Nuclear Power Plants

On April twenty fifth, 1986, a Soviet nuclear reactor melted down in the city of Chernobyl. The accident immediately killed 30 people and it is estimated that nearly 4,000 more people will die from the radiation. The disaster at Chernobyl and to a lesser extent the scare at Three Mile Island, often comes to mind when nuclear energy is discussed. Though, if properly managed, nuclear power can be a safe energy alternative to fossil fuel. Unlike the fossil fuels that are usually used to obtain electricity, nuclear power creates no hazardous green house gases. Nuclear power is used to generate about seven percent of the world's electric power and about 20 percent of the United States' electrical power.

Nuclear Fuel

Uranium, number 92 on the periodic table, is a very dense and naturally radioactive metal. The most common type of uranium is U-238 which eventually decays into U-234. The isotope U-235 which only accounts for .7% of naturally occurring uranium is used in reactors because of its unique ability to undergo induced fission. Fission is the splitting of the uranium nucleus into several nuclei which results in the release of energy in the form of heat and gamma radiation. Fission is achieved in reactors through the collision of a neutron and the uranium nucleus. For uranium to be used in a nuclear plant it must be approximately 3% U-235 and 97% U-238.

Nuclear Power Plant Design

For uranium to be safely used it must be properly contained: thus the design of the plant must build around the uranium. The uranium is shaped into small cylinders that are about an inch long. These cylinders are placed into rods that are bundled together in a pressurized tank. The tank, filled with water, acts as a coolant for the heat generated by the fission of uranium. To prevent the bundles from overheating, control rods are used. Control rods are able to absorb neutrons involved the fission of the uranium. By mechanically inserting the control rods into the bundles the rate of the reactions can be controlled. When more heat needs to be generated the rods are removed so that more neutrons are moving through the bundle which then causes more fission to occur. The water in the tank is turned into steam from the heat of reactions. The steam is run through piping into a steam turbine which turns a generator to produce electricity. This type of reactor is known as a thermal reactor.

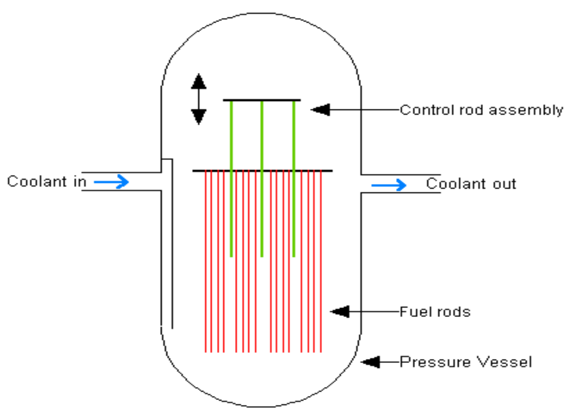

Fig 1 Nuclear Reactor

http://www.angelfire.com/wi3/foxy/BeardIwww/core.gif

Fig 2 Cooling Tower

http://static.howstuffworks.com/gif/nuclear-power-tower1.jpg

Light water thermal reactors use ordinary distilled water (H_2O) to surround the bundles of uranium. When light water is used enriched uranium (U-235) must be used to achieve fission. Heavy water reactors use deuterium oxide, which is similar to water, but the normal hydrogen atom is replaced by the hydrogen isotope, deuterium. Heavy water is used in a reactor as a neutron moderator to slow down neutrons in fission. When heavy water is used naturally occuring U-238 can be used in the reactor. The drawback is that the U-238 eventually degrades into plutonium (P-239) which is used in most modern nuclear weapons.

