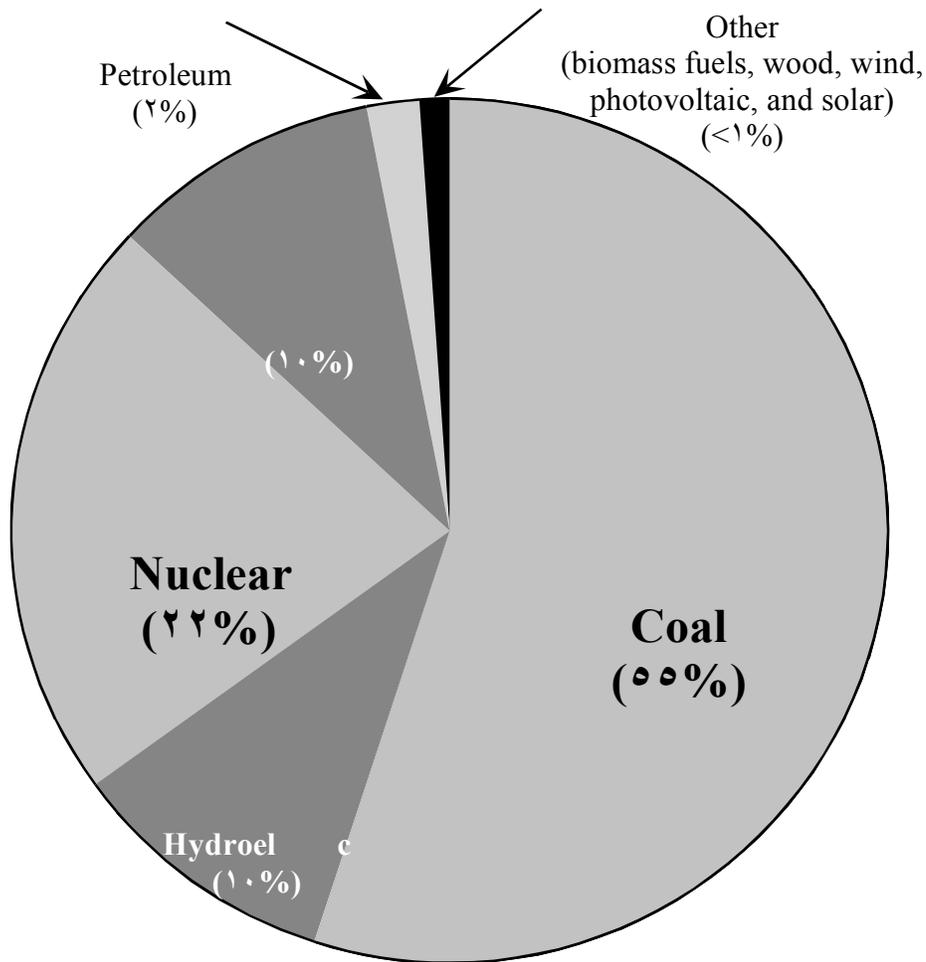
The pressurized water reactor (PWR) differs from the boiling water reactor in that steam is produced in the steam generator rather than in the reactor vessel. The pressurizer keeps the water that is flowing through the reactor vessel under very high pressure (more than 2,200 pounds per square inch) to prevent it from boiling, even at operating temperatures of more than 300°F. Pressurized water reactors make up about two-thirds of the power reactors in the United States.

Pressurized water reactors were manufactured in the United States by Westinghouse Electric Corporation (Pittsburgh, Pennsylvania), Babcock and Wilcox Company (Lynchburg, Virginia), and the Combustion Engineering Company (Windsor, Connecticut).



## High Temperature Gas-Cooled Reactor (HTGR)

Another type of reactor uses helium gas instead of water as its media for removing heat from the core. The only high temperature gas-cooled reactor (HTGR) in the United States was the Fort St. Vrain plant in Colorado. The plant was manufactured by General Atomic Company of La Jolla, California. High temperature gas-cooled reactors are widely used in other countries.

