## CANada Deuterium-Uranium reactor (CANDU)

A thermal nuclear power reactor in which heavy water (99.8% deuterium oxide D2O) is the moderator and coolant as well as the neutron reflector. The CANDU reactor was developed (and is used extensively) in Canada, where a full scale commercial reactor of this type first started operation in 1967.

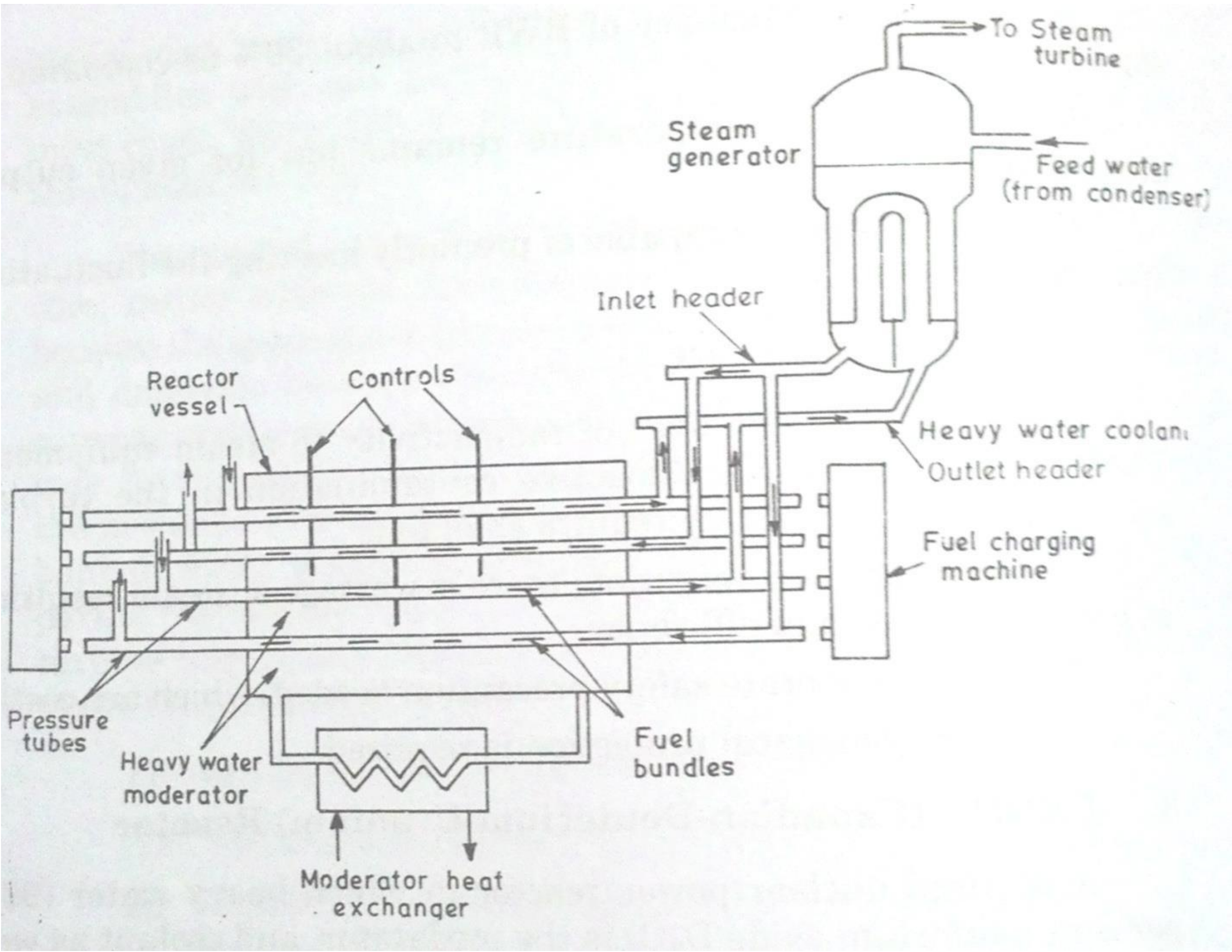
A few CANDU reactors are operating or under construction in some other countries. These reactors are more economical to those countries which do not produced enriched uranium, as the enrichment of uranium is very costly. In this type of reactors the natural uranium (0.7% $U^{235}$) is used as fuel and heavy water as moderator.

A basic design difference between the CANDU (heavy water) reactor and light-water reactors (LWRS) is that in the latter the same water serves as both moderator and coolant, whereas in the CANDU reactor the moderator and coolant are kept separate.

