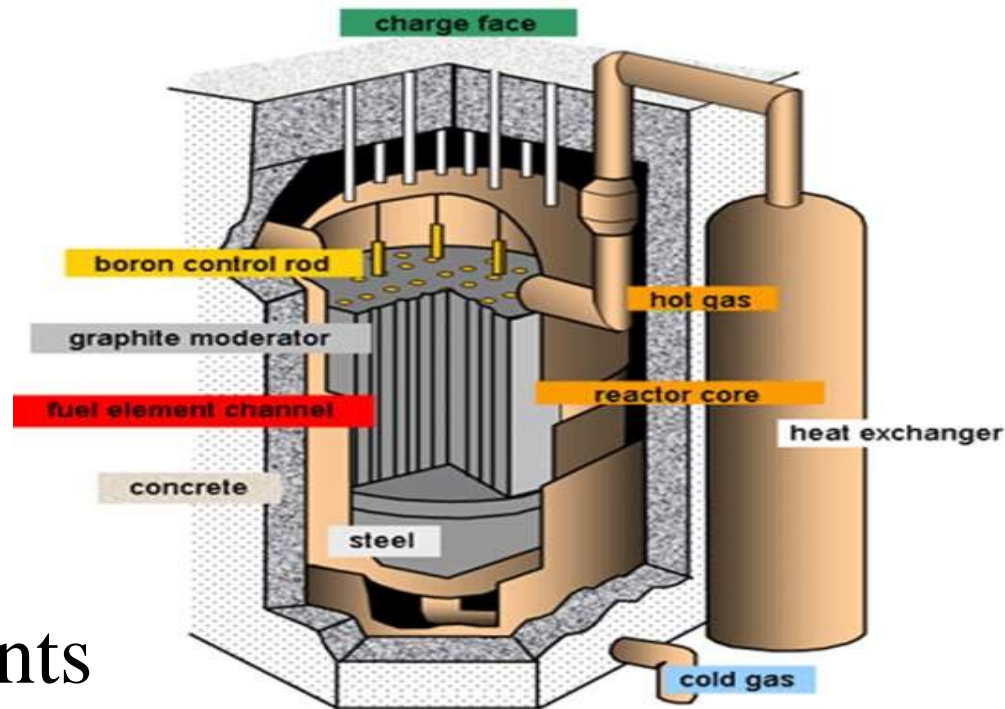
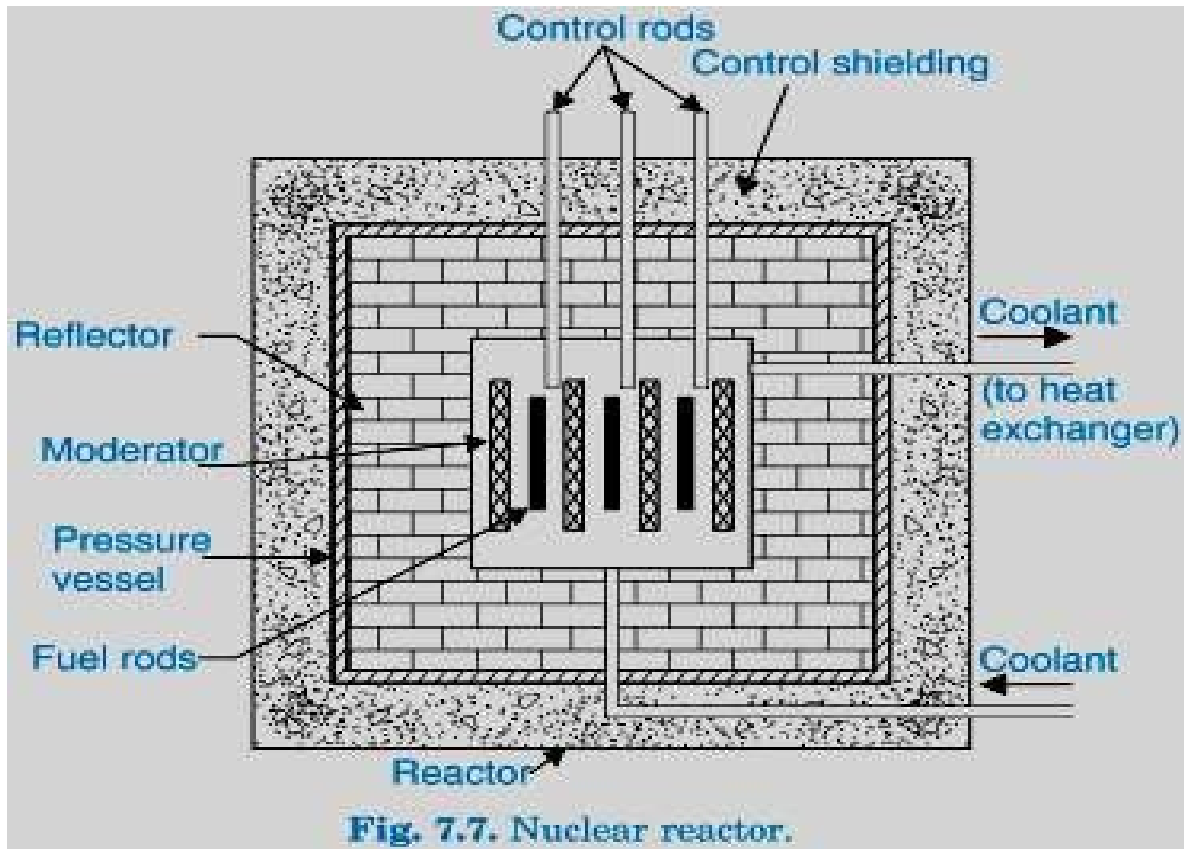



NUCLEAR REACTOR– Principal Components

1. Reactor core
2. Reflector
3. Control mechanism
4. Moderator
5. Coolants
6. Measuring instruments
7. Shielding



Nuclear Reactor





✚ **Reactor Core** : This is the main part of reactor which contain the fissionable material called **reactor fuel**. *Fission energy is liberated in the form of heat for operating power conversion equipment.* The fuel element are made of plate of rods of uranium.