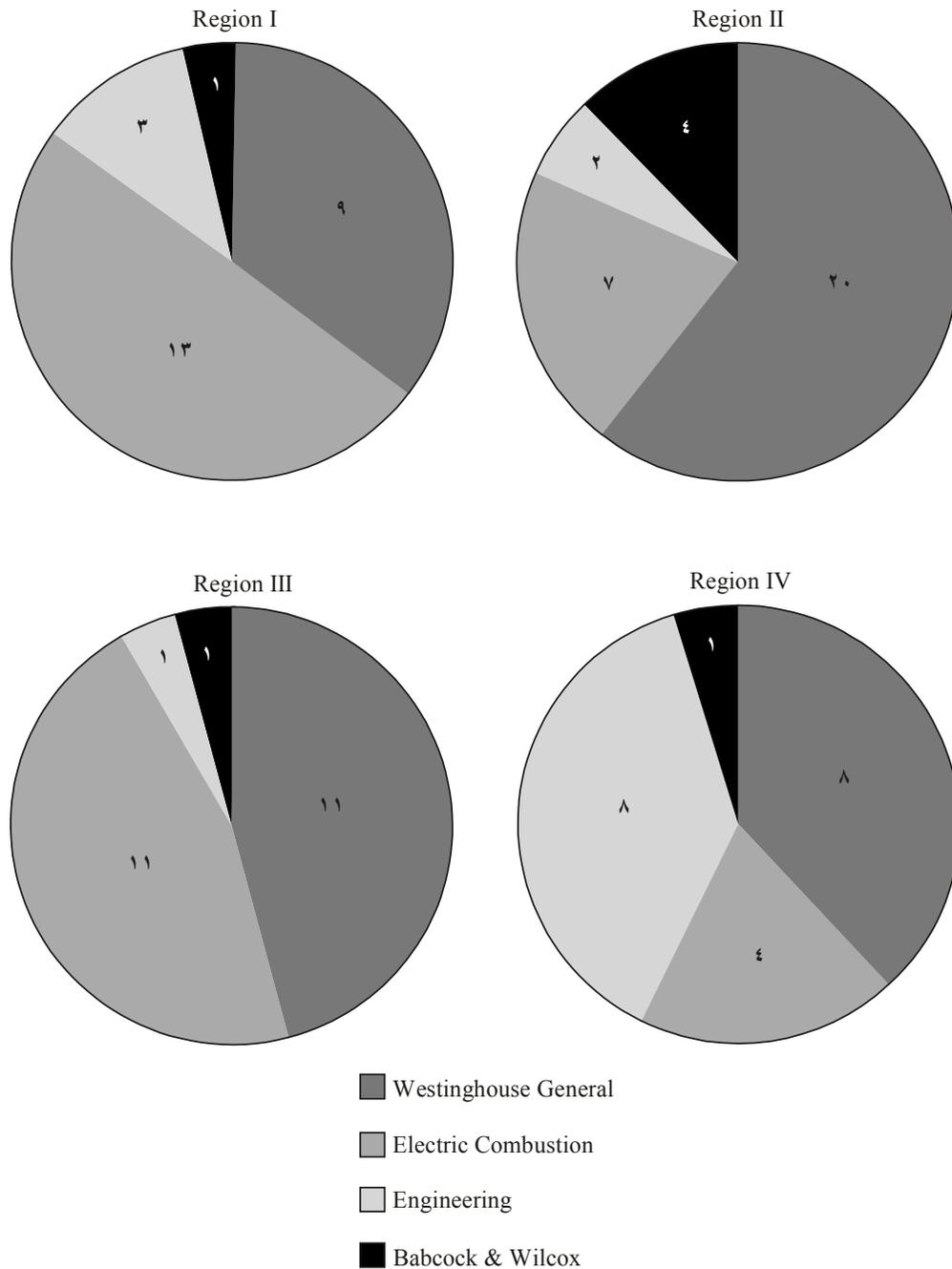


## Electrical Production by Type

Commercial nuclear power plants generate approximately 22% of the electricity produced in the United States. The total generation is approximately 3,800 thousand gigawatt-hours.

