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Pressurized water reactor - Energy Education

8–10 minutes

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Figure 1. The Watts Bar Nuclear Generating Station in Tennessee uses PWRs in its operation.[1]

Figure 2. Nuclear submarines make use of the high power-to-weight ratio of PWRs in their operation.[2]

The **pressurized water reactor** (**PWR**) is a type of nuclear reactor used to the generate electricity and propel nuclear submarines and naval vessels.[3] They make use of light water (ordinary water, as opposed to heavy water) as their coolant and neutron moderator. It is one of three types of light water reactors, with the others being the boiling water reactor and the supercritical water cooled reactor.

It was originally designed for the U.S. Navy, however, it quickly grew to become the most widely used reactor in nuclear power plants; with 297 in operation around the world as of 2018.[4] This makes them by far the most dominantly used reactor in the world, with the second most (the boiling water reactor) having only 80 in operation. Construction of PWRs diminished greatly after the Three Mile Island nuclear accident, mainly as a result of public support becoming weaker.

Their use on naval vessels and nuclear ships are of extreme importance to various militaries around the world.Nuclear power has a huge advantage over fuels like gasoline or diesel as it allows ships to run for very long periods without the need to refuel. PWRs make a good reactor for these ships since they have a high specific power (high power for their mass) due to their use of high pressure. This allows the reactors to be fairly compact, especially with the use of highly enriched uranium.

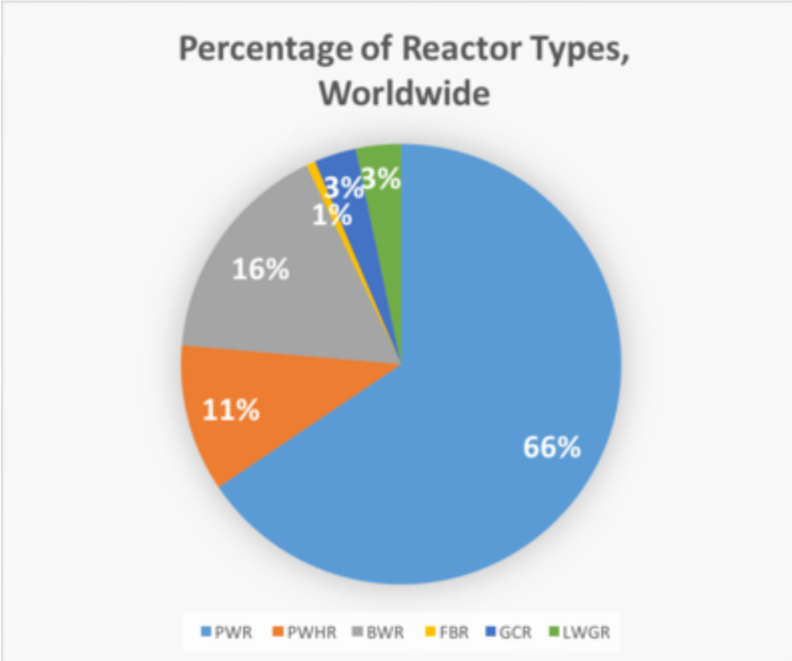

Figure 3. Percentage of Rector types worldwide.[4]

Type	Number of Reactors
PWR	297
BWR (Boiling Light-Water Cooled and Moderated Reactor)	75
PHWR (Pressurized Heavy-Water Moderated and Cooled Reactor)	49
LWGR (Light-Water Cooled, Graphite Moderated Reactor)	15
GCR (Gas Cooled, Graphite Moderated Reactor)	14
FBR (Fast Breeder Reactor)	3

Characteristics

Fuel

Pressurized water reactors must use enriched uranium as their nuclear fuel, because of their use of light water. This is because light water would absorb too many neutrons if natural uranium was used, so the fuel content of fissile Uranium-235 must be increased. This is done through a uranium enrichment process, in which the concentration of Uranium-235 is increased from 0.7% to around 4%.[5]

The enriched uranium is packed into fuel rods which are assembled into a fuel bundle, as seen in Figure 3. There are about 200-300 rods in each bundle for a PWR, with a large reactor containing 150-250 bundles in their core.[6] This corresponds to about five cubic meters of uranium, or 80-100 tonnes of uranium.[6]

The bundles are arranged vertically in fuel tubes within the core. As the fuel is "burned" in the reactor, its density gradually increases, resulting in small voids to develop inside the fuel tube. These void spaces can cause a problem because high pressures could cause stress to the tubes, increasing the likelihood of a rupture. To avoid this problem, the tubes are pressurized with helium at about 3.4 MPa. As fission gas products accumulate over the fuel's lifetime, the pressure gradually balances with the high pressure of the core.[3]

Figure 3. A nuclear fuel bundle for a PWR.[7]

Coolant and Moderator

As mentioned before, light water is used as the coolant and moderator for a pressurized water reactor. Light water is *much* more abundant than heavy water, as it makes up 99.99% of natural water.[8]

Light water does not make as good of a moderator as heavy water or graphite as a result of its relatively high absorption of neutrons. However, its use as a moderator makes for an important safety feature; if there is a loss of coolant accident (LOCA), there will also be a loss of moderator causing the nuclear chain reaction to stop. Also if the moderating water overheats and becomes steam inside the bottom reactor core, there will be less moderator and therefore the chain reaction will stop.