Reactor Core → Where the nuclear fission process takes place.

✚ **Reactor reflector** :The region surrounding the reactor core is known as **reflector**. Its function is to **reflect** back some of the **neutron** that **leak** out from the surface of core.

✚ **Control rods** : The rate of reaction in a nuclear reactor is controlled by control rods. Since the neutrons are responsible for the progress of chain reaction, suitable neutron absorbers are required to control the rate of reaction.

- For starting the reactor
- To keep the production at a steady state
- For shutting down the reactor under normal or emergency conditions

❖ **Cadmium** and **Boron** are used as control rods.

Control rods :

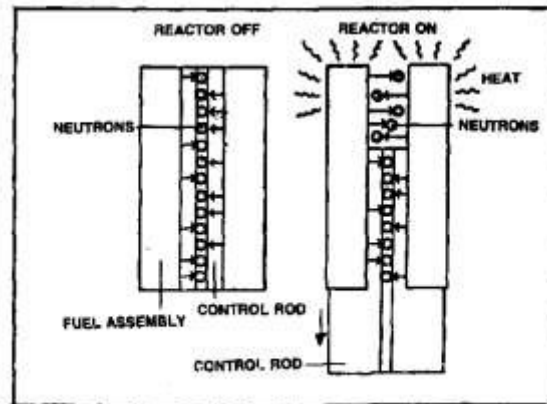


Fig. 3.8: CONTROL RODS

Control rods limit the number of fuel atoms that can split. They are made of boron or cadmium which absorbs neutrons

- **Moderator** :The function of a reactor is to **slow down** the fast **neutron**. The moderator should have
 - High slowing down power
 - Non corrosiveness
 - High melting point for solids and low melting point for liquids.
 - Chemical and radiation stability.
 - High thermal conductivity
 - Abundance in pure form.

Moderator : **This reduces the speed of fast moving neutrons.**

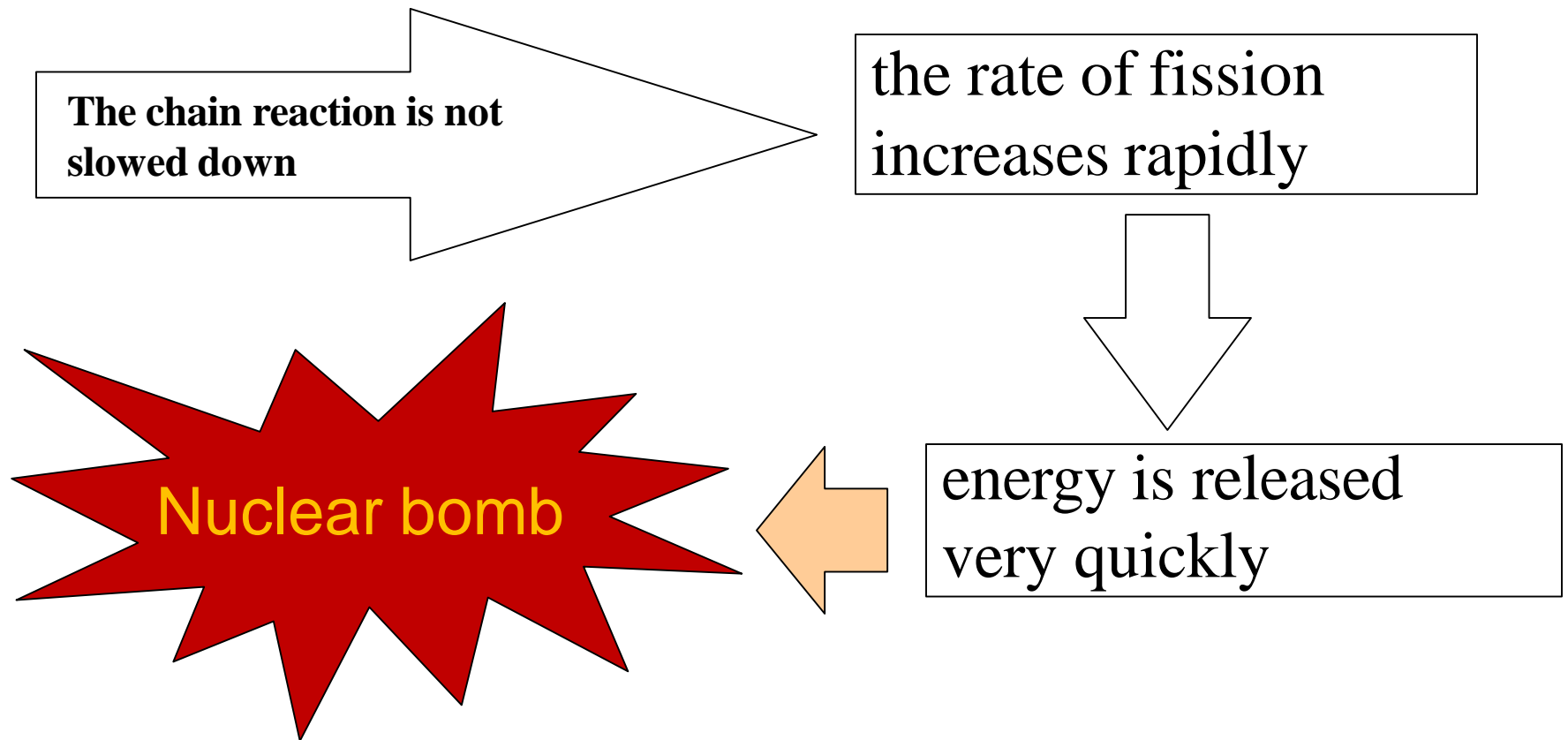
The commonly used moderator are :

- **Ordinary water**
- **Heavy water**
- **Graphite.**

- **Coolant** :The material used to **carry the intense heat generated** by fission as fast as liberated is known as **reactor coolant**. The coolant generally pumped through the reactor in the form of liquid or gas. It is circulated throughout the reactor so as to maintain a uniform temperature.
- **Measuring Instruments:** Main instrument required is for the purpose of measuring **thermal neutron flux** which determines the power developed by the reactor.
- **Shielding:** The large steel recipient containing the core, the control rods and the heat-transfer fluid.