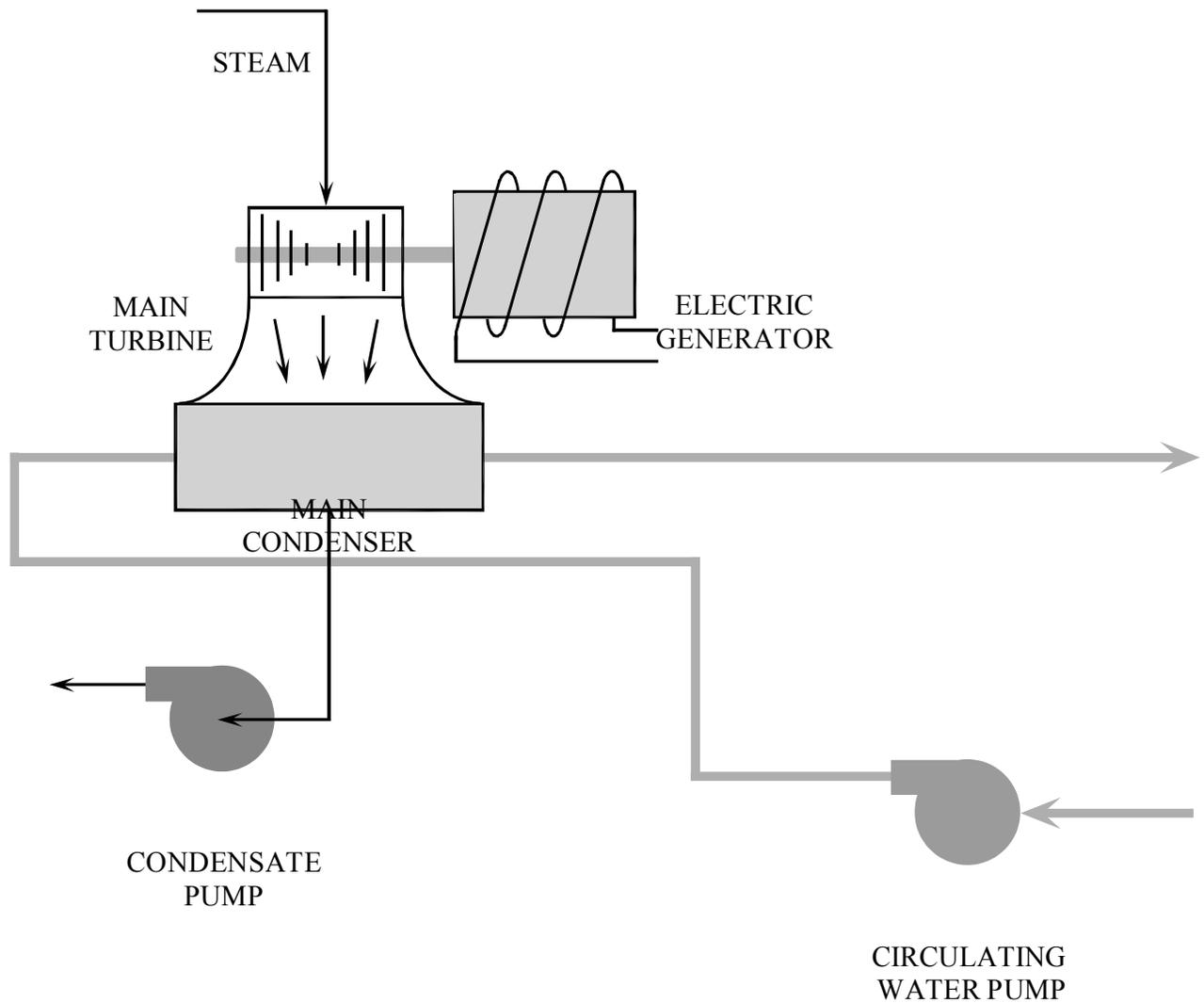
For comparison purposes, nuclear generation accounts for the following of the total electrical production in some other countries: 70% in France, 46% in Sweden, 43% in Ukraine, 39% in south Korea, 30% in Germany, and 30% in Japan.

The electricity produced in the United States from nuclear power is equivalent to 31% of the world's total nuclear generated electrical power. This compares with 16% for France, 13% for Japan, 9% for Germany, 0% for Russia, and 4% for South Korea and United Kingdom.

