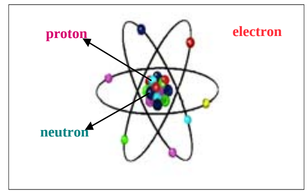
HOW DO NUCLEAR POWER STATIONS WORK?

What is an atom? What is a nucleus?

We see many substances around us. What are these made of really? This question has been asked since ancient times. We now know that every substance is simply a collection of a large number of very minute particles known as atoms. It has been found that there are 92 different kinds of atoms present in nature.

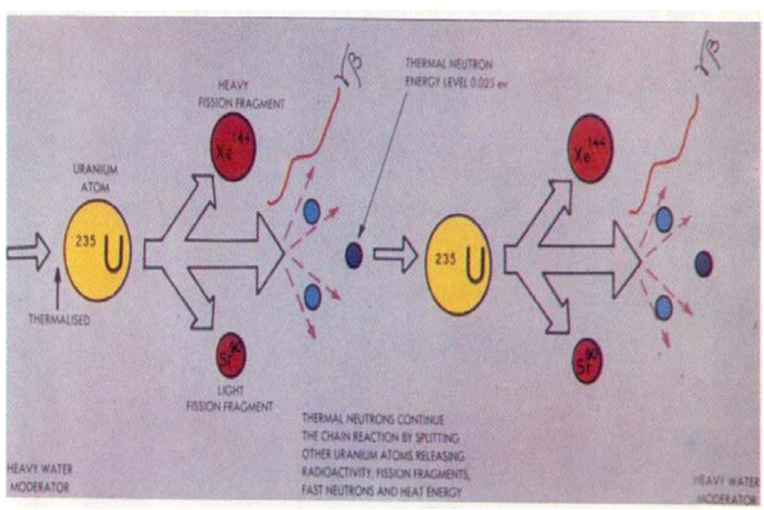


Some substances consist of only one kind of atoms. These substances are known as elements, e.g. hydrogen, carbon, oxygen, uranium. Atoms of hydrogen are very much smaller than atoms of uranium. Other substances contain two or more kinds of atoms joined together in groups, e.g. water which contains atoms of hydrogen and oxygen joined together. Some atoms of hydrogen are heavier than others. When these heavy hydrogen atoms combine with oxygen atoms, we get heavy water.

What are the atoms made up of, in their turn? For a long time, it was believed that atoms cannot be broken up into two smaller parts. In fact, the word atom means indivisible. Modern scientific discoveries have shown that an atom itself is a collection of still smaller particles. Three such particles are known namely electrons, protons, and neutrons. The structure of an atom has also been identified. The neutrons and protons are packed together in the central part of the atom called the nucleus. The electrons keep hovering around the nucleus.

How is energy released from the atom?

Atoms of uranium are the largest and also the heaviest known to occur on earth. Being heavy they are also unstable. The nucleus of a uranium atom can easily break up into two smaller pieces. This process is called fission. The two fragments so produced fly apart with tremendous speed. As they collide with other atoms in a lump of uranium they come to a stop. In the process they heat up the uranium lump. This is how energy is released from the atom and converted to heat. The energy produced in fission is described as atomic energy by some and nuclear energy by others. Besides uranium, the atoms of plutonium are also fissionable. But plutonium does not occur in nature.



It has been found that 2 or 3 free neutrons are also released as a uranium atom breaks up during fission. When one of these neutrons collides with another uranium nucleus that nucleus also breaks up. In this manner using one neutron from every fission, we can cause another fission. This is known as chain reaction and produces heat at a steady rate.

In contrast to fission, when a lump of coal burns, the atoms of carbon in coal combine with atoms of oxygen in the air and form carbon dioxide. Heat is released in the process and we see it as a flame. Smoke is also generated. When fission generates heat in uranium, there is no flame and no smoke.

How does a nuclear power station produce electricity?