All the components of the reactor are contained in a solid concrete structure that guarantees further isolation from external environment. This structure is made of concrete that is one-metre thick, covered by steel.

Uncontrolled nuclear reaction



Types of Nuclear Reactors:

1. Pressurised Water Reactor (PWR)
2. Boiling Water Reactor (BWR)
3. CANDU (Canadian-Deuterium-Uranium) Reactor
4. Gas-Cooled Reactor
5. Liquid Metal Cooled Reactor
6. Breeder Reactor

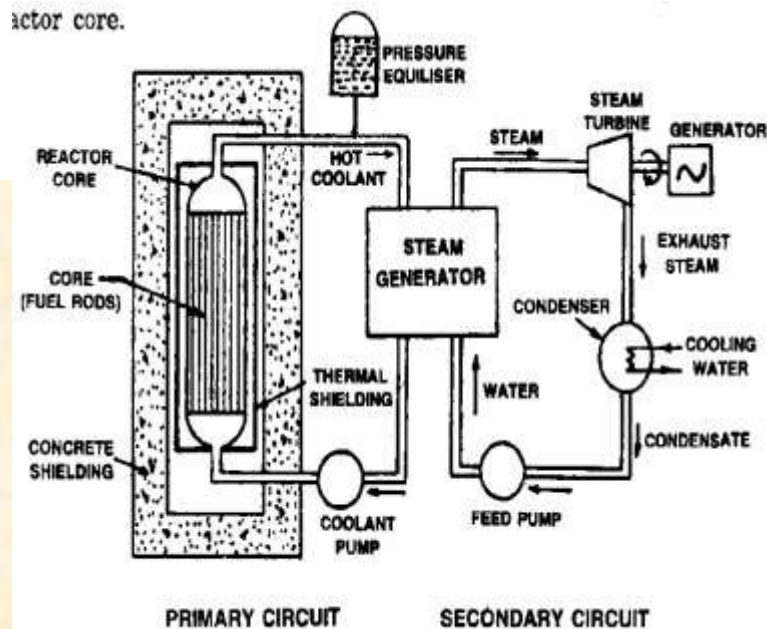


Fig. 3.9: PRESSURISED WATER REACTOR PLANT

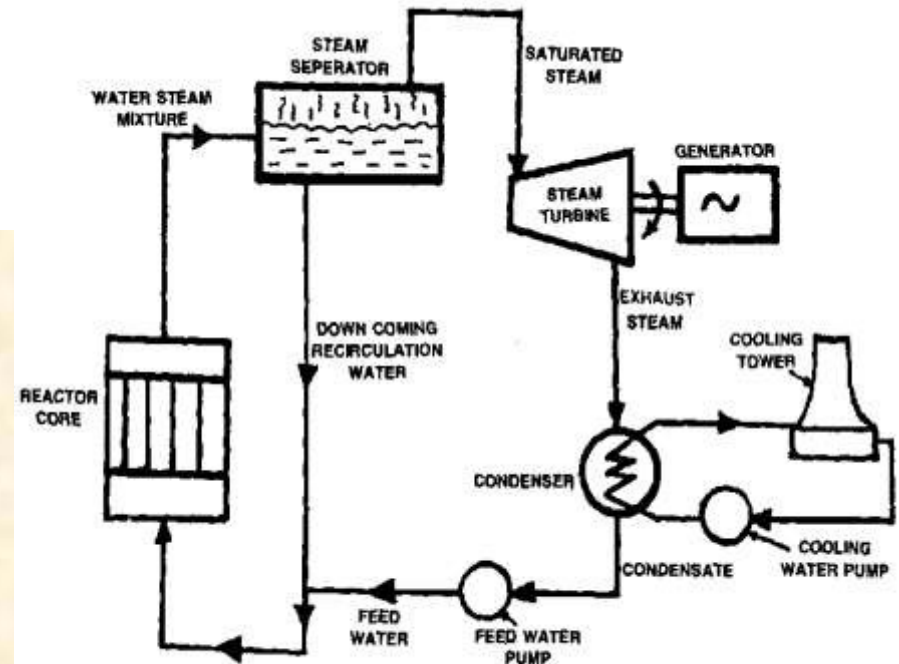


Fig. 3.10: BOILING WATER REACTOR PLANT

Comparison of Reactors

Reactor Type	Coolant	Moderator	Fuel	Comment
Pressurised water reactors (PWR, VVER)	Light water	Light water	Enriched uranium	Steam generated in secondary loop
Boiling water reactors (BWR)	Light water	Light water	Enriched uranium	Steam from boiling water fed to turbine
Pressurised heavy water reactor (PHWR)	Heavy water	Heavy water	Natural uranium	
Gas-cooled reactors (Magnox, AGR, UNGG)	CO ₂	Graphite	Natural or enriched uranium	
Light water graphite reactors (RBMK)	Pressurised boiling water	Graphite	Enriched uranium	Soviet design

Pressurised Water Reactor

- ✓ **(PWR)** Heat is produced in the reactor due to nuclear fission and there is a chain reaction.
- ✓ The heat generated in the reactor is carried away by the coolant (water or heavy water) circulated through the core.
- ✓ The purpose of the pressure equalizer is to maintain a constant pressure of 14 MN/m^2 . This enables water to carry more heat from the reactor.
- ✓ The purpose of the coolant pump is to pump coolant water under pressure into the reactor core.

