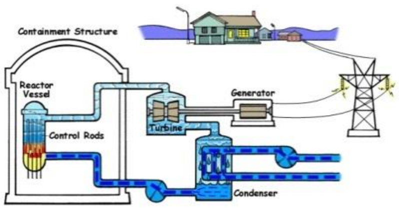
Thermal Power Stations II



Lecture (4)
on
Nuclear Reactors

By

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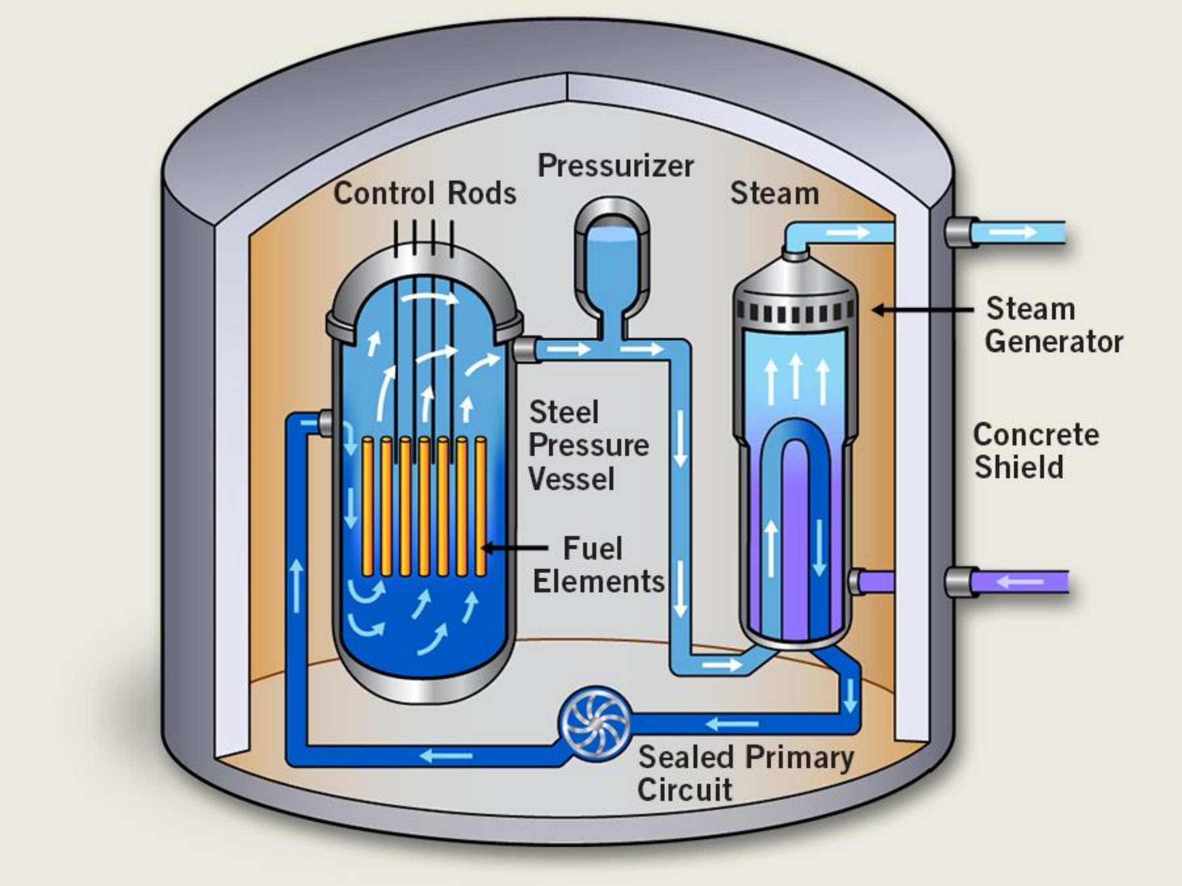
Water Cooled Reactors

Pressurized Light Water Reactor (PLWR)



Water Cooled Reactors

Pressurized Light Water Reactor (PLWR)

- Almost 63% of commercial reactors operating in today's global fleet are a type of PLWR design
- PLWR using plain water as a coolant and moderator with enriched UO2 as fuel, clad in zinc alloy and the pressure vessel of steel.
- The pressure vessel and the heat exchanger are surrounded by a concrete.
- Water is pressurized which keeps it from boiling, even at 300°C. The pressurized water is pumped through a closed system of pipes called the primary circuit.

Water Cooled Reactors

Pressurized Light Water Reactor (PLWR)

- Heat from the primary circuit warms up water in a secondary circuit which is allowed to boil, turning into steam that spins turbines.
- This system completely isolates water that has come in contact with the radioactive core from the water vapour that is used to generate electricity
- Water is passed into reactor at 190°C, 138 bar pressure and is discharged from reactor at 270°C. This water passes through heat exchanger where steam is raised. The steam is of rather poor quality, tern around 250°C and pressure 41 bar.