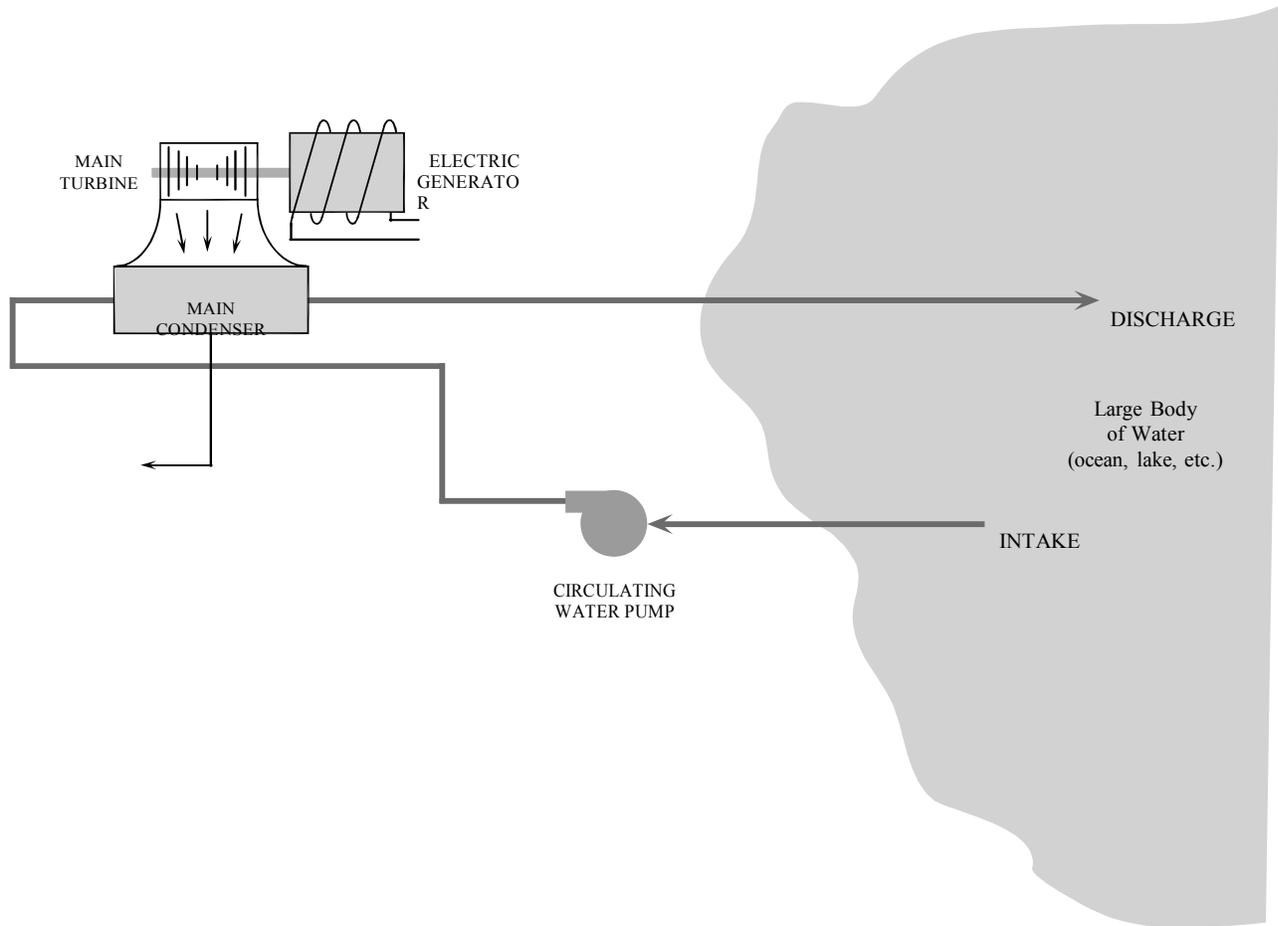


There are currently 104 licensed commercial nuclear power plants in the United States. Of the 104 plants, 28 were built by Westinghouse, 30 by General Electric, 14 by Combustion Engineering, and 7 by Babcock & Wilcox.