Consequently unlike the pressure vessel of a LWR, the CANDU reactor vessel, which contains the relatively cool heavy water moderator, does not have to withstand a high pressure. Only the heavy water coolant circuit has to be pressurized to inhibit boiling in the reactor core.

### General Description

Reactor vessel and core: The arrangement of the different components of CANDU type reactor is shown in figure The reactor vessel is a steel cylinder with a horizontal axis. (Length and diameter of a typical cylinder are 6m x 8m respectively). The vessel is penetrated by some 380 horizontal channels called pressure tubes because they are designed to withstand a high internal pressure.




CANDU (Canadian Deuterium-Uranium) Reactor

The channels contain the fuel elements and the pressurized coolant flows along the channels and around the fuel elements to remove the heat generated by fission. Coolant flow is in the opposite directions in adjacent channels.

The high temperature (310˚C) and high pressure 100 atm (10Mpa) coolants leaving the reactor core enters the steam generator, as described below. Roughly 5% of the fission heat is generated by fast neutrons escaping into the moderator, and this is removed by circulation through a separate heat exchanger.

The fuel in the CANDU reactor is normal (i.e. unenriched) uranium oxide as small cylindrical pellets. The pellets are packed in corrosion—resistance zirconium alloy (zircaloy) tube, nearly 0.5m long and 1.3 cm diameter, to form a fuel rod. The relatively short rods are combined in bundles of 37 rods, and 12 bundles are placed end to end in each pressure tube. The total mass of fuel in the core to about 97,000 kg.

The CANDU reactor is unusual in that refueling (i.e. removal of spent fuel and replacement by fresh fuel) is conducted while the reactor is operating. A refueling machine inserts a fresh fuel bundle into one end at a horizontal pressure tube which is temporarily disconnected from the main coolant circuit.

A spent fuel bundle is thus displaced at the other end and is removed. This procedure is carried out, like the coolant flow, in opposite directions in adjacent channels.

**Control and protection system.** The CANDU reactor has several types of vertical control elements. T hey includes a number of strong neutron absorber (i.e. poison) rods of cadmium which are used mainly for reactor shutdown and start up.

In addition there is other less strongly, absorbing rods to control power variations heat (power) distribution throughout the core. In an emergency situation, the shut down rods would immediately drop into the core, followed if necessary by the injection of a gadolinium nitrate solution into the moderator (Gadolinium is a very strong absorber of thermal neutrons)

**Steam System.** The respective ends of the pressure tubes are all connected into inlet and outlet headers (manifolds). The high temperature coolant leaving the reactor passes out the outlet header to a steam generator of the conventional inverted U tube (as in pressurized water reactor) and is then pumped back to the reactor by way of the inlet header.

Steam is generated at a temperature of above 265˚C. There are two coolant outlet (and two inlet) headers, one at each end of the reactor vessel, corresponding to the opposite direction of coolant flow through the core. Each inlet (and outlet) header is connected to a separate steam generator and pump loop. A single pressurizer, of the type used in pressurized-water reactors, maintains an essentially constant coolant system pressure.

**Safety features.** A break in a single pressure tube would result in some loss of coolant, but the particular tube could be disconnected and reactor operation would proceed with the other tubes. A mere loss of coolant accident, with possible damage to the fuel and release of radioactive fission products would develop from a break in one of the coolant header or in the pipes to or from the steam generators.

An emergency core-cooling system would then supply additional coolant. The separate moderate system would also provide a substantial heat sink.

A concrete containment structure encloses the reactor vessel and the steam generator system. A water spray in the containment would condense the steam and reduce the pressure that would result from a large break in the coolant circuit.

**Advantages:**

1. Enriched fuel is not required.
2. The reactor vessel does not have to withstand a high pressure as vessel of PWR and BWR. Only the heavy water coolant circuit (fuel tubes) has to be pressurized to inhibit boiling in the reactor core, therefore, the cost of the vessel is less?
3. The moderator can be kept at low temperature which increases its effectiveness in slowing down neutrons.
4. Heavy water is used as moderator, which has higher multiplication factor and low fuel consumption.
5. Site construction requires lesser time as compared with PWR and BWR.

**Disadvantages**

1. Heavy water is very costly
2. Leakage problems.
3. Very high standard of design, manufacture and maintenance are needed.
4. The reactor size is extremely large as power density is low as compared with PWR and BWR.