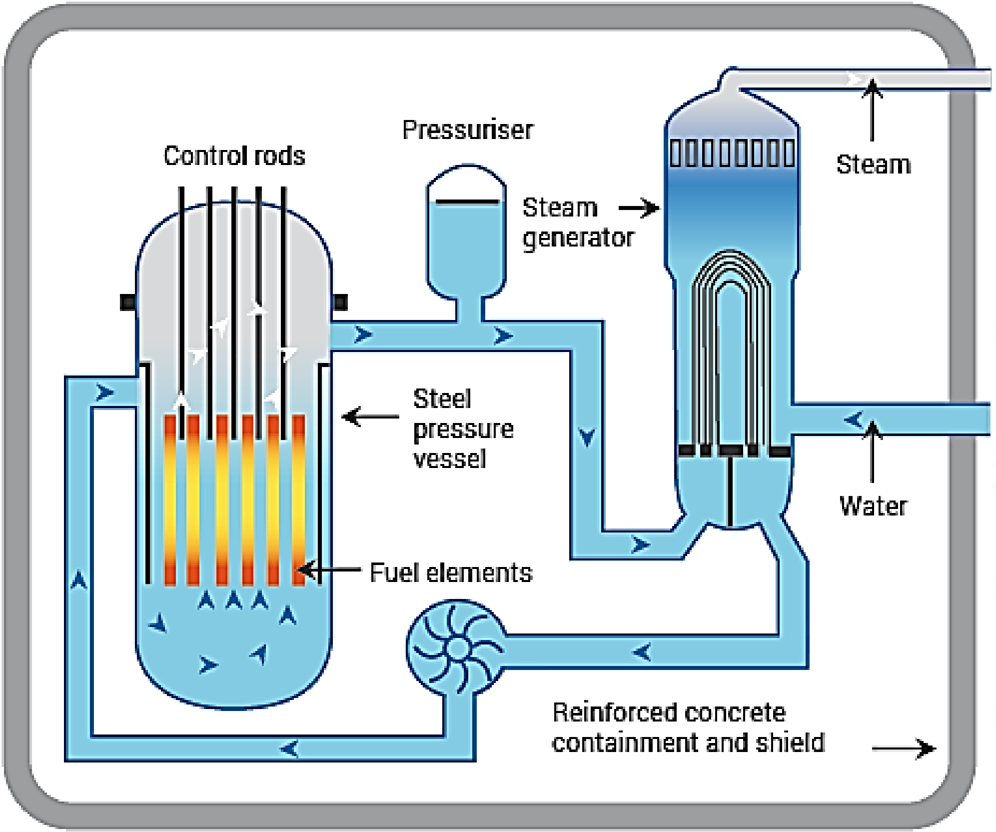
Water Cooled Reactors

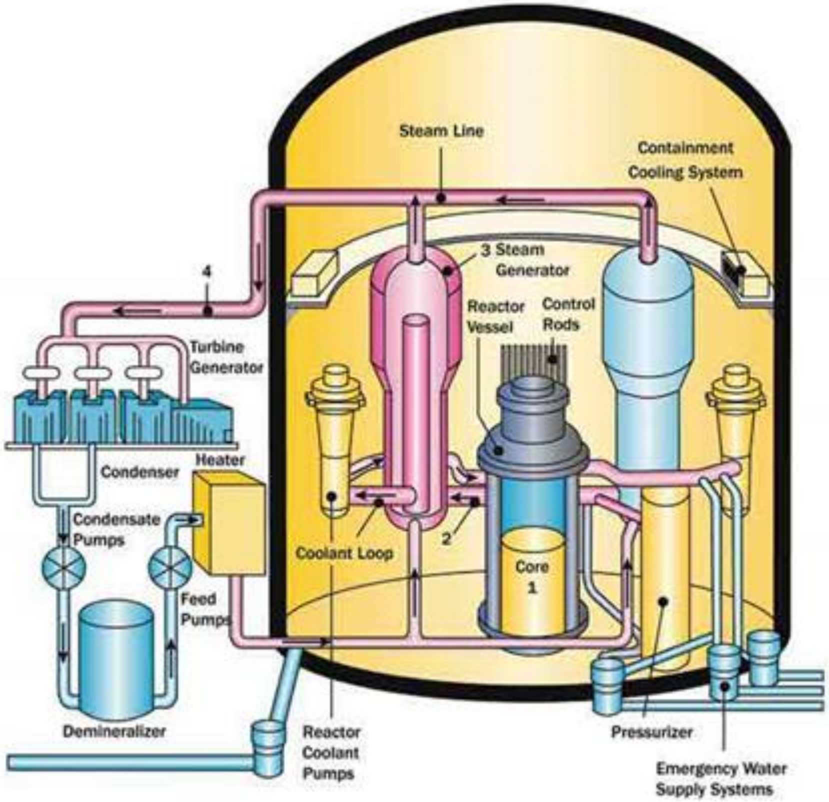
Pressurized Light Water Reactor (PLWR)

- The main drawback of this reactor is the design of high strength pressure vessel.
- The advantage is that steam supplied to the turbine is completely free from contamination.
- The overall efficiency is about 33%.
- They are located in primarily the USA, Europe and eastern Asia.

Water Cooled Reactors

Pressurized Light Water Reactor (PLWR)





Water Cooled Reactors

Pressurized Heavy Water Reactor (PHWR)

- About 11% of commercial operating reactors are PHWRs which use heavy water as coolant and moderator along with natural uranium as fuel.
- Heavy water is a rare but natural form of water and an effective moderator for natural uranium reactors.
- The advantage of heavy water is that it permits the use of natural uranium as fuel. This means two less steps in the conversion process resulting in a more economical fuel source.

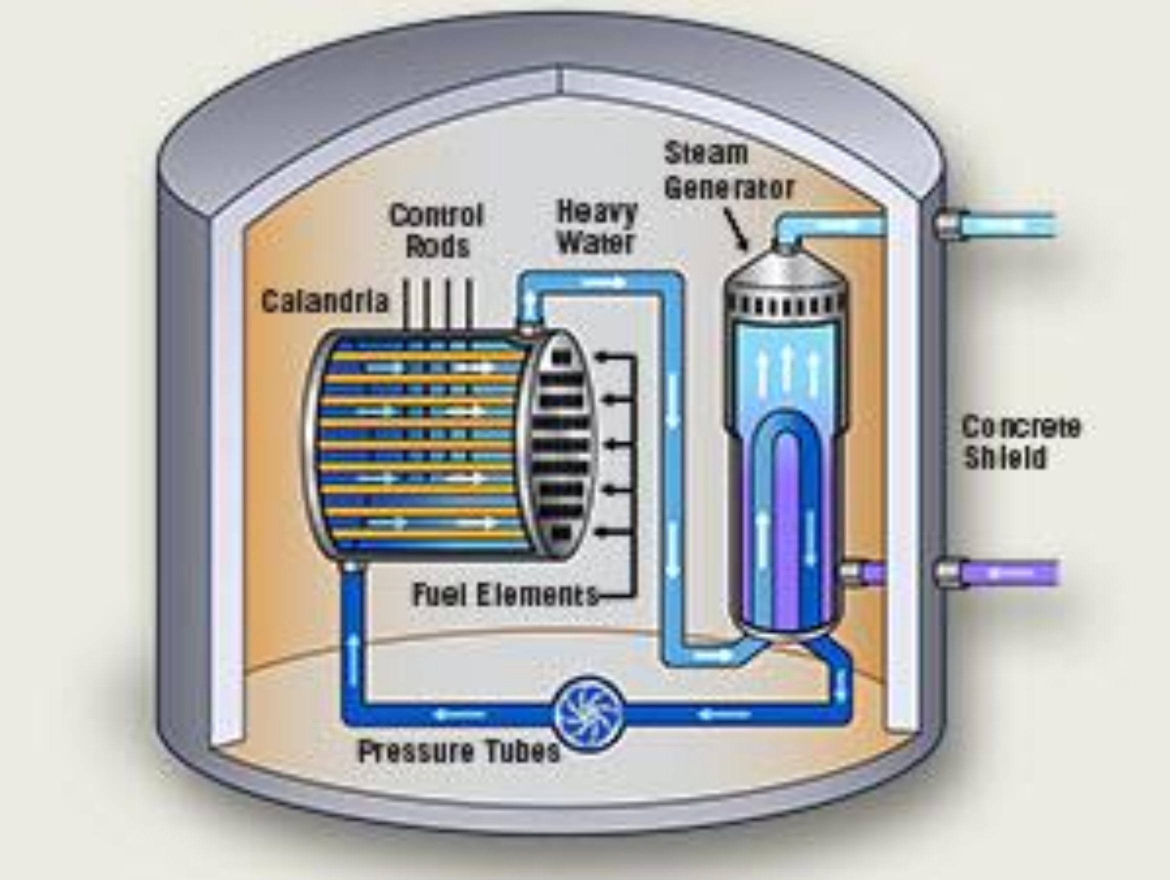
Water Cooled Reactors

Pressurized Heavy Water Reactor (PHWR)

- Fuel bundles are placed horizontally in a tank called a calandria.
- Heavy water coolant is pumped through tubes containing the fuel assemblies to absorb heat from the nuclear reaction. It's then circulated to the steam generator to produce the steam to drive turbines.
- Most are operated in Canada and India.
- As with other PWRs, the two water circuits are separate and transfer only heat, increasing safety.

