Nuclear Reactors

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Thermal reactors

Most of the world's operational reactors are thermal reactors, that is they contain a moderator to slow down the neutrons emitted in the fission process.

Fuel

Most modern reactors use enriched uranium. Natural uranium is mostly uranium-238 which will not undergo fission (it usually absorbs the neutrons), so the amount of uranium-235 is increased from 0.7% to around 3%. This is enough to sustain the reaction.

Moderator

The core is filled with water as the moderator. The neutrons that pass between the fuel rods are slowed to thermal energies to promote fission.

Control rods

Each fission reaction produces several neutrons, but only one must be allowed to go on to cause further fission. The extra neutrons are captured by the control rods which are made of a material that will readily absorb neutrons. These are placed in the core, between the fuel rods. They are suspended by electromagnets, and can move up and down in between the fuel rods. The lower down the rods, the more neutrons are absorbed, and so the reaction will 'slow'. If less than one neutron per fission goes on to cause further fission, the reaction is said to be subcritical, more than one and it is supercritical, and exactly one and the reactor is critical. It is the use of the control rods that allows the reaction to stay critical.

Coolant

The coolant takes heat from the core into a heat exchanger where it transfers heat to another fluid to turn turbines. In the pressurized water reactor (PWR), the moderator and the coolant are the same—water, which is kept under pressure to stop it from boiling—although in many other types a solid moderator is used, along with a liquid or gas coolant.

Choice of materials

The moderator, control rods and coolant are chosen to do specific tasks, and the choice of material is critical in how efficiently these tasks are carried out. No material is perfect for each component, but a particular material can offer a combination of good properties.

Moderator The moderator should be made of a material whose nucleus

- does not absorb neutrons (i.e. has a low absorption cross-section)
- has a low mass (as the energy is transferred by collisions, more energy will be lost by the neutron when colliding with a nucleus of similar mass)
- does not become too radioactive when bombarded with neutrons

Examples are heavy water (deuterium oxide) and graphite.

Control rods The control rods should be made of a material that

- readily absorbs neutrons upon bombardment (has a high absorption cross-section)
- has a high melting point (as the kinetic energy of the neutron is deposited upon absorption)

Examples are cadmium and boron.

Coolant The coolant should

- have a high specific heat capacity
- have a good thermal conductivity
- have a low viscosity

Examples are heavy water, carbon dioxide, liquid sodium.