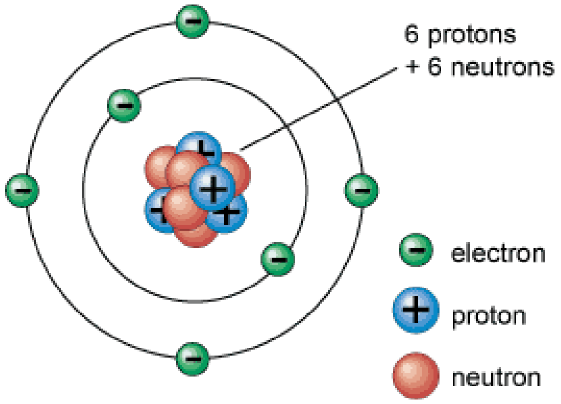
ENE 101 – Introduction to Energy Engineering

WEEK 10

Energy Consumption and Conversion Continue:

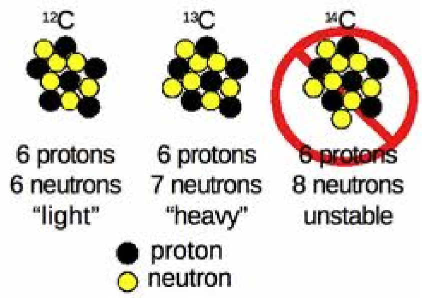
- **Nuclear Energy Technology**

Nuclear technology takes advantage of the power locked in structure of atoms, the basic particle of matter. The nucleus of an atom contains all of its positively-charged protons and non-charged neutrons. Negatively-charged electrons orbit the nucleus. Atoms always contain equal numbers of protons and electrons, making them electrically neutral.



Carbon atom

- Atoms can have different numbers of neutrons in their nuclei.
- Nuclei from the same element with different numbers of neutrons are called isotopes.
- Most isotopes are stable, but some can spontaneously break apart, emitting energy and particles. This is radiation.

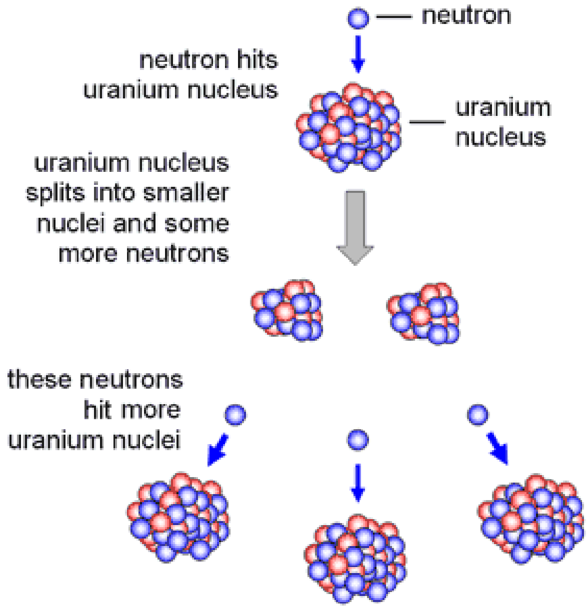


- **Nuclear Fission**

Nuclear weapons harness a specific type of decay called nuclear fission. This is the splitting of the nucleus into two smaller fragments. The fuel used by the first nuclear weapons was *Uranium-235*, a naturally occurring isotope. Uranium-235 has an extremely large nucleus that can be split when it is hit with a high-speed neutron.

- **Nuclear Bomb**

In a nuclear bomb, a large amount of uranium-235 is clustered together, so that when fission is initiated in one of the atoms, it splits and released more neutrons, which then cause fission in other atoms.
This creates a fission chain reaction.
Each time a nucleus splits, a large amount of energy is released.
Multiplied across the entire chain reaction…