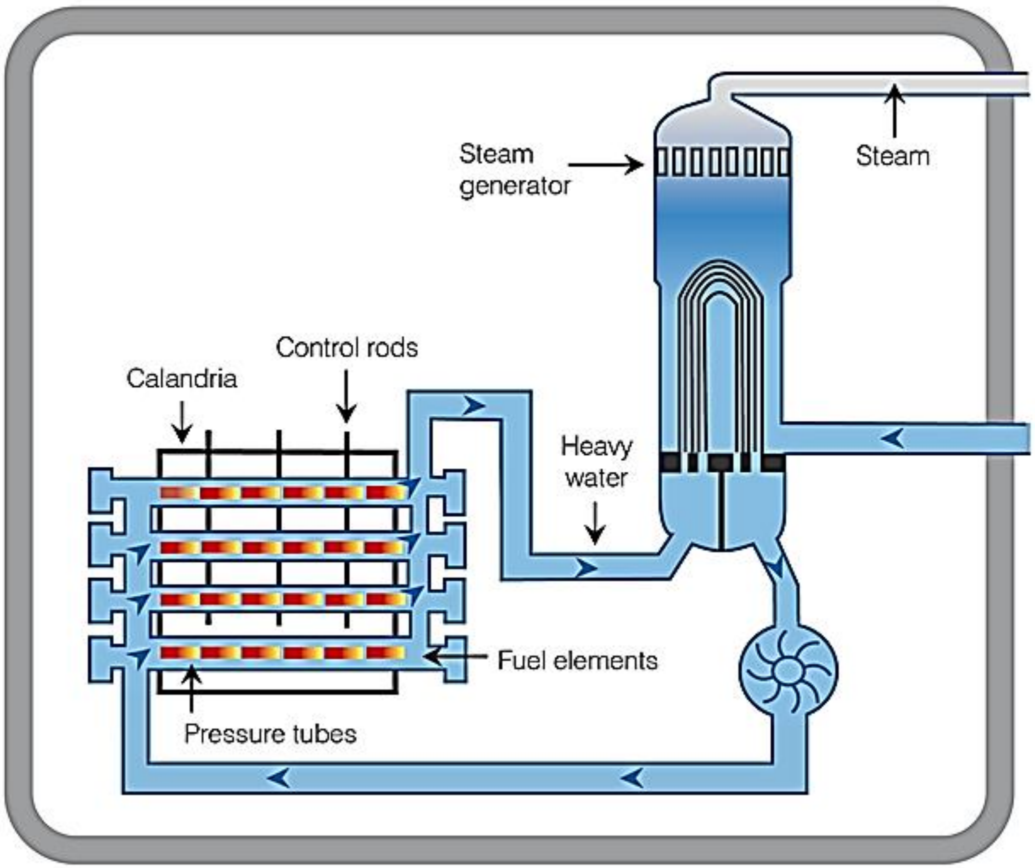
Water Cooled Reactors

Pressurized Heavy Water Reactor (PHWR)



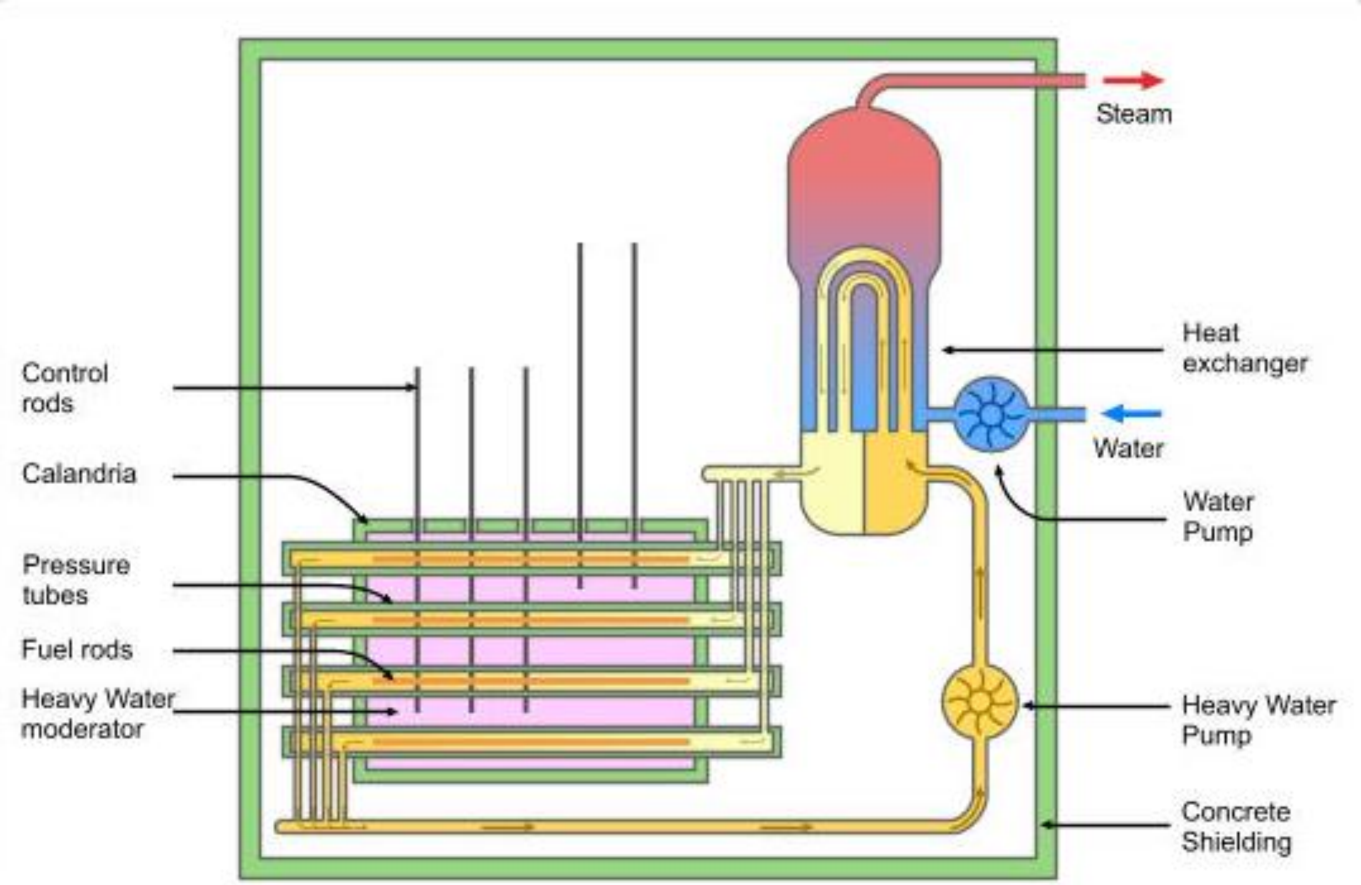
Water Cooled Reactors

Pressurized Heavy Water Reactor (PHWR)



