Nuclear Propulsion

Submarine Nuclear Propulsion Plant

A nuclear-powered submarine is constructed with the nuclear power plant inside a section of the sub called the reactor compartment. The components of the nuclear power plant include a high-strength steel reactor vessel, heat exchanger(s) (steam generator), and associated piping, pumps, and valves. Each reactor plant contains over 100 tons of lead shielding, part of which is made radioactive by contact with radioactive material or by neutron activation of impurities in the lead.

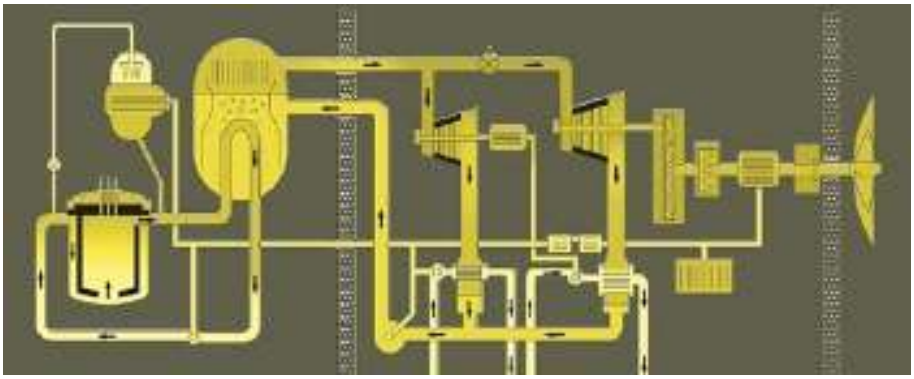

Figure 1: Pressurized water nuclear propulsion plant

The propulsion plant of a nuclear-powered submarine uses a nuclear reactor to generate heat. The heat comes from the fissioning of nuclear fuel contained within the reactor. Since the fissioning process also produces radiation, shields are placed around the reactor so that the crew is protected.

The nuclear propulsion plant uses a pressurized water reactor design which has two basic systems - a primary system and a secondary system. The primary system circulates ordinary water and consists of the reactor, piping loops, pumps and steam generators. The heat produced in the reactor is transferred to the water under high pressure so it does not boil. This water is pumped through the steam generators and back into the reactor for re-heating.

In the steam generators, the heat from the water in the primary system is transferred to the secondary system to create steam. The secondary system is isolated from the primary system so that the water in the two systems does not intermix.

In the secondary system, the steam flows from the steam generators to drive the turbine generators, which supply the ship with electricity, and to the main propulsion turbines, which drive the propeller. After passing through the turbines, the steam is condensed into water which is fed back to the steam generators by the feed pumps. Thus, both the primary and secondary systems are closed systems where water is recirculated and renewed.

Since there is no step in the generation of this power which requires the presence of air or oxygen, this allows the ship to operate completely independent from the earth's atmosphere for extended periods of time.

Source: "Nuclear Propulsion," http://www.fas.org/man/dod-101/sys/ship/eng/reactor.html

Fission in the Nuclear Reactor

A nuclear reactor does not work through nuclear decay of radioactive elements but through a nuclear chain reaction. A chain reaction is a series of several nuclear reactions. To start the chain reaction a neutron must collide with the nucleus of an atom of the nuclear fuel. In a submarine, the nuclear fule is Uranium-235. When stuck by a neutron the Uranium-235 nucleus undergoes a process called fission. The Uranium-235 nucleus splits into two lighter nuclei such as strontium and xenon and releases neutrons, gamma radiation, and heat. The neutrons produced in the first reaction strike more Uranium-235 nuclei causing the fission process to continue. The repetitive nature of this process is called a nuclear chain reaction.

Once fission occurs and begins a nuclear chain reaction, the number of fission reactions occurring may need to be moderated so that too much heat is not produced and the chain reaction does not get out of control. Since the neutrons that are produced during the splitting of the nucleus are the reason that a fission reaction occurs, something is needed to prevent the neutrons from colliding with more Uranium-235 atoms. The device that is used is called a control rod. A control rod is composed of elements that can absorb neutrons thereby controlling the number of fission reactions taking place. Materials that can absorb neutrons include silver, cadmium, and indium.

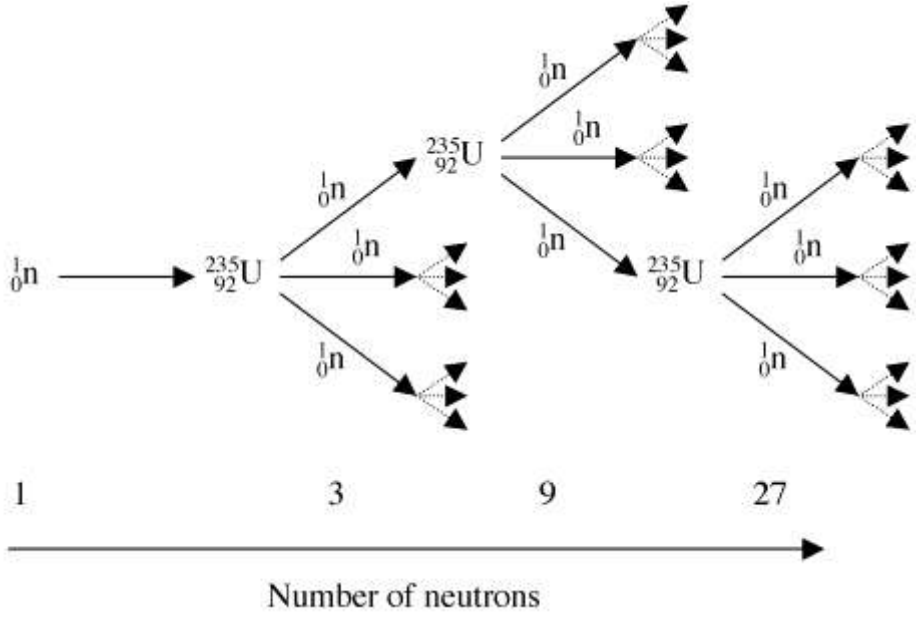

Figure 2: A nuclear chain reaction