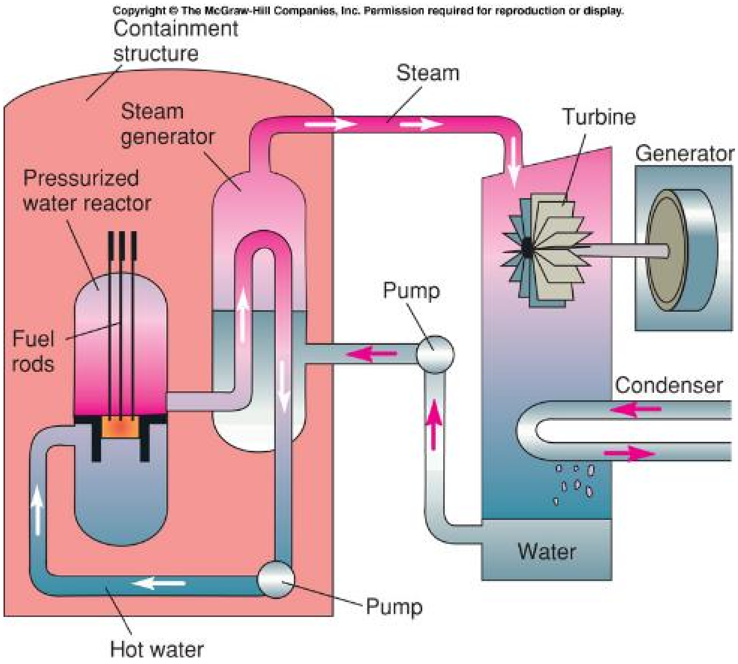
Nuclear Disasters: Two atomic bombs were dropped during World War II – Hiroshima and Nagasaki, Japan. Each had yields of 15-21 kilotons of TNT. These blasts ended World War II.

- **Nuclear Reactors**

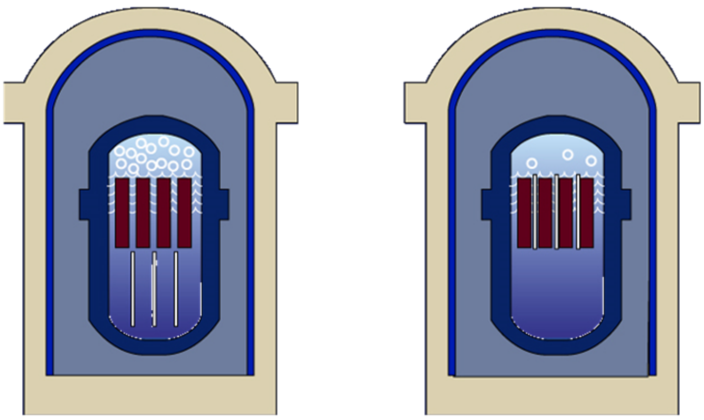
The process of converting nuclear energy into electricity is similar to that of using fossil fuels. Water is boiled, the steam is passed through a turbine, which spins a generator.

Both reactor vessel and steam generator are housed in a special containment building preventing radiation from escaping, and providing extra security in case of accidents.

Under normal operating conditions, a reactor releases very little radioactivity.