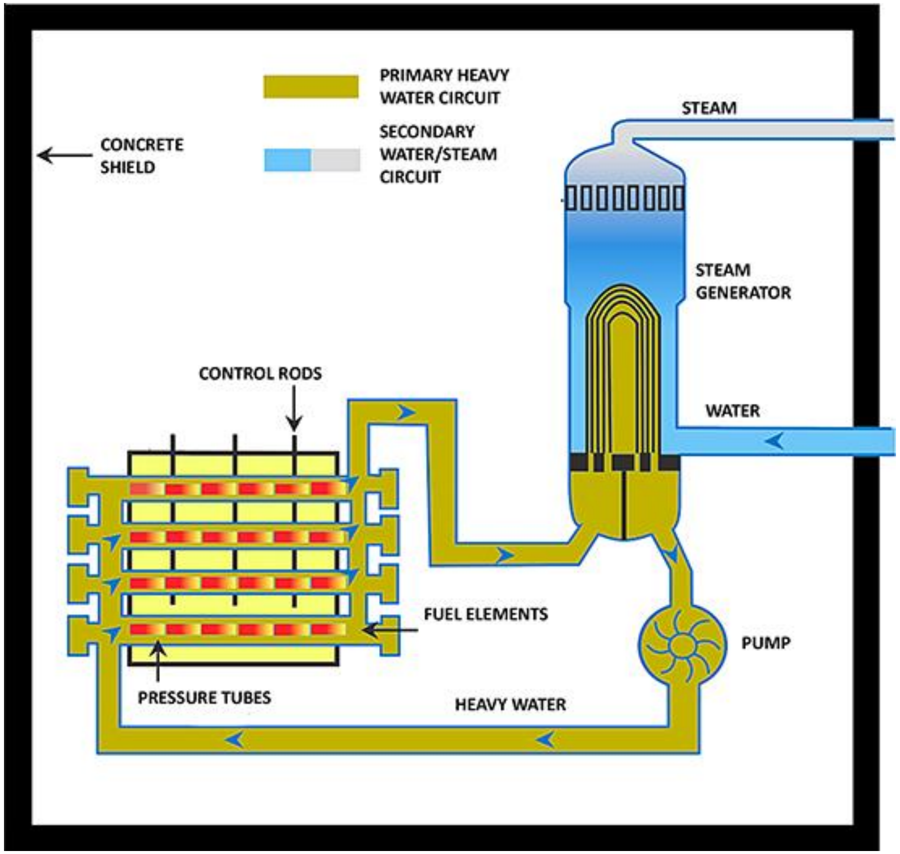
Water Cooled Reactors

Pressurized Heavy Water Reactor (PHWR)



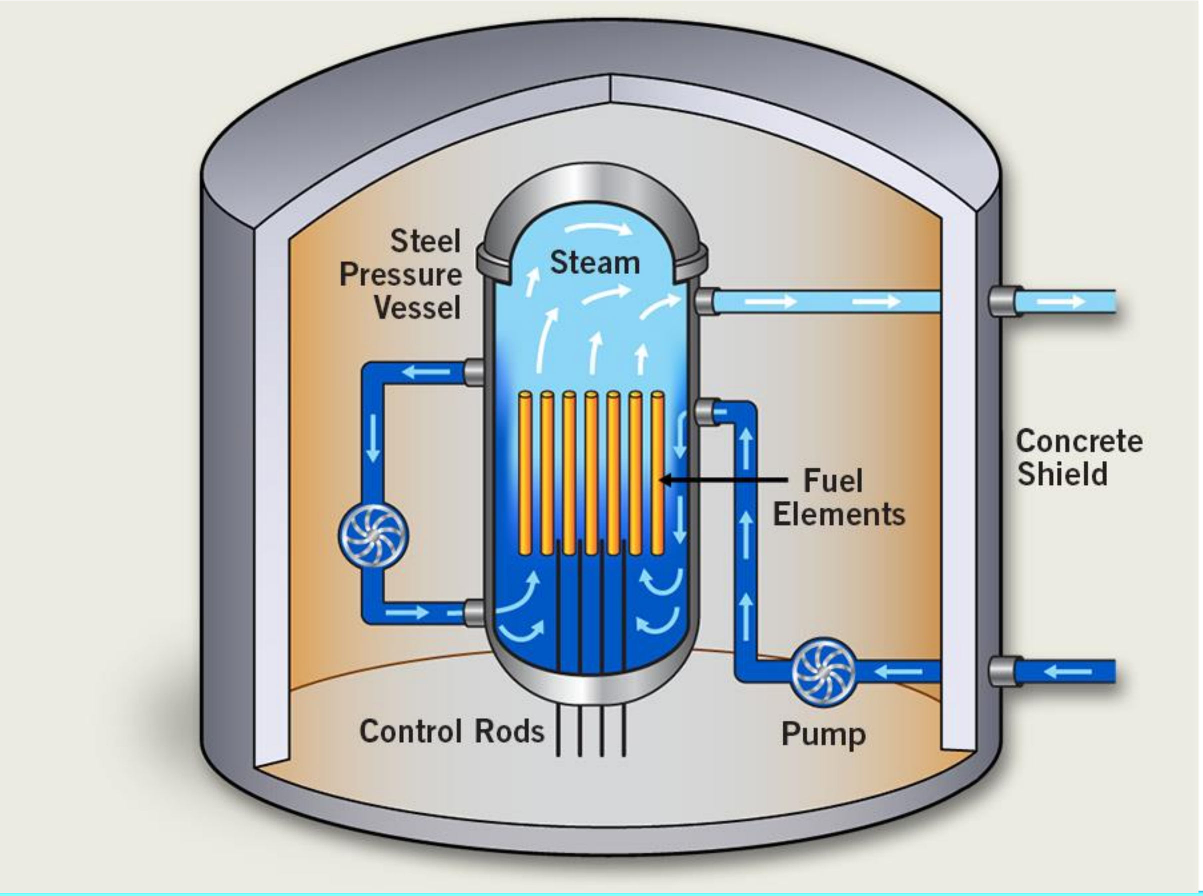
Water Cooled Reactors

Pressurized Heavy Water Reactor (PHWR)



Water Cooled Reactors

Boiling Water Reactor (BWR)



Water Cooled Reactors

Boiling Water Reactor (BWR)

- Roughly 20% of the world's commercial fleet consists of BWR reactors that use ordinary water as coolant and moderator and enriched UO_2 as fuel and has a steel pressure vessel surrounded by concrete shield.
- It is a direct cycle reactor. The steam is generated in the reactor itself and this steam, after passing through turbine and condenser, returns to the reactor.
- In view of the direct cycle, there is danger of radioactive contamination of steam.

