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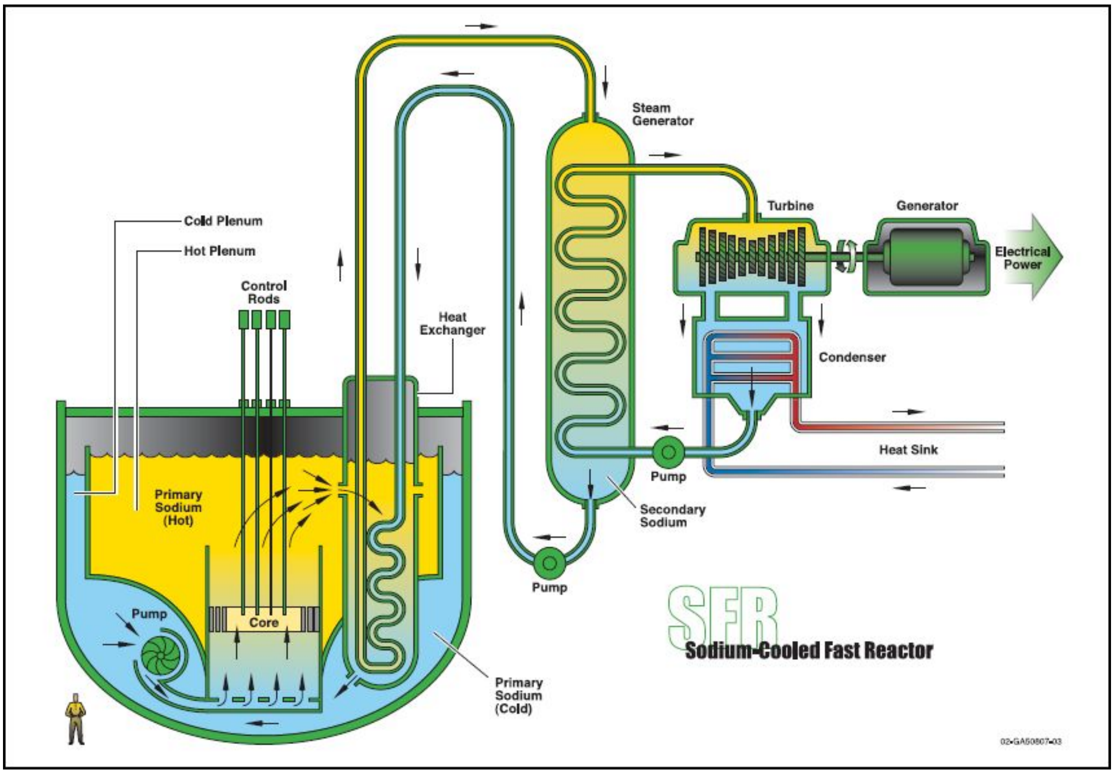
Fast Neutron Reactors (Approved 2/6/06, Revised 14/7/12)

Unlike the present generation of thermal nuclear power reactors which use water or graphite to moderate (ie decrease) the energy of neutrons to a few electron volts and are water- or gas-cooled, fast reactors operate without a moderator at neutron energies of several hundred thousand electron volts. Fast reactors require fuel with a higher fissionable content than thermal reactors to reach criticality but are more efficient at converting fertile material into fissile material. Also, because fast reactors operate at higher temperatures, they require liquid metal or gas coolants which have excellent heat transfer properties and little moderating effect. To minimise the risk of contaminating the generation plant, heat removed from the core by the primary coolant loop is transferred to a secondary non-radioactive loop before passing to a steam generator and turbine.

The fuel is usually uranium or plutonium metal, oxide or carbide or a mixed uranium/plutonium oxide. Mixed oxide fuels contain 10-20% plutonium with 80-90% uranium (depleted or natural). The core is surrounded by a uranium-238 blanket to capture neutrons which would otherwise escape. India, which has large thorium deposits but little uranium, is developing a reactor which uses mixed uranium/plutonium carbide fuel and a thorium-232 blanket to produce uranium-233 which is then burned in advanced heavy water reactors with thorium-232. Most fast reactors are capable of breeding more fissile material than they consume, and are often referred to as fast breeder reactors or FBRs. However, depending upon design, fuel and method of operation, a fast reactor can be either a breeder, a regenerator or a plutonium burner.