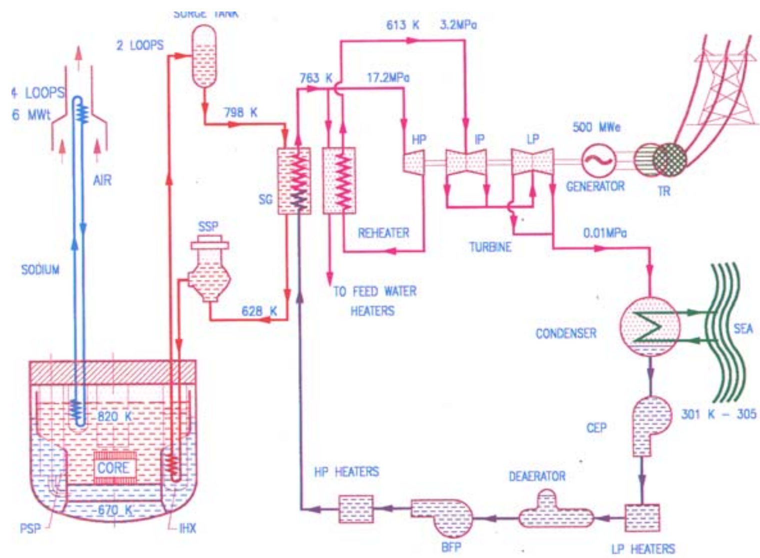
Basically, all power stations adopt the same method to produce electricity. A turbine is caused to rotate. A generator is attached to the shaft of the turbine. As the turbine turns, electricity is produced in the generator. This electricity is sent out through transmission lines to a distribution station of the Electricity Board.

In hydroelectric power stations, the turbine is turned by flowing water. In thermal power stations, steam is produced by heating water in a furnace which burns coal or oil. In nuclear power stations, the steam is produced by the heat generated in the fission process.

How is power generation controlled in a nuclear power station?

Control of operation of the nuclear power station involves two things. i.e. regulation of power generation to maintain it at a safe and steady level and secondly total shutdown of the reactor very quickly if needed.

At MAPS, the power is kept constant by the use of what are known as adjuster rods. These are stainless steel rods. When these rods are introduced into the reactor vessel, the chain reaction slows down and heat generation drops. If the control rods are slightly pulled out of the reactor vessel, the chain reaction picks up and power level rises. To shutdown the reactor completely, the heavy water is drained out of the reactor vessel in a fraction of a second. In the absence of heavy water in the vessel, the chain reaction ceases totally.



What are the fuel requirements for a nuclear power station?

Compared to the burning of coal, the fission process is far more efficient. One gram of fissionable uranium can produce a million times more heat than one gram of coal. At MAPS which produces 400 MW of electricity, only 20 kg of uranium fuel is required per day, i.e. about one truck load of fuel per month from Hyderabad where the fuel is produced. In comparison, a coal burning thermal power station of the same capacity would require about 2000 tonnes of coal daily, i.e. 2-3 train loads of coal to be transported everyday from the coal mines of Singareni over 1000km away. Also the coal has to be continuously fed to the furnace at the rate of 4 tonnes each minute. At MAPS, fresh fuel is charged into the reactor about once daily.

What Safety Measures are provided in Nuclear Power Stations?

Radioactive materials are produced in the core of the reactor when the fission process occurs. Most of these remain within the uranium fuel itself. To prevent their release to the environment at least 3 successive barriers are provided. Failure of all 3 barriers at the same time is indeed highly improbable. The uranium fuel is packed in a tube and the tube is completely sealed at both ends. There are 4000 such tubes in the reactor. Experience shows that development of leak in a tube is very rare. If this occurs the defective tube is quickly identified and removed from the reactor. Any radioactive materials released are still contained in the heavy water flowing around the tube. The pipe work, pumps, valves and other parts through which the heavy water flows are highly leak tight. As a further barrier the reactor is housed in a massive containment building. The special feature of the containment at MAPS is that it is of double walled construction. The walls are 60cm thick each. The inner wall is of prestressed concrete construction and is stronger than the outer one. An area around the station upto 1.5 km is acquired and kept totally free of any habitation.

Any large release of radioactive materials is possible only if the fuel is allowed to overheat and melt. Multiple level safety provisions are included to avoid such a situation. The instruments that monitor the power levels are provided in triplicate, so that even if one fails two others are available to indicate the status. This also helps to check the instruments very frequently even when reactor is in operation. In the same manner, the devices which shut down the reactor are also provided in triplicate. Their operation status is checked everyday.

Flow of coolant water through the core is also ensured by providing 2 or 3 pumps and valves wherever one is adequate. This assures that the flow will not be interrupted. As an additional measure of precaution against failure of any pipe, other pathways are also available to send water to the core. If heavy water coolant is not available, provision has been made to pump ordinary water into the core. To ensure that electrical power is always available for all the instruments and equipment which maintain the reactor in a safe condition, four different and independent supply lines have been provided. One of these derives power from Emergency Diesel Generators. Here again 2 or 3 generator sets are provided where one will do. Finally, even if the diesel sets do not operate, a battery bank can supply essential power for several hours.

The safety provisions in nuclear power stations are indeed unmatched by any other industry.