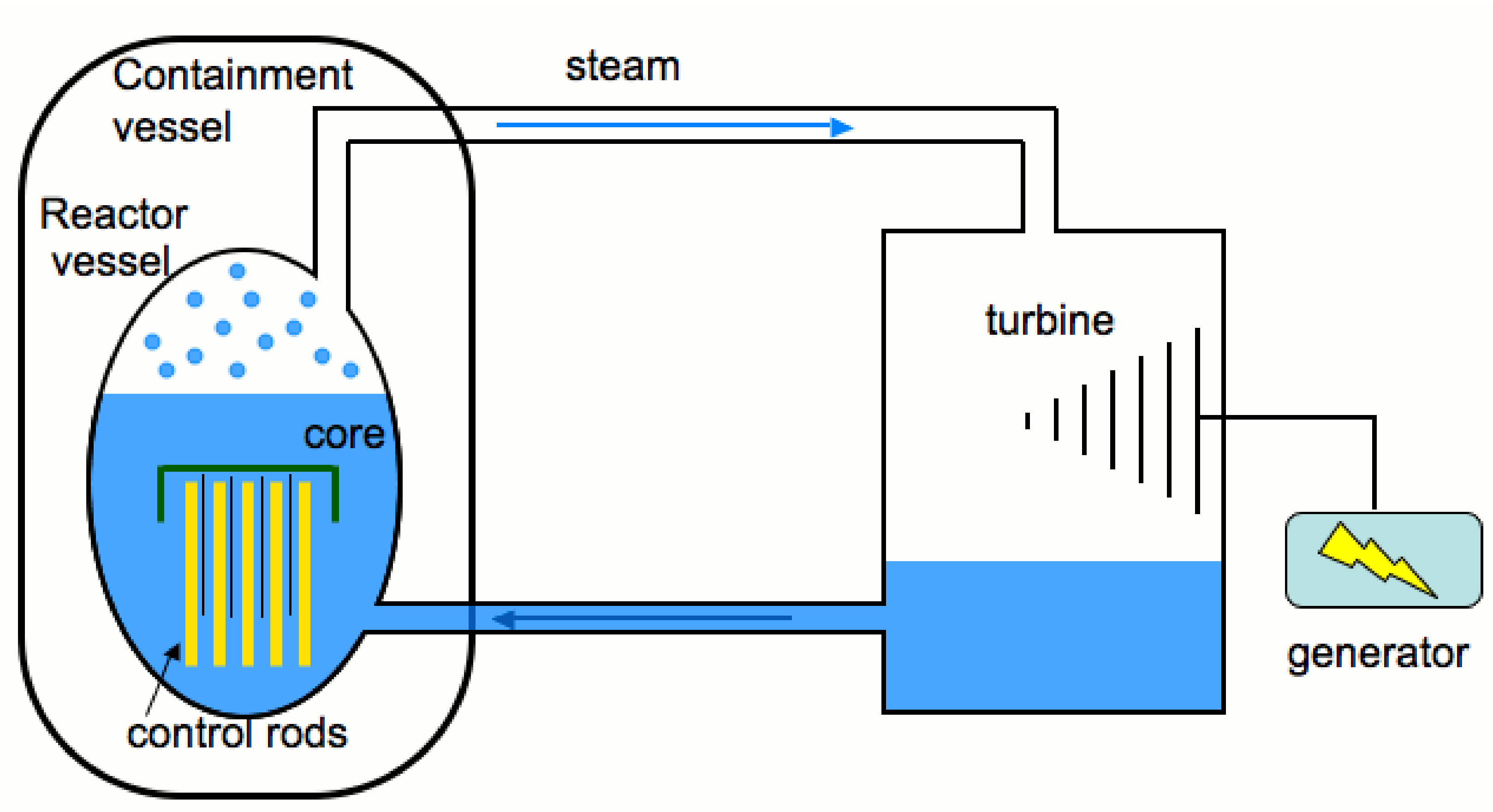
Water Cooled Reactors

Boiling Water Reactor (BWR)

- Because of the danger of small amounts of fissile material passing through along with the coolant, more biological protection is necessary. No one should go within 3 meters of the turbine when it is operating.
- The costs of additional protective measures tend to balance the savings seen from the simplified design.
- The advantages of this reactor include a small size pressure vessel, high steam.
- The BWR reactor design is more streamlined, and less expensive to build, than PWRs.
- The overall efficiency is about 33%.
- They are located in primarily the USA, Europe and eastern Asia.

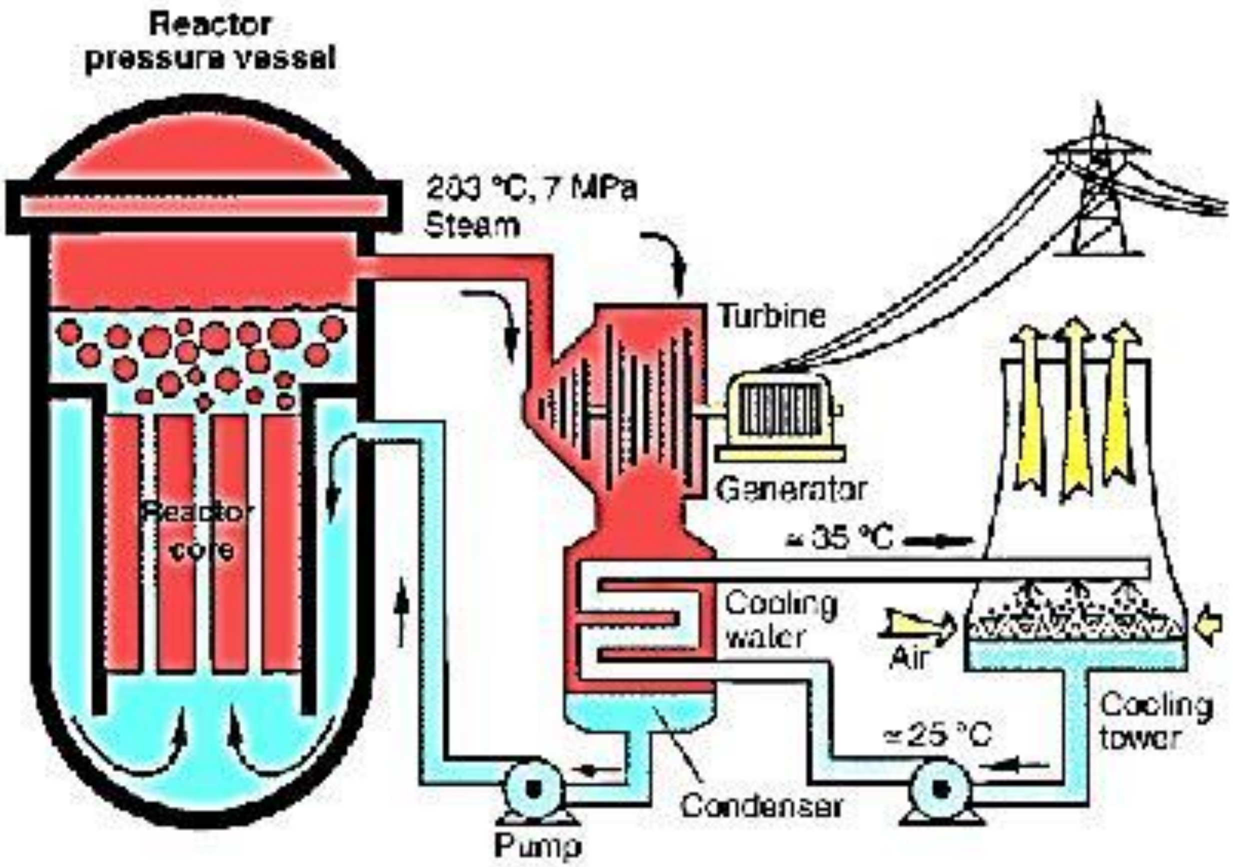
Water Cooled Reactors

Boiling Water Reactor (BWR)