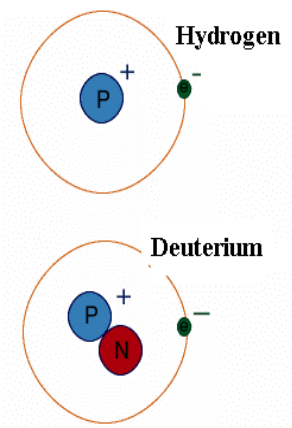

Fig 3

http://www2.iap.fr/Fuse/figures/FUSE_H_D.gif

Reactions Inside the Nuclear Reactor

When neutrons moving around inside the reactor strike the uranium nucleus, the nucleus will split into smaller particles and emit neutrons. These newly emitted neutrons can then strike other uranium molecules. This emission of neutrons is known as fission. For each fission that occurs, if one emitted neutron causes fission in another U-235 atom the uranium is said to be at a critical state. If on average the number of emitted neutrons creating more fissions is less than one the uranium is at a subcritical state. If on average the number of emitted neutrons striking other U-235 atoms is above one the uranium is considered to be at a supercritical state that will cause increased heat in the reactor. In a nuclear reactor it is best if the uranium is at a critical state so that the highest level of heat can be reached safely. To help obtain the critical state for uranium scientists and engineers must find the critical mass of uranium which is about 2 pounds (.9 kg). The shape of the uranium also has an effect on its state. It has been determined that a sphere is the best shape to obtain the critical state because it centralizes the uranium more efficiently allowing more collisions between neutrons and nuclei to occur.

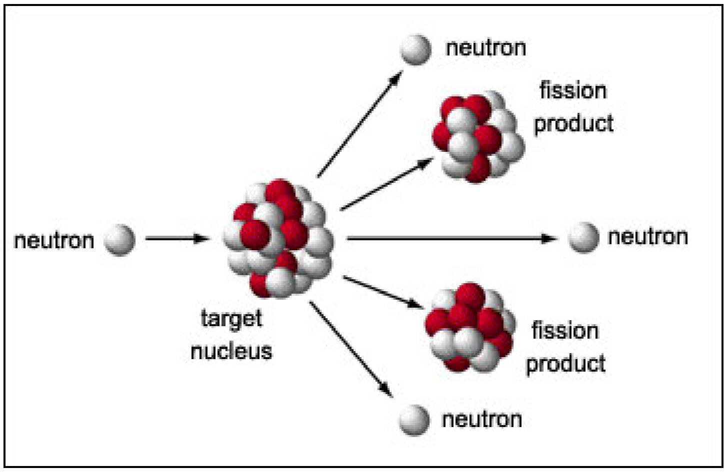

Fig 4 Nuclear Fission
http://www.atomicarchive.com/Fission/Fission1.shtml

Problems Associated with Nuclear Power Plants

Although nuclear plants produce generally clean electricity they are far from perfect. The most dangerous aspect of nuclear power is the radioactivity associated with uranium. Once the uranium in a plant has been used to the point where it is no longer efficient it has to be stored. With a half life of 4.5 billion years uranium is not easily destroyed. Since the uranium remains hazardous it has to be stored in a protected site that is isolated from human populations. The uranium must also be stored in a place in which it cannot harm the environment and where the land is safe from natural disasters. For these reasons it is very hard for governments to find proper storages sites.

Another issue with nuclear power plants is their high cost. The last 20 plants built in the United States all cost between 3 and 4 billion dollars. Not only are the plants expensive to build but they are also expensive to repair because only a small amount of companies are qualified to work with nuclear reactors. Despite the high cost of building and maintenance current plants have a lifetime of only between 15 and 40 years. When plants can no longer be run they must undergo the lengthy and costly process of decommissioning. During this process the plant must be decontaminated of radioactivity and dismantled.

The Future of Nuclear Power

For the most part Governments are the ones deciding the fate of nuclear power. The United States government has not sanctioned the building of a new nuclear power plant since the mid 1980s. Advocates of nuclear power see it as clean energy substitute for natural gas and coal. Others see nuclear power as a financial risk not worth taking. Opponents of nuclear power also cite that there are limited locations for nuclear waste to be stored. Which of these sides prevails is not likely to become clear any time soon.

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