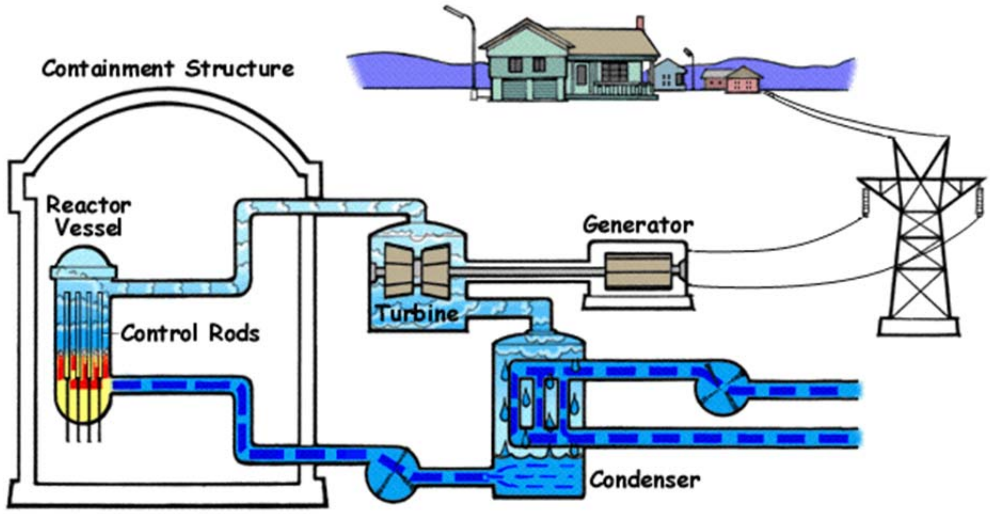


As with nuclear bombs, the primary fuel is uranium-235. Uranium ore is enriched and formed into fuel pellets. The fuel pellets are stacked into long, cylindrical fuel rods. Control rods, made of a neutron-absorbing material, are placed amongst the fuel rods. They can be removed and inserted to adjust the rate of the chain reaction.
Withdraw control rods, reaction increases:

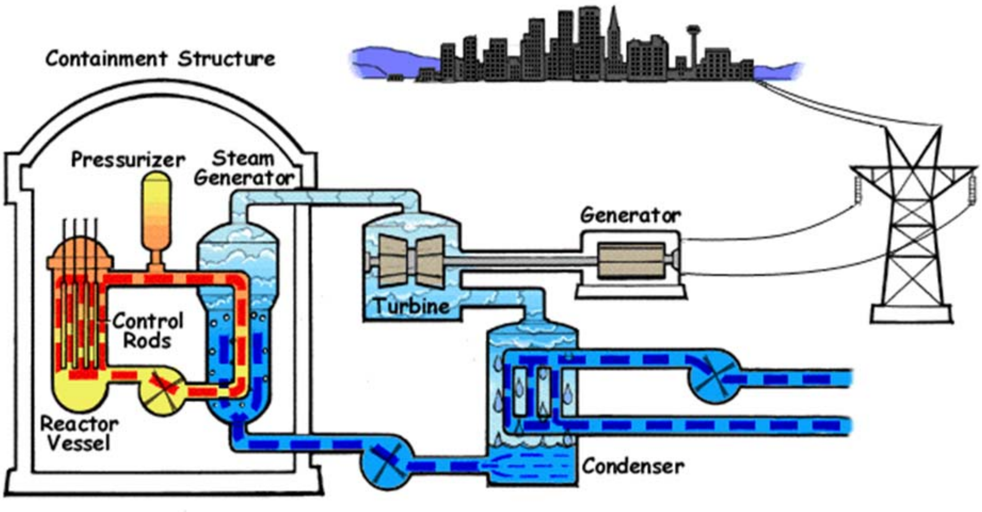


- **Types of Nuclear Reactors**

- **Boiling Water (BWR) Nuclear Reactors:** The core, turned to steam, boils In a BWR the water and that steam is used to drive the turbines, which generates the electricity. The spent steam is cooled back to liquid and recycled through the core.