Water Cooled Reactors

Boiling Water Reactor (BWR)



Water Cooled Reactors

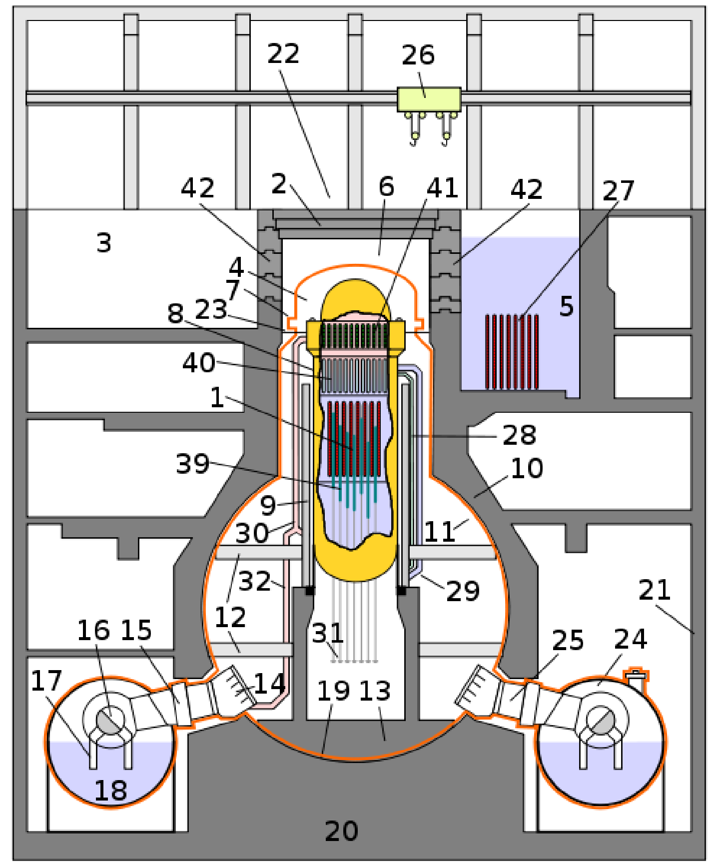
Boiling Water Reactor (BWR)

Fukushima Daiichi Nuclear Power Plant , the plant consists of six boiling water reactors (BWR). These light water reactors drove electrical generators with a combined power of 4.7 GWe, making Fukushima Daiichi one of the 15 largest nuclear power stations in the world.

Water Cooled Reactors

Boiling Water Reactor (BWR)

Fukushima Daiichi Nuclear Power



Water Cooled Reactors

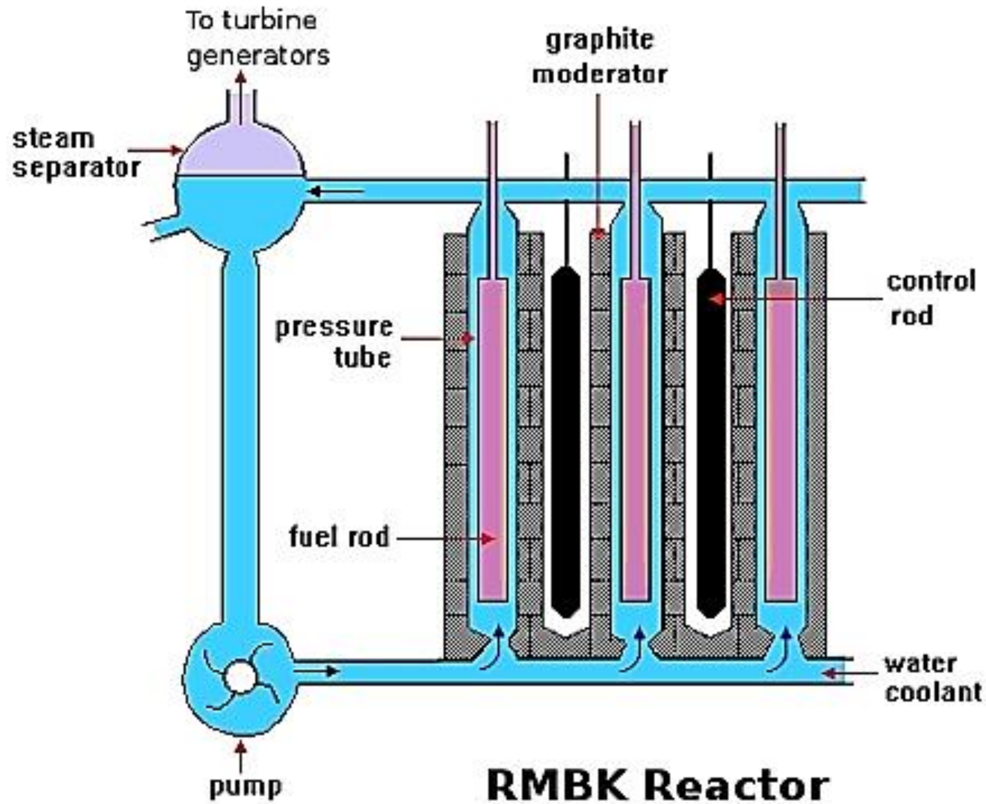
Light water graphite-moderated reactor (RBMK)

- Operating solely in Russia, RBMK reactors represent a mere 3.4% of the world's fleet.
- The RBMK is very different from most other power reactor designs as it was derived from a design originally intended for plutonium production.
- It was used in Russia briefly to produce plutonium but is only used to produce electricity now.
- It is a pressurized water-cooled reactor with individual fuel channels, using graphite as its moderator. It employs long vertical pressure tubes running through the moderator, and is cooled by water.
- The water is allowed to boil in the core at 290°C, much like a BWR.

Water Cooled Reactors

Light Water Graphite-moderated Reactor (RBMK)

The Chernobyl Power station consisted of four reactors of type RBMK, each capable of producing 1,000 megawatts (MW) of electric power (3.2 GW of thermal power), and the four together produced about 10% of Ukraine's electricity at the time of the accident.