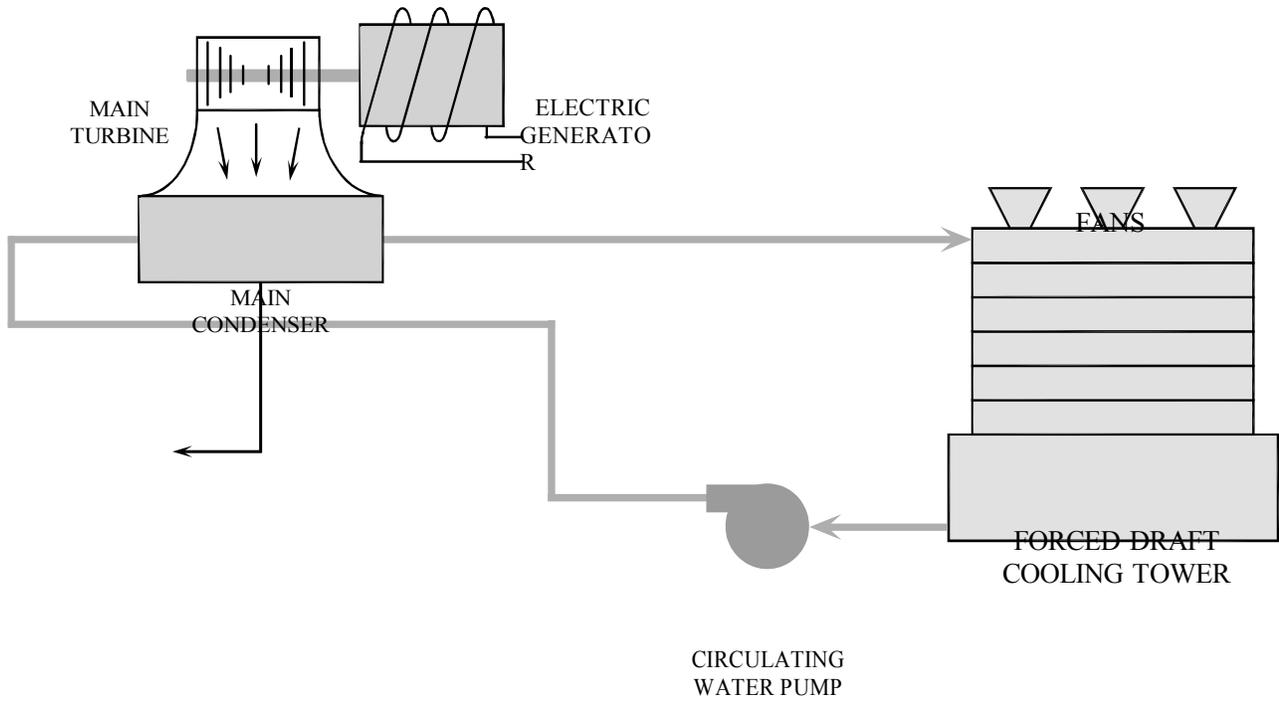
The illustration above shows the breakdown of the plants, by vendor, assigned to the four NRC Regions.



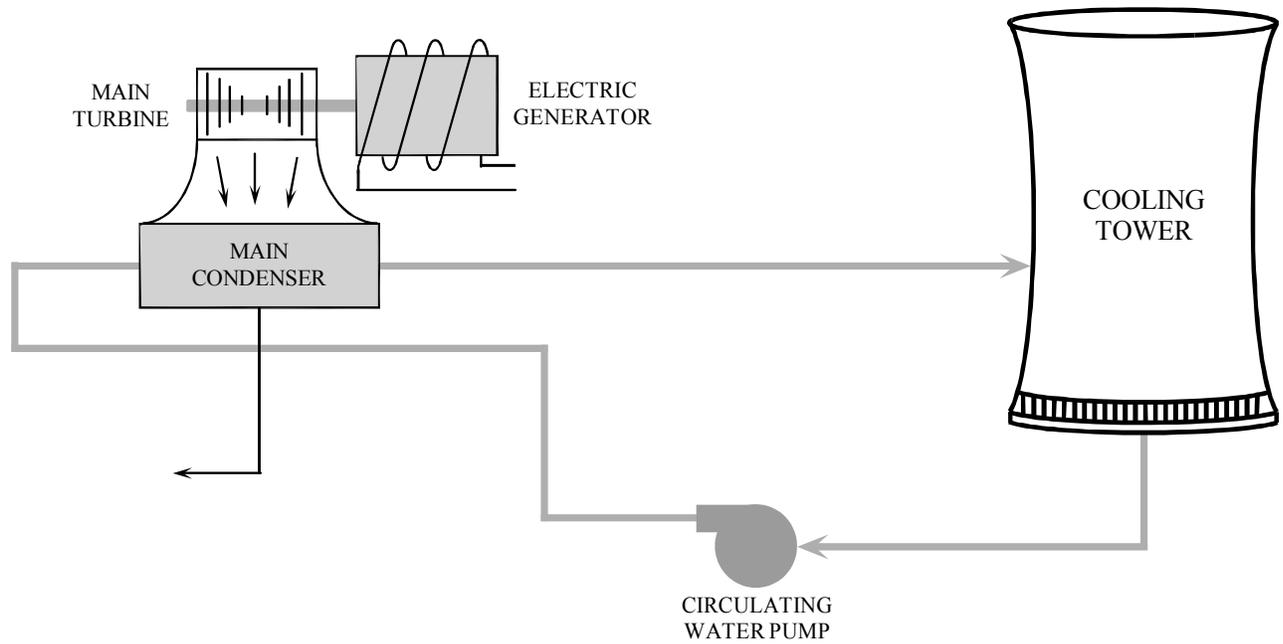
To operate properly, all steam plants, whether nuclear or fossil-fueled, need a circulating water system to remove excess heat from the steam system in order to condense the steam, and transfer that heat to the environment. The circulating water system pumps water from the environment (river, lake, ocean) through thousands of metal tubes in the plant's condenser. Steam exiting the plant's turbine is very rapidly cooled and condensed into water when it comes in contact with the much cooler tubes. Since the tubes provide a barrier between the steam and the environment, there is no physical contact between the plant's steam and the cooling water. Because a condenser operates at a vacuum, any tube leakage in this system will produce an "inflow" of water into the condenser rather than an "outflow" of water to the environment.



