PEP

POWER EFFICIENCY PROJECT

Professor Max Powers' Power Efficiency Project (PEP) is brought to you by the Kansas Corporation Commission and Kansas State University Engineering Extension. Funding provided by a grant from the U.S. Department of Energy.

How Nuclear Energy is Collected and Distributed

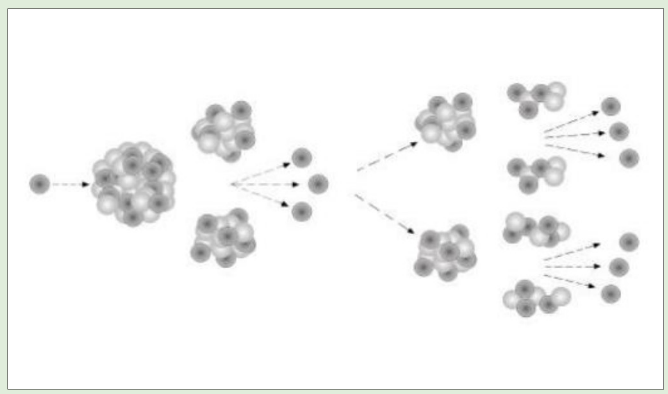
What is Nuclear Fission?

An **atom** is the smallest unit of matter that maintains the properties of a chemical element. It consists of a **nucleus** (which contains densely packed **protons** and **neutrons**) surrounded by electrons. When "bombarded" with a neutron, an atom can be split apart.[1] A **nuclear material** is any element that splits apart easily. **Hydrogen** is the lightest element containing only one proton, and **uranium** is the heaviest naturally-occurring element with 92 protons. Since uranium is relatively larger, the bonds holding it together are much weaker and can be split more easily. Thus, isotopes of uranium are used in most **nuclear power plants**. A **nuclear reactor** combines neutrons with the nuclear material to cause a fission chain reaction. **Fission** is the process of splitting isotopes of an element to release energy as heat. A series of fission is called a **chain reaction** as seen in **Figure 1**. When enough isotopes are added to the process (termed the **critical mass**), the reaction becomes a self-sustaining chain reaction which releases enough energy to boil water and generate steam to turn turbines.

One advantage of using nuclear material for electricity generation is the **high-energy density** of uranium. Uranium contains two to three million times as much energy as the equivalent weight in coal.[2] This allows nuclear generating stations to use less fuel for the same amount of electricity produced. Another advantage is the consistency of the electricity generation when using nuclear power. Many **renewable** alternatives to fossil fuels are critiqued because of the irregular availability of the resources (i.e., solar can only be utilized during a clear, bright day or wind can only be captured when the wind velocity stays within the tolerance of the turbine). Because **nuclear energy** uses uranium, a widely available resource that can be stockpiled, these intermittent gaps in energy production are not a problem.[3]

Figure 1: Example of Nuclear Fission.

Source: https://www.energy.gov/sites/prod/files/The%20History%20of%20Nuclear%20Energy_0.pdf



Using Nuclear Energy to Generate Electricity

There are two designs for nuclear reactors: **pressurized water reactor** and **boiling water reactor**. In both set-ups, the core creates heat. The top image in **Figure 2** (on the next page) shows the diagram for the pressurized water reactor. In this reactor, the pressurized water in the primary coolant loop carries heat to the steam generator. Inside the steam generator, heat from the primary coolant loop vaporizes the water in a secondary loop which produces steam. The steamline directs steam to the main turbine, causing it to turn the generator and produce electricity.[4]

In the boiling water reactor (**Figure 2**), a mixture of steam and water is produced when the coolant moves upward through the core, absorbing heat. The steam-water mixture leaves the top of the core and enters the moisture separation stage where

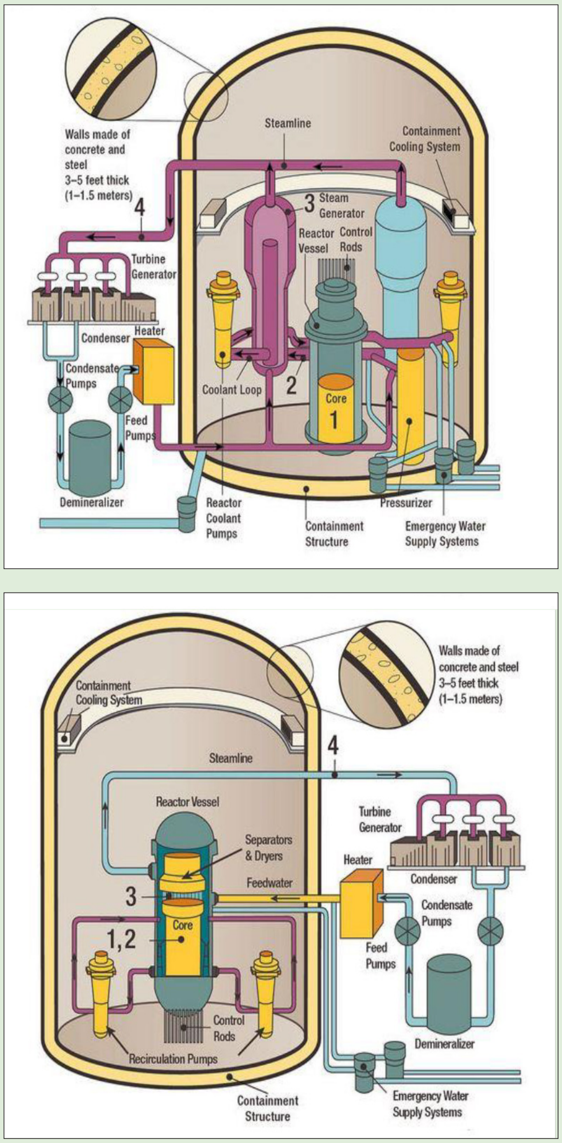


Figure 2: System Diagrams for the Pressurized Water Reactor (top). Pressurized Boiling Water Reactor (bottom).