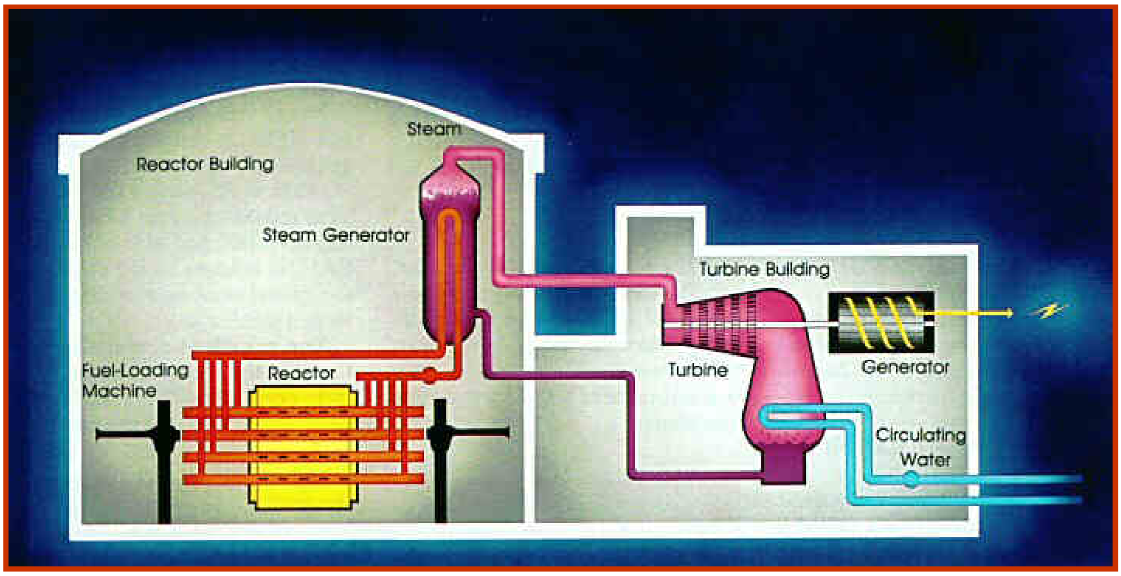


- **Pressurized Water (PWR) Nuclear Reactors**: In a PWR, water is heated in the core and converted to superheated steam. This is a closed system and is called the primary loop. This contaminated water/steam does not exit the containment. The heat from the steam in the primary loop is transferred to a separate water supply (the secondary loop) causing it to boil and turn to steam. This is done by using “steam generators” which have many small tubes inside. The steam from the primary loop travels through the tubes giving up heat to the water surrounding the tubes. The steam in this 2ndry loop is used to run the turbines to generate the electricity. In this way, the contaminated water supply is always maintained inside the containment unless of course the steam generator tubes leak causing cross contamination in the secondary loop. After passing through the turbines, the spent steam in the secondary loop is cooled back to water and run through the steam generators again.



- **Canada Deuterium Uranium (CANDU):** It is a pressurized-heavy-water, natural-uranium power reactor designed first in the late 1950s by a consortium of Canadian government and private industry. All power reactors in Canada are CANDU type. The CANDU reactor uses natural uranium fuel and heavy water (D_2O) as both moderator and coolant (the moderator and coolant are separate systems). It is refueled at full-power, a capability provided by the subdivision of the core into hundreds of separate pressure tubes.

  Each pressure tube holds a single string of natural uranium fuel bundles (each bundle half a meter long and weighing about 20 kg) immersed in heavy-water coolant, and can be thought of as one of many separate "mini-pressure-vessel reactors" - highly subcritical of course. Surrounding each pressure tube a low-pressure, low-temperature moderator, also heavy water, fills the space between neighboring pressure.



- **Advanced Nuclear Reactors:** Today's nuclear reactor technology is distinctly better than that represented by most of the world's operating plants, and the first advanced reactors are now in service in Japan. The first advanced reactors now operating in Japan. Nine new nuclear reactor designs either approved or at advanced stages of planning. Incorporate safety improvements and are simpler to operate, inspect, maintain and repair.

- **The new generation of reactors:**

- have a standardized design for each type to expedite licensing, reduce capital cost and reduce construction time,
- are simpler and more rugged in design, easier to operate and less vulnerable to operational upsets,
- have higher availability and longer operating life,
- will be economically competitive in a range of sizes,
- further reduce the possibility of core melt accidents,
- have higher burn-up to reduce fuel use and the amount of waste.
  - **Components of a Nuclear Plant**

  - **Control Building:** From this location, the operator controls the reactor.

- **Containment Building:** This is the location of the core and primary components including the steam generators if it is a PWR.

- **Turbine Building:** This is where the steam is converted to electricity. In a PWR it is “clean” whereas in a BWR, the steam is contaminated since it is produced from water which has been in contact with the core. Thus, the turbine floor in a BWR has elevated radiation levels.

- **Fuel Building:** This is where the spent fuel is stored onsite in a pool.

- **Diesel Generator Building and Auxiliary Buildings:** This is the location of the generators, which support emergency power, and the other components, which support the water/steam system.

- **Nuclear Reactors**

Reactor building don’t always look the same. Many people believe the cooling towers are the reactors. They are not. They provide cooling for the lake or river water which is used to condense the spent steam back to water in the closed system. They typically exhaust condensation from the cooling process. This condensation cloud is sometimes mistaken for leakage from the reactor.

References:

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2.https://www.nei.org/Knowledge-Center/How-Nuclear-Reactors-Work

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4.http://slideplayer.com/slide/6850772/