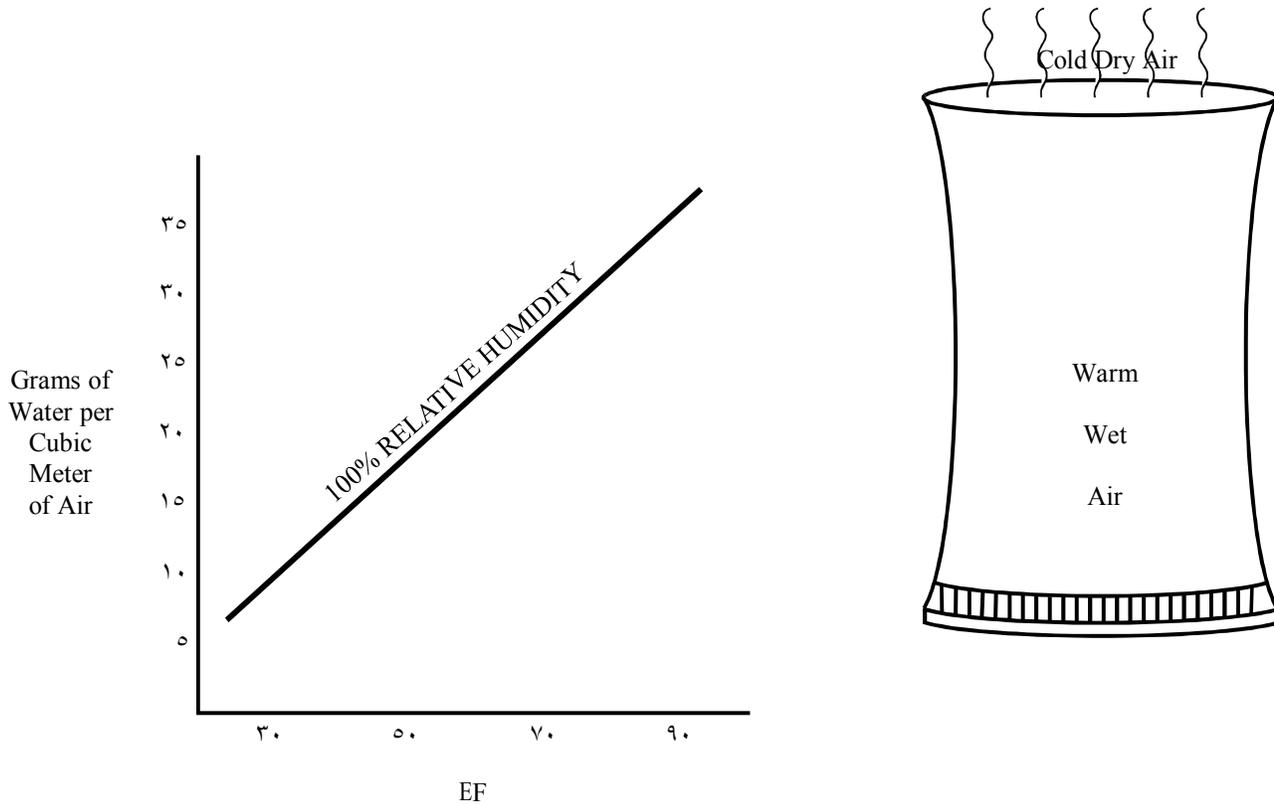
Power plants located on the ocean (or other large bodies of water) will often discharge their circulating water directly back to the ocean under strict environmental protection regulations. Water is taken from the ocean, pumped through the thousands of small tubes in the condenser to remove the excess heat, and is then discharged back into the ocean. The expected temperature increase from circulating water inlet to outlet is about  $9^{\circ}$  to  $10^{\circ}$  degrees Fahrenheit.