Source: United States Nuclear Regulatory Commission.

Figure 3: Wolf Creek Generating Station.

Source: https://www.nrc.gov/info-finder/reactors/wc.html

water droplets are removed before the steam enters the steamline. The reactor works identically to the pressurized water reactor at this point as the steamline directs the steam to the **turbine-generator**.[5]

Pressurized water reactors are usually more expensive, but can accommodate sudden increases in energy demand.[10] Boiling water reactors tend to be less expensive to build, but are less capable of handling these demand spikes.[11] The reactor used depends on the budget and the needs of the power plant.

Safety of Nuclear Power Generation

Safety is one of the predominant concerns surrounding the use of nuclear energy. However, a review of significant nuclear events done by the **Nuclear Regulatory Commission** (NRC) indicated that human error was a factor in 79 percent of events.[12] These significant events have made safety hazards more apparent to government organizations, which subsequently enhance emergency preparedness plans and develop stricter safety regulations accordingly. For example, after the **Three Mile Island** incident, the regulations and oversight of the NRC became much more robust and plants were more strictly scrutinized during inspections. These changes have since reduced overall risk to public health and safety.[6]

What Happens to Nuclear Waste?

Nuclear waste is also a concern. Currently, there are about 250,000 metric tons of nuclear waste in storage.[7] This waste can take anywhere from 1,000 to 10,000 years to lose all its radioactivity.[14] Some argue that nuclear waste can be diminished through waste recycling or **reprocessing** by using breeder reactor technologies. A **breeder reactor** uses liquid sodium instead of water to transfer heat which allows the neutrons to maintain a high-energy state and produces more fuel than it consumes.[8]

However, the idea of plutonium reprocessing has spawned numerous issues. There are concerns that because of the large amount of plutonium being separated from the spent fuel, nuclear terrorism could become a threat due to such wide availability of the substance. Additionally, the demand for nuclear fuel has decreased considerably, thus driving down the cost of uranium, meaning that this new, controversial source of fuel is no longer necessary for the time being.[13]

Nuclear Energy in Kansas

Kansas has a nuclear generating station located directly northeast of Burlington (**Figure 3**). The Wolf Creek Nuclear Operating Corporation (WCNOC) is owned by Westar Energy, Great Plains Energy, and Kansas Electric Power Cooperative, Inc. (KEPCo). WCNOC cost 3 billion dollars to construct and is licensed to generate 3,565 MW using a pressurized water reactor.[9] In September 2016, production had to shut down unexpectedly because of a leak inside of the containment area; however, no radiation was released.

For more information on how nuclear energy is collected and distributed, contact Kansas State University Engineering Extension at 785-532-4998 or dcarter@ksu.edu.

Curriculum & Activity Links

Primary

- Uranium Factsheet, Grades K-2, http://www.need.org/files/curriculum/infobook/UraniumP.pdf
- Uranium Factsheet, Grades 3-5, http://www.need.org/files/curriculum/infobook/UraniumE.pdf
- Hands-On Activity: The Fission Game, Grades 3-8, http://www.nuclearscienceweek.org/wp-content/uploads/2015/09/The_Fission_Game.pdf

Intermediate

- Uranium Factsheet, Grades 6-8, http://www.need.org/files/curriculum/infobook/UraniumI.pdf
- Energy From Uranium: Teacher Guide, Grades 6-8, http://www.need.org/files/curriculum/guides/EnergyFromUranium.pdf
- Hands-On Activity: Nuclear Popcorn, Grades 7-12, http://www.nuclearscienceweek.org/wp-content/uploads/2014/09/Nuclear-Popcorn.pdf
- Hands-On Activity: The Fission Game, Grades 3-8, http://www.nuclearscienceweek.org/wp-content/uploads/2015/09/The_Fission_Game.pdf

Secondary

- Uranium Factsheet, Grades 9-12, http://www.need.org/files/curriculum/infobook/UraniumS.pdf
- Hands-On Activity: Modeling Atomic Structure, Grades 9-12, http://www.need.org/files/curriculum/webcontent/nuclear/AtomGame.pdf
- Exploring Nuclear Energy: Teacher Guide, Grades 9-12, http://www.need.org/files/curriculum/guides/ExploringNuclearEnergy.pdf
- Hands-On Activity: Nuclear Popcorn, Grades 7-12, http://www.nuclearscienceweek.org/wp-content/uploads/2014/09/Nuclear-Popcorn.pdf

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2. "Fuel Comparison." European Nuclear Society, www.euronuclear.org/info/encyclopedia/f/fuelcomparison.htm
3. "Supply of Uranium." World Nuclear Association, Dec. 2016, www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx
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