Pressure, Temperatures and Water flow

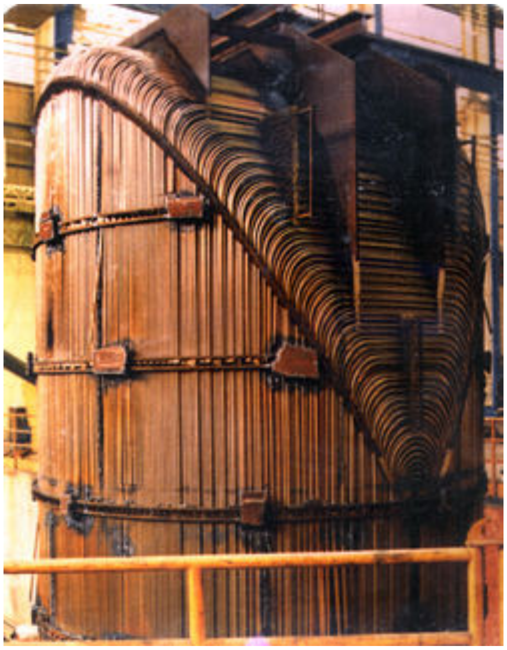

Figure 4. The inverted U-tube bundle in the steam generator of a PWR.[9]

As the name implies, the water in the reactor is pressurized. This is due to the fact that as the pressure gets higher, the boiling point of water increases with it. This means that at high pressures the water can operate at extremely high temperatures without boiling to steam. This is important for the reactor as higher pressures allow for greater power output and higher thermal efficiency.[10] The pressure is maintained by the "pressurizer" (Figure 4), which acts to stabilize pressure changes caused by changes in electrical load.[3]

Water enters the reactor at 290°C, and by the time it exits it is at around 325°C.[3] In order for it to remain a liquid at these temperatures, the pressure must be 15 MPa, or about 150 times atmospheric pressure.[6] By keeping the water in liquid form, the control rod system is simplified as they are able to be placed in from the top, rather than from the bottom like in a boiling water reactor. Therefore, if the power is lost in the plant, the electromagnetic system holding the rods will give out, and gravity will cause the rods to fall into the core, stopping the reaction.[3]

The hot water flowing from the reactor flows through inverted U-tubes (Figure 4) which acts as a heat exchanger, heating up a secondary loop of water in what is called a "steam generator". This secondary loop is at a lower pressure so it is able to boil to steam, which then passes through turbines in order to generate electricity. Large reactors have up to *4 steam generators*,[3] each of which may be larger than the reactor itself.

The basic operation of a PWR can be seen below.

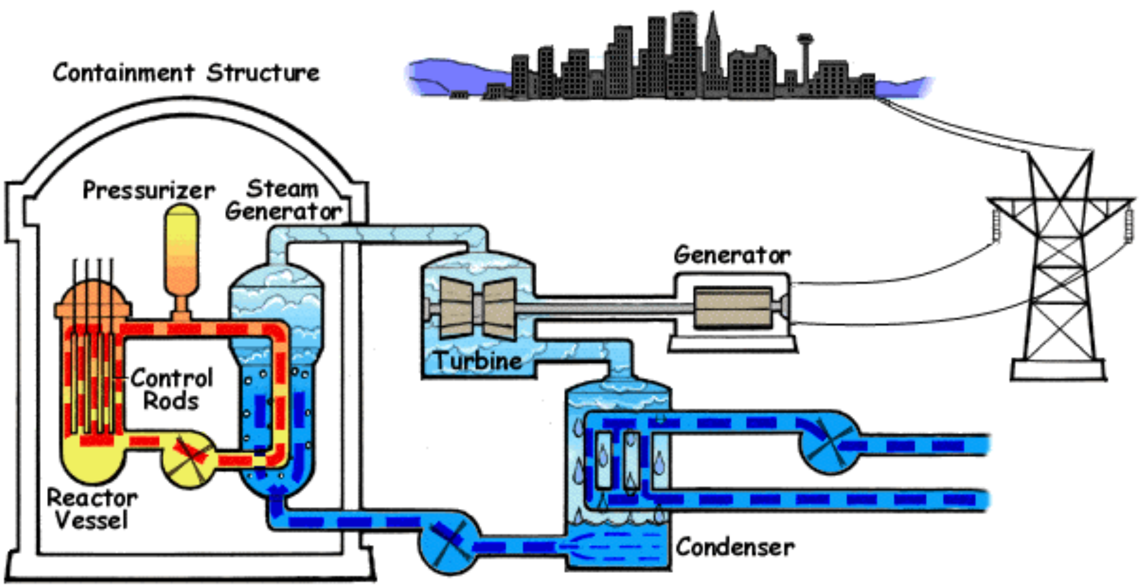

Figure 5. The basic cycle and water flow of a PWR.[11]

For Further Reading

- Nuclear power
- Nuclear reactor
- Nuclear power plant

- Boiling water reactor
- Uranium
- Or explore a random page

References

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