Most nuclear power plants not located on the ocean need cooling towers to remove the excess heat from the circulating water system. One type of cooling tower is the forced draft cooling tower. The circulating water is pumped into the tower, after passing through the condenser, and allowed to splash downward through the tower, transferring some of its heat to the air. Several large electrical fans, located at the top of the cooling tower, provide forced air circulation for more efficient cooling.

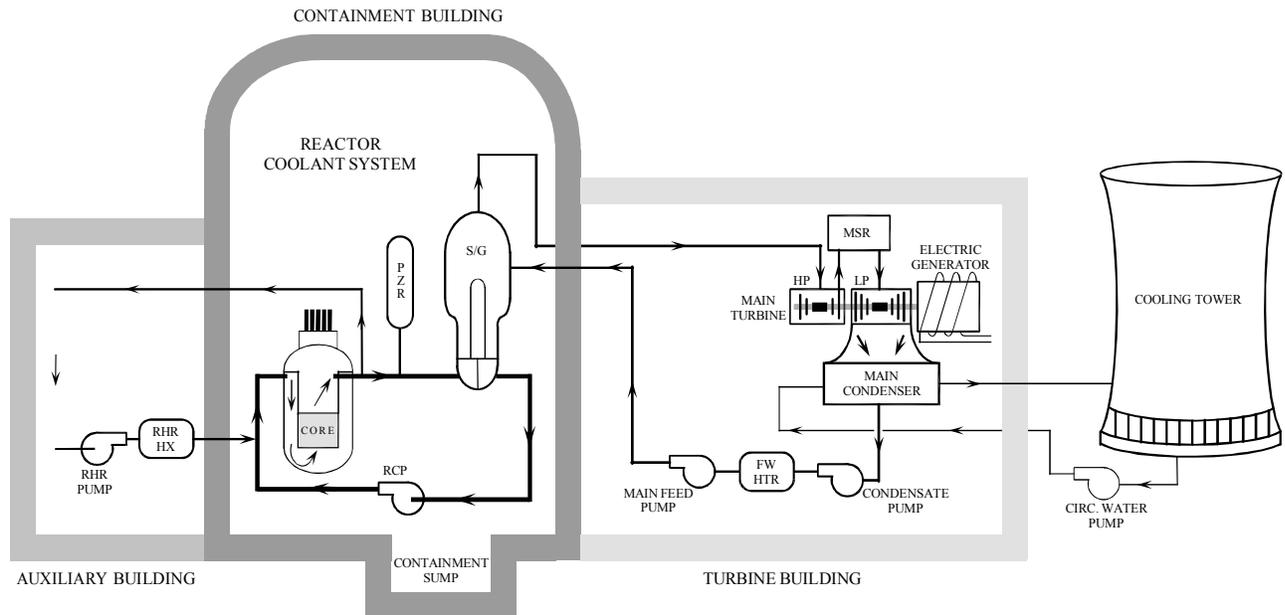


The taller hourglass shaped, natural convection cooling towers do not require fans to transfer the excess heat from the circulating water system into the air. Rather, the natural tendency of hot air to rise removes the excess heat as the circulating water splashes down inside the cooling tower. These towers are typically several hundred feet tall.