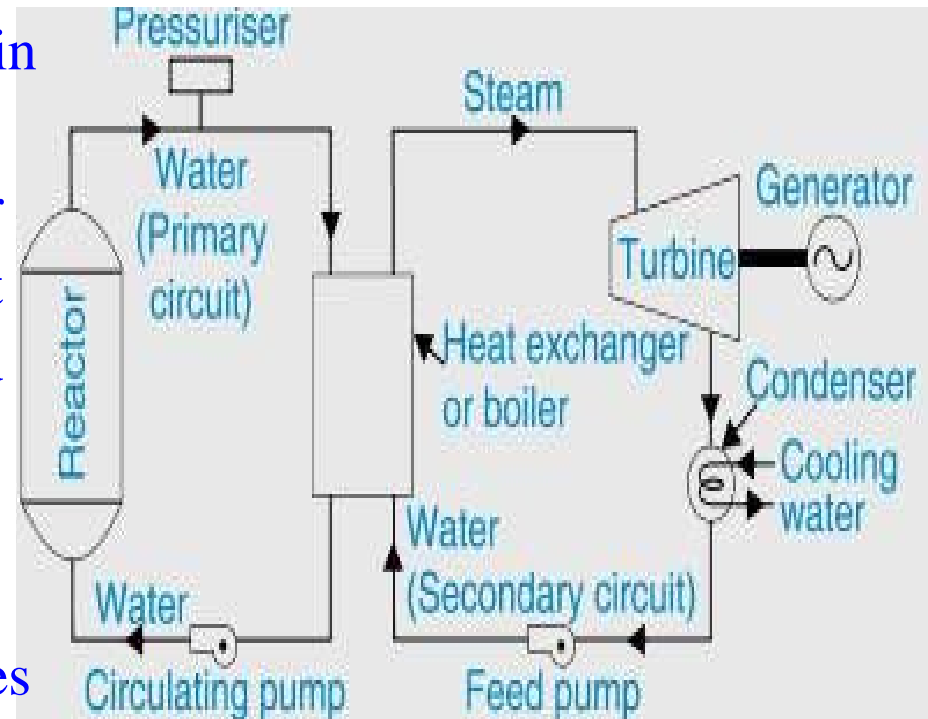
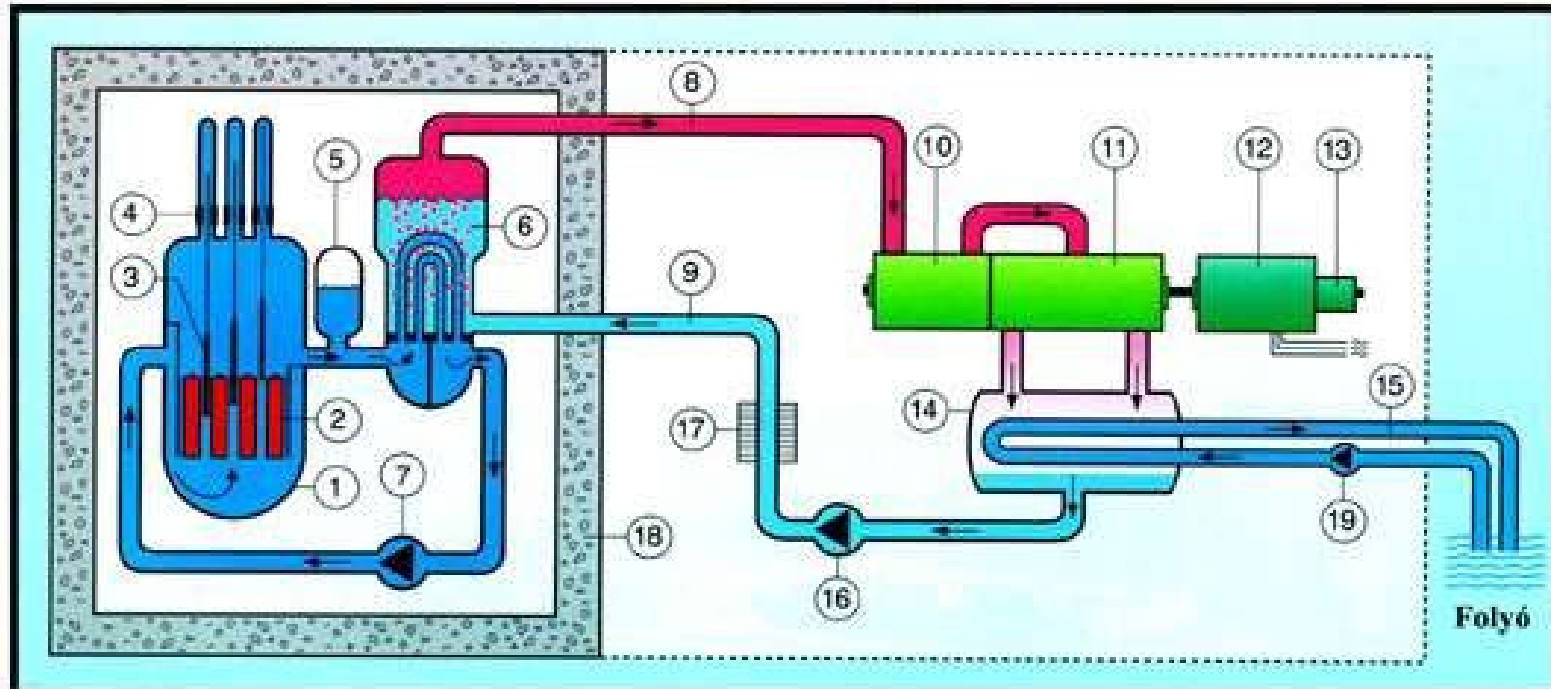