RMBK Reactor (eg, Chernobyl)

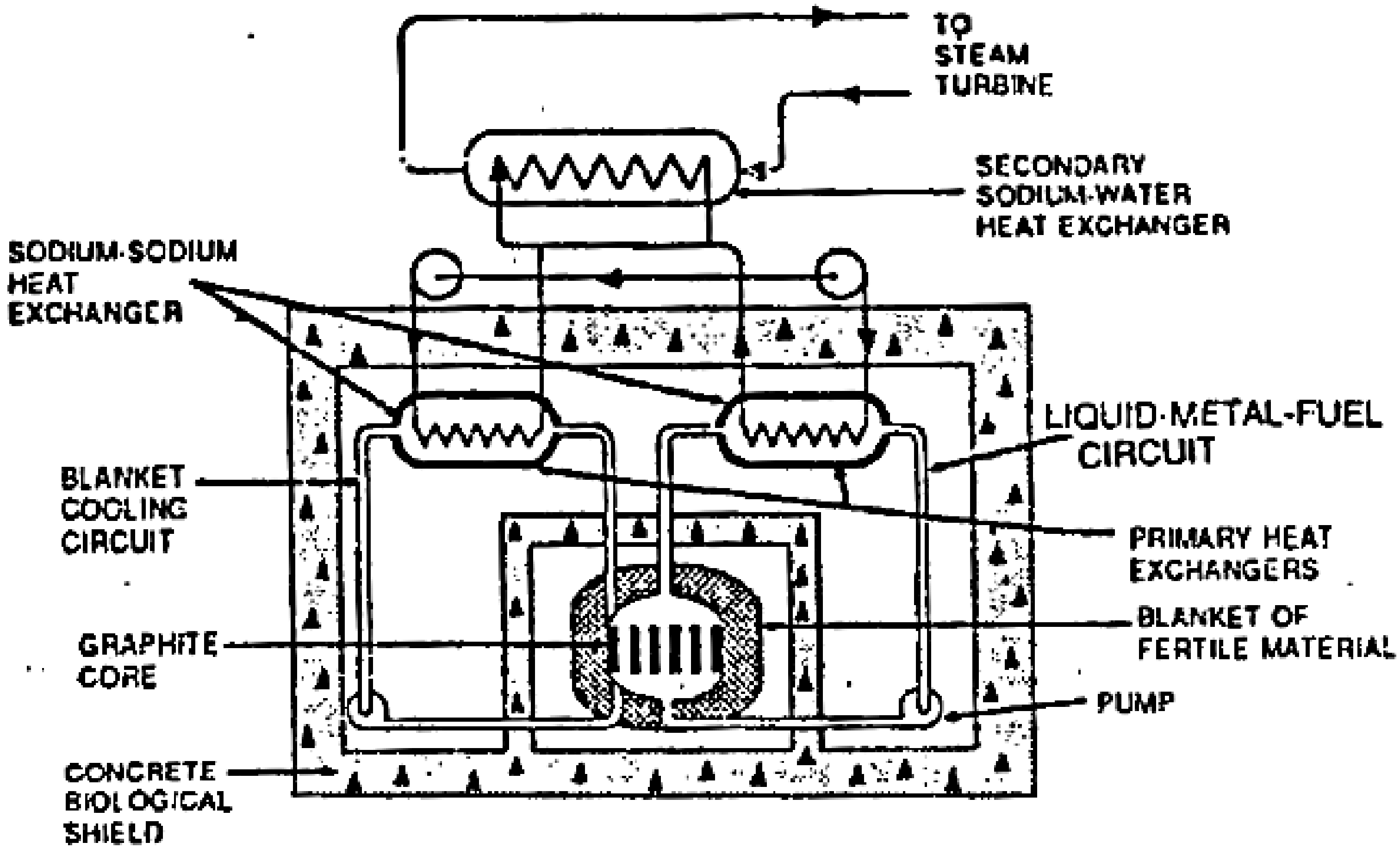
Liquid Metal Fuelled Reactor (Sodium Graphite Reactor)

- A metal in liquid form has many advantages as a coolant. The properties permit high excellent heat transfer operating temperatures and ratings. Since the vapor pressure of liquid metals is low, the design of the pressure vessel is simple.
- Liquid metal as coolant can be used both in thermal as well as fast reactors.
- Liquid metal fuelled reactor uses liquid metal fuel, i.e. uranium in sodium, graphite as moderator and sodium as a coolant.
- The reactor core, with graphite moderator, has the liquid metal fuel (i.e., uranium in sodium) passing through it and through a heat exchanger.

Liquid Metal Fuelled Reactor (Sodium Graphite Reactor)

- The core is surrounded by a blanket of fertile material (e.g. Thorium) through which a separate coolant passes to a separate heat exchanger.
- It is necessary to have primary and secondary heat exchangers. The primary heat exchanger is a sodium-sodium heat exchanger. The secondary heat exchanger is a sodium-water heat exchanger.
- Thus, in the secondary heat exchanger. sodium gives up heat to water which gets converted into steam and is fed to the steam turbine.

Liquid Metal Fuelled Reactor (Sodium Graphite Reactor)



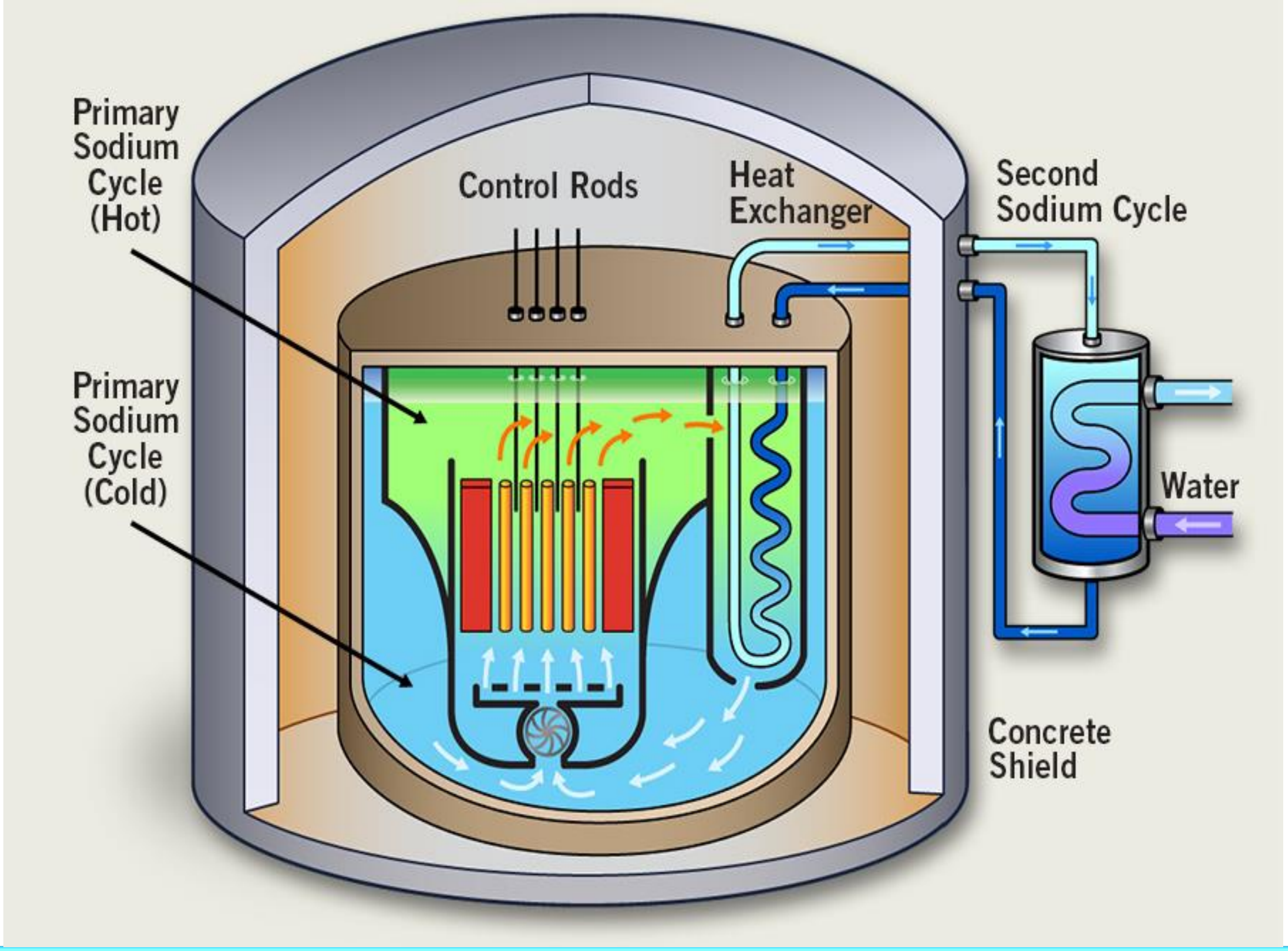
Fast Breeder Reactor (FBR)