The “steam” vented from the top of a cooling tower is really lukewarm water vapor. IT IS NOT RADIOACTIVE. As the warm, wet air from inside the cooling tower contacts the cooler, dryer air above the cooling tower, the water vapor which cannot be held by the cooler air forms a visible cloud. This is because the colder the air is, the lower its ability to hold water. The released cloud of vapor will only be visible until it is dispersed and absorbed by the air. The graph above shows air’s ability to hold water as air temperature increases.

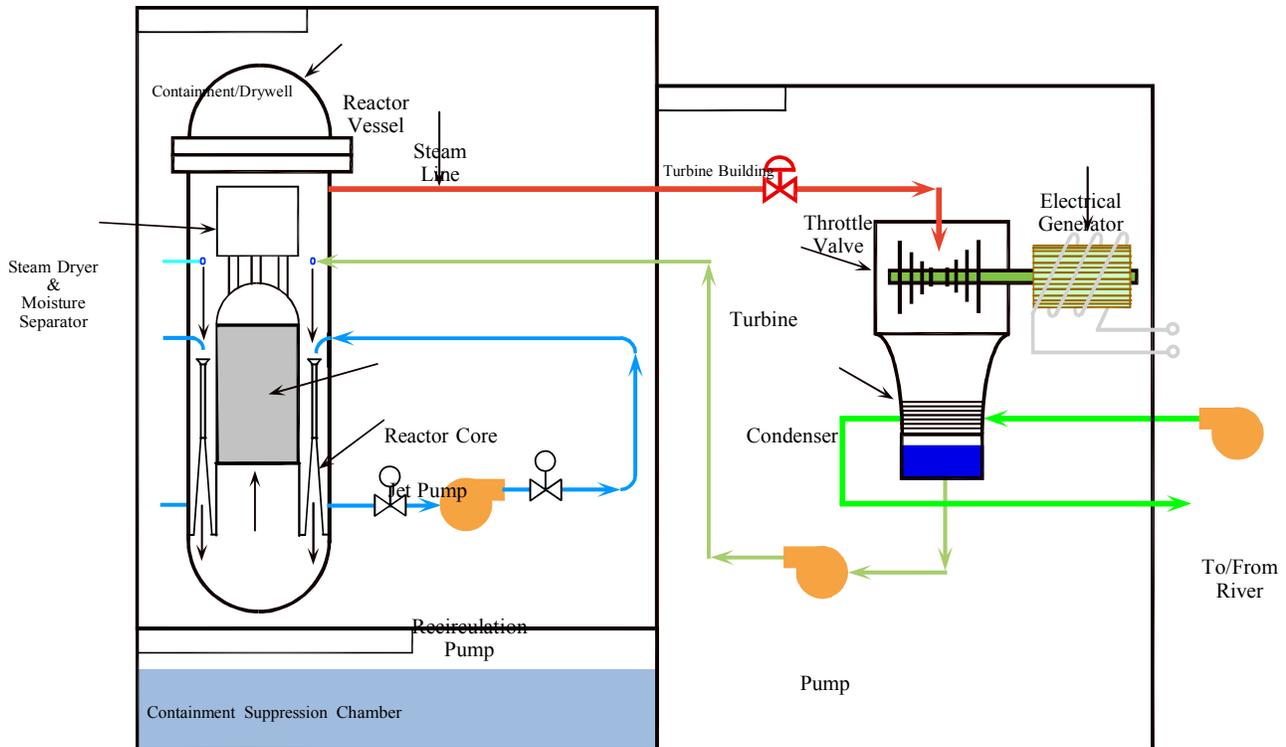
## PRESSURIZED WATER REACTOR PLANT LAYOUT



The major structures at a pressurized water reactor plant are:

- The containment building, which houses the reactor and its high pressure steam generating equipment;
- The turbine building, which houses the steam turbines, condensers, and the electrical generator; and
- The auxiliary building, which houses normal and emergency support systems (such as the residual heat removal (RHR) system, fuel handling and storage equipment, laboratories, maintenance areas, and the control room).

Depending upon the plant location and environmental regulations, there may or may not be a cooling tower to remove the excess heat from the facility.



The major structures at a boiling water reactor plant are:

- The primary containment, which includes the suppression chamber, and houses the reactor and recirculation pumps;
- The reactor building (secondary containment), which surrounds the primary containment and serves many of the same functions as a pressurized water reactor's auxiliary building; and
- The turbine building.

Depending upon the plant location, there may or may not be a cooling tower to remove excess heat from the facility.