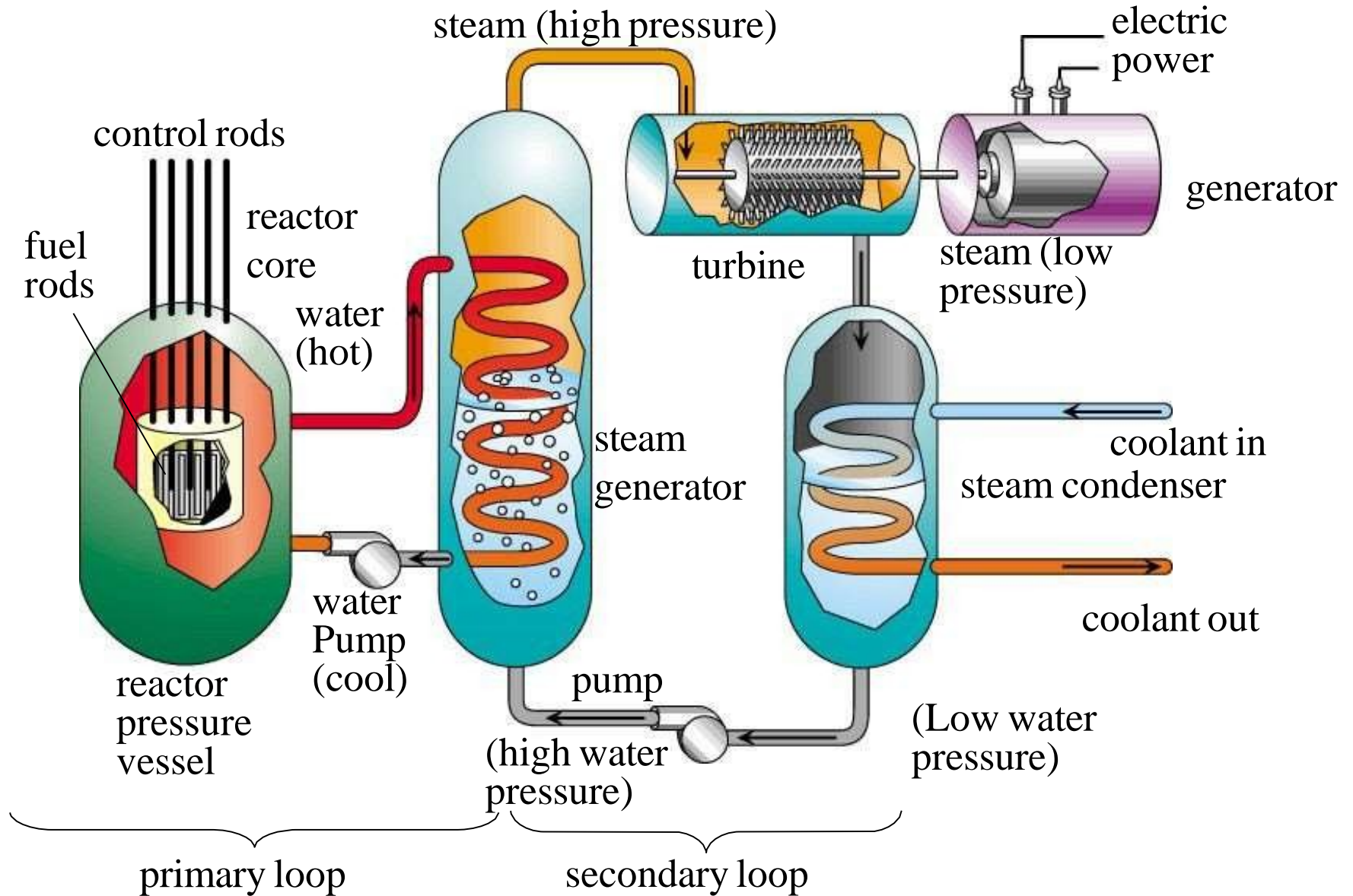
Fig. 7.12. Pressurised water reactor.

PWR: Pressurized Water Reactor



- | | | |
|-------------------------|--------------------------|-------------------------|
| 1 Reactor vessel | 8 Fresh steam | 14 Condenser |
| 2 Fuel elements | 9 Feedwater | 15 Cooling water |
| 3 Control rods | 10 High pressure turbine | 16 Feedwater pump |
| 4 Control rod drive | 11 Low pressure turbine | 17 Feedwater pre-heater |
| 5 Pressurizer | 12 Generator | 18 Concrete shield |
| 6 Steam generator | 13 Exciter | 19 Cooling water pump |
| 7 Main circulating pump | | |

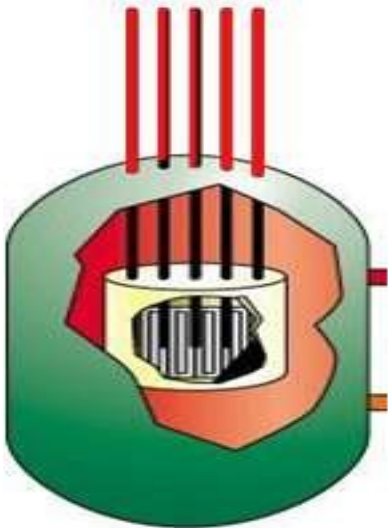
Schematic diagram of a PWR nuclear power plant