- Initially developed in the 1950's, only a handful of FBR reactors have produced electricity on any commercial scale.
- A fast breeder reactor is different from the previous thermal reactors . A thermal reactor uses fissile nuclear fuel and produces heat. A fast breeder reactor produces heat and at the same time converts fertile material into fissile material.
- A fast breeder reactor has a closed fuel cycle. It breeds its own fuel; therefore the fuel cycle is closed. They have a core of plutonium surrounded by rods of non-fissile U238. The U238 nuclei absorb neutrons from the core and are transformed into plutonium (P239). For every four atoms of plutonium that are used up in the core of the breeder, five new plutonium atoms are made from the U238. They are not equipped with a moderator to slow down neutrons, and for this reason are called "fast" breeders.

Fast Breeder Reactor (FBR)

- FBR can utilize uranium at least 60 times more efficiently than a normal reactor. However, they are very expensive to build, and current supply of moderately priced uranium does not make them economic for power generation at this point.
- Fast breeder reactors work at such a high temperature that they need a special coolant such as liquid sodium. Because they operate under such high temperatures, researchers are studying the potential use of FBRs as high-level radioactive waste burners.
- The possibility of core being overheated and destroyed has to be taken into account. The heat transfer and control problems of these reactors need special attention.
- Only one, located in Russia, is generating electricity commercially today.

Fast Breeder Reactor (FBR)



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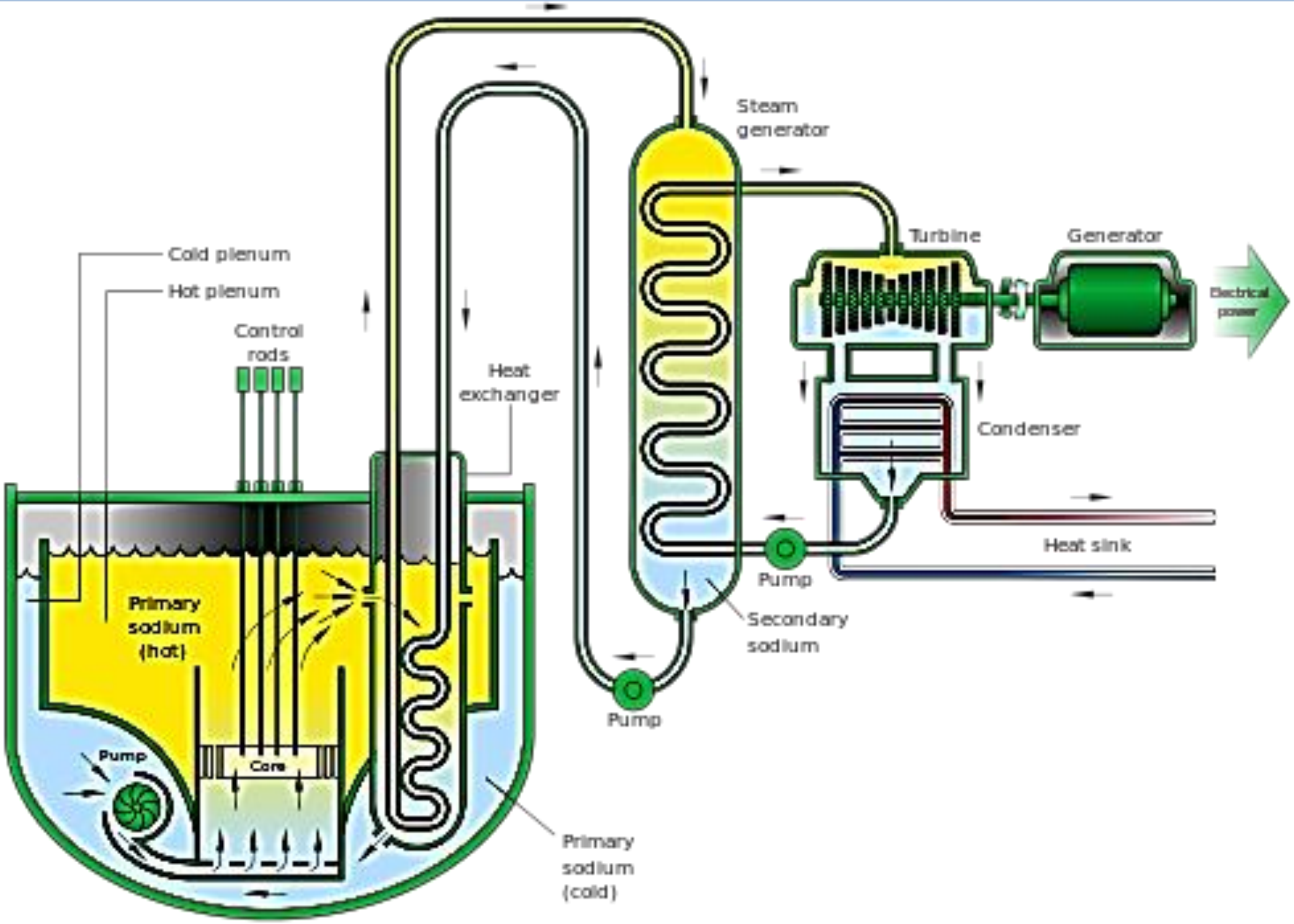

Thank you