fuel rods



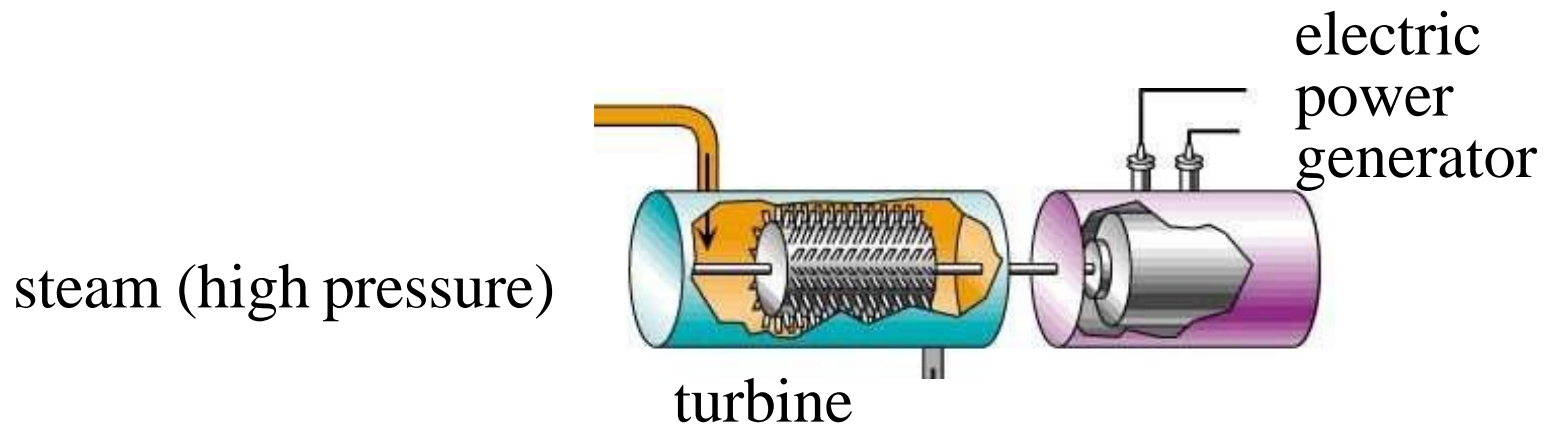
control rods



- They are surrounded by a **moderator (water or graphite)** to *slow down the neutrons released.*
- They contain the nuclear fuel: **uranium (U-235)**

- ❖ They control the rate of reaction by moving in and out of the reactor.
 - Move in: rate of reaction ↓ Down
 - Move out: rate of reaction ↑ up
 - All are moved in: the reactor is shut down
- ❖ They are made of **boron** or **cadmium** that can *absorb neutrons.*

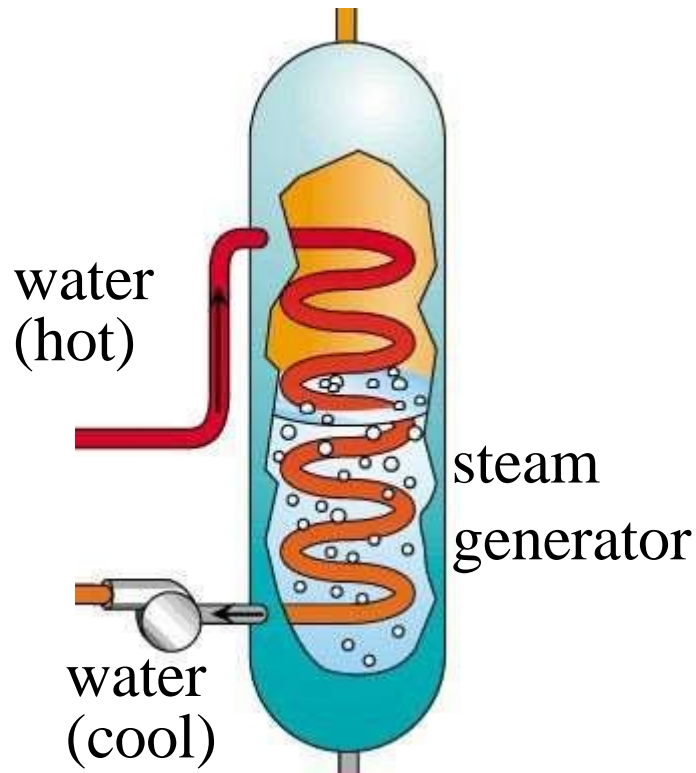
pump



The steam drives a turbine, which turns the generator.

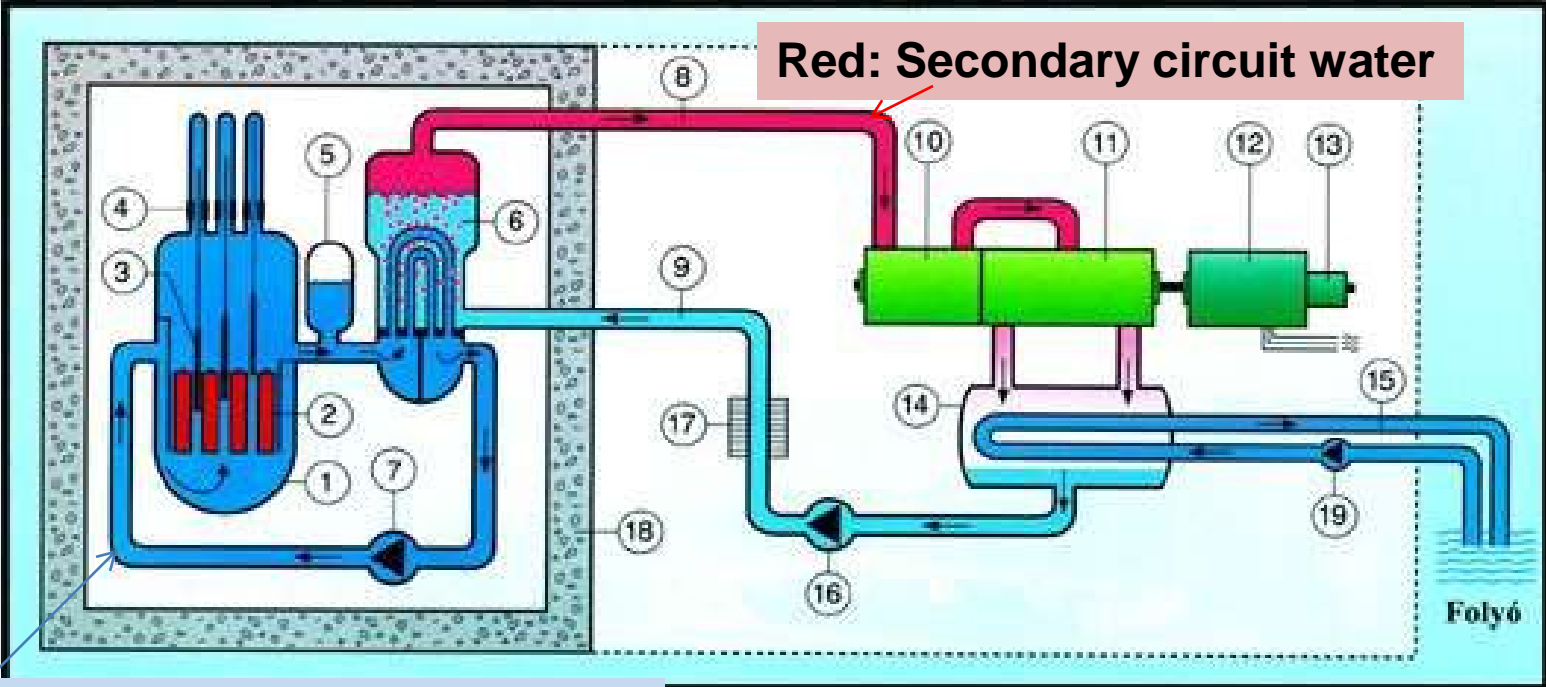
Electricity is produced by the Generator

Two separate water systems are used to avoid radioactive substances to reach the turbine.



- The energy released in fissions heats up the water around the reactor.
- The water in the secondary loop is boiled to steam.

PWR: Pressurized Water Reactor



Red: Secondary circuit water

Dark Blue: Primary circuit water

- | | | |
|-------------------------|--------------------------|-------------------------|
| 1 Reactor vessel | 8 Fresh steam | 14 Condenser |
| 2 Fuel elements | 9 Feedwater | 15 Cooling water |
| 3 Control rods | 10 High pressure turbine | 16 Feedwater pump |
| 4 Control rod drive | 11 Low pressure turbine | 17 Feedwater pre-heater |
| 5 Pressurizer | 12 Generator | 18 Concrete shield |
| 6 Steam generator | 13 Exciter | 19 Cooling water pump |
| 7 Main circulating pump | | |

PWR: Pressurized Water Reactor

- The pressurized water reactor belongs to the light water type: the moderator and coolant are both light water (H₂O). It can be seen in the figure that the cooling water circulates in two loops, which are fully separated from one another.
- The **primary circuit water** (dark blue) is continuously kept at a very high pressure and therefore it does not boil even at the high operating temperature. (Hence the name of the type.)
- The primary circuit water transferred its heat to the secondary circuit water in the small tubes of the steam generator, it cools down and returns to the reactor vessel at a lower temperature.
- Since the **secondary circuit** pressure is much lower than that of the primary circuit, the secondary circuit water in the steam generator starts to boil (red).

Pressurized Water Reactor

- The steam goes from here to the turbine, which has high and low pressure stages. When steam leaves the turbine, it becomes liquid again in the condenser, from where it is pumped back to the steam generator after pre-heating
- Normally, primary and secondary circuit waters **can't mix**.
- In this way it can be achieved that any potentially radioactive material that gets into the primary water should stay in the primary loop and cannot get into the turbine and condenser.
- This is a barrier to prevent radioactive contamination from getting out.
- In pressurized water reactors the fuel is usually low (3 to 4 percent) enriched uranium oxide, sometimes uranium and plutonium oxide mixture (MOX).
- In today's PWRs the primary pressure is usually 120 to 160 bars, while the outlet temperature of coolant is 300 to 320 °C.
- PWR is the most widespread reactor type in the world: they give about 64% of the total power of the presently operating nuclear power plants.

FYI: Pressurized Water Reactor

Dimensions of a typical
PWR reactor pressure vessel:

Height : 15 m (49 ft)

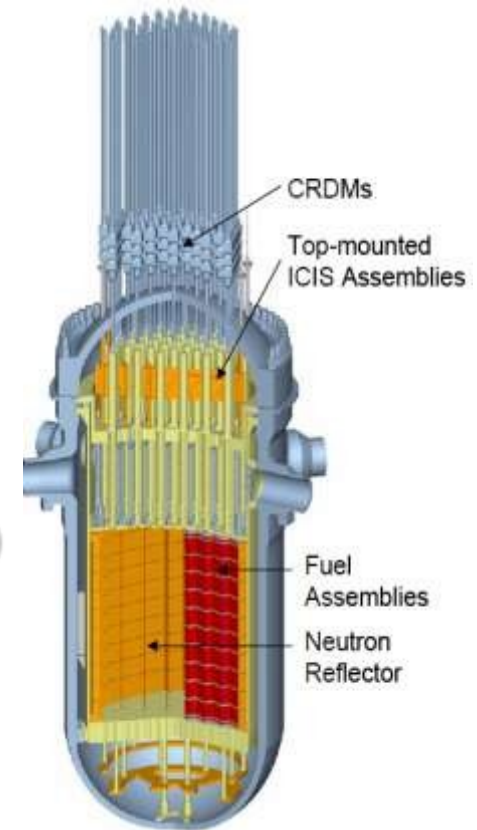
Diameter : 5 m (16 ft)

Wall : 25 cm (10 in) thick steel

Containment : 1 m thick concrete (steel lined)

Core loading : 82 tons of UO_2

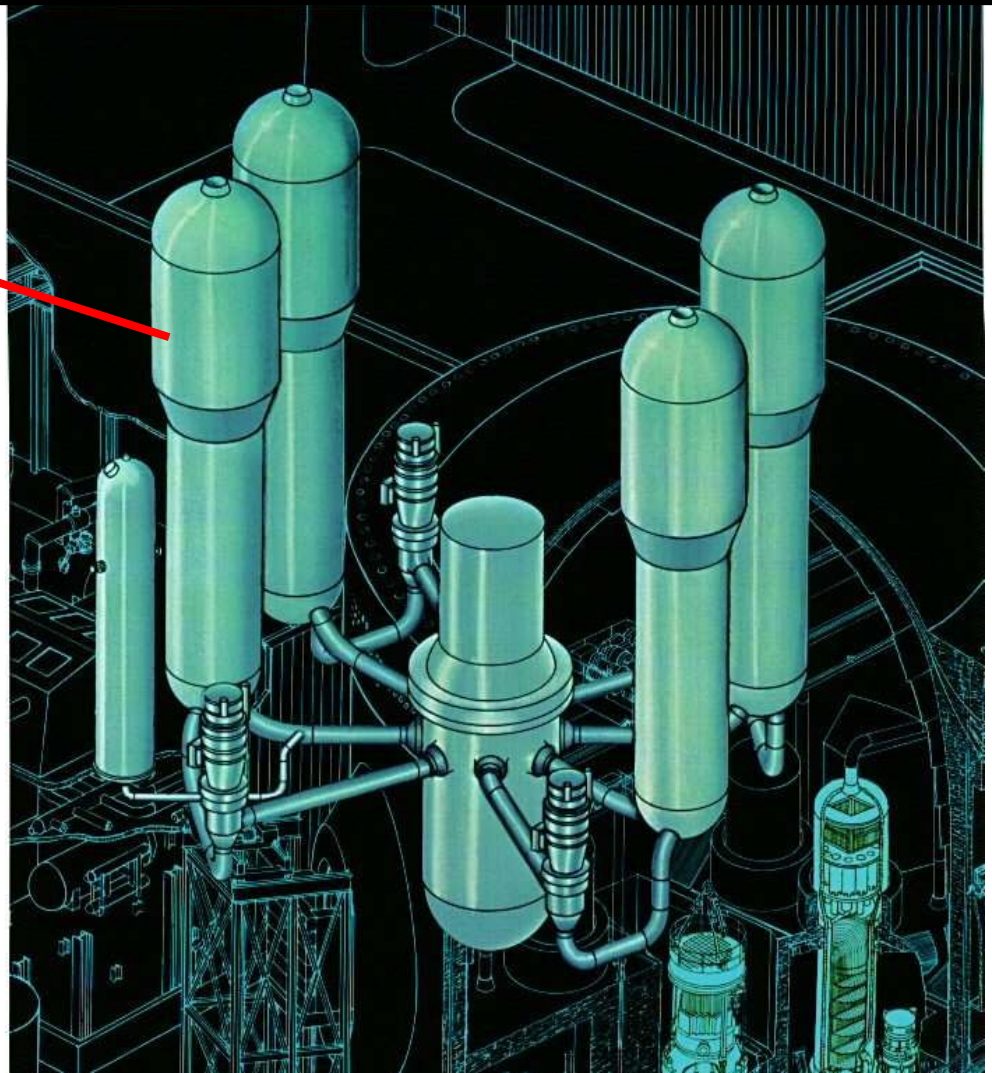
Pressure (Pri.) : 2250 psig (158 Atmos)



PWR: Pressurized Water Reactor



Arrangements of **RPV**,
Steam Generators,
Primary pumps,
Pressurizer, etc.



RPV: Reactor Pressure Vessel

PWR in Operation...



PWRs in Diablo Canyon - CA , the USA



**Kudankulam nuclear plant
Tamilnadu, India**

PWR: Pressurized Water Reactors

Advantages **Pressurized Water Reactor**

- PWR reactors are very **stable** and **easier** to operate.
- PWR reactors lifetime is **longer** and safer control over power level.
- Because PWR reactors use **enriched uranium** as fuel, they can use ordinary water as a moderator rather than the much more expensive heavy water as used in a pressurized heavy water reactor.
- PWR turbine cycle loop is separate from the primary loop, so the water in the secondary loop is **not contaminated** by radioactive materials.
- Water is used in reactor is **cheap and easily available**.
- Small number of control rods are required

Disadvantages **Pressurized Water Reactor**

- Requires high **strength piping** and a heavy pressure vessel and hence **increases construction costs**.
- Most pressurized water reactors **cannot be refueled** while operating. This decreases the availability of the reactor—it has to **go offline** for relatively **long periods of time**
- The high temperature water **coolant** with boric acid dissolved in it is **corrosive** to carbon steel
- Natural uranium is only 0.7% uranium-235, the isotope necessary for thermal reactors. This makes it necessary to enrich the uranium fuel, which increases **the costs of fuel production**.
- If **heavy water** is used, it is possible to operate the reactor with natural uranium, but the production of heavy water requires large amounts of energy and is hence **expensive**.
- Because water acts as a neutron moderator, it is **not possible** to build a **fast neutron reactor** with a PWR design. A reduced moderation water reactor may however achieve a breeding ratio greater than unity, though this reactor design has disadvantages of its own.