Fast neutron reactors have a number of advantages over thermal neutron reactors:

- Since fast reactors do not use fuel enriched in uranium-235, the high cost of uranium enrichment and the possible misuse of highly enriched uranium in nuclear weapons are avoided.
- Because of their very high boiling point, liquid metal coolants can be used at atmospheric pressure at high operating temperatures. Embrittlement of steel pressure vessels (a potential hazard with pressurised water reactors (PWRs» is avoided and the potential consequences of loss-of-coolant accidents are greatly reduced.
- Fast reactors extract much more energy from fuel than thermal reactors. Fast reactors with recycling of fuel have fuel efficiencies more than 60 times greater than is currently obtained with the once-through process in thermal reactors. This is because fast reactors burn mainly uranium-238 (rather than uranium 235 which is much less abundant), and are much more likely to cause heat-producing fission reactions with heavy elements than neutron capture which produces little heat. In this way, the transuranics (plutonium, neptunium, americium, curium), which are formed in the reactor and constitute most of the long-lived radioactive waste from thermal reactors, are burned and produce useful energy.
- Fast reactor spent fuel is suitable for reprocessing by an electrorefining procedure presently under development which separates the material into three streams: (i) a small short-lived but highly radioactive fission product waste stream, (ii) a mixed transuranic stream which is converted into fast reactor fuel and (iii) a uranium stream constituting about 92% of the spent fuel which is recyclable as fast reactor fuel. This reprocessing greatly reduces the requirements for long term storage of radioactive waste and, because plutonium-239 is not obtained in a pure form suitable for weapons, removes the risk of nuclear proliferation.
- The higher operating temperature achievable with fast reactors provides greater efficiency compared to current water-cooled and moderated reactors in converting heat into electricity (Second Law of Thermodynamics).
- Current stockpiles of depleted uranium (from enrichment tails) and spent fuel (from the once-through thermal process) can be turned into fuel for fast reactors. This will greatly prolong the life of the world's low-cost uranium reserves and avoid the mining and milling of low-grade ores.



The first fast reactor EBR-1 was built in the US in 1951 and was the first nuclear reactor to produce electricity (but only 200 kWe). EBR-1 was followed by others in the US, the UK, France, West Germany, Japan, India, Soviet Union and, in 2010 in China. Work on fast reactors was largely abandoned in the US by the early 1980s when it became clear that uranium supplies were much greater than originally believed and that the expansion of nuclear power would be much slower. Also, problems with sodium coolant leaks and high capital and operating costs led to the closure of reactors in several countries. At the present the countries with operating power-producing fast reactors are: India (the PFBR, 500 MWe). Japan (Monju, 280 MWe), China (CEFR, 20 MWe), and Russia (BOR60,12 MWe; BN600, 600 MWe; BN800, 880 MWe).

Governments in 10 countries, including the US, UK, France, Canada and Japan, have expressed renewed interest in fast reactors to extend uranium resources, to burn up long-lived nuclides and to produce hydrogen from water at high temperatures. Newer, safer Generation IV fast reactors are now being designed for both power generation and the destruction of plutonium from weapons and the transuranics from reprocessed spent fuel, thereby reducing the long-lived components of high level waste (HLW) and storage requirements from tens of thousands of years to a few hundred years. US designs will be capable of burning 660kg of transuranics annually in a 600 MWe plant and can be run to transmute several long-lived transuranic isotopes (including plutonium 239) into plutonium-238 and plutonium-240 which are unsuitable for weapons. They use sodium metal, lead, lead/bismuth eutectic (LBE), helium or carbon dioxide (all of which are less corrosive than water) as coolants and operate at near atmospheric pressure with thermal efficiencies of about 38%. Experience gained with earlier designs has been used to reduce the likelihood of sodium leaks and the associated risk of fire. New passive designs ensure that there is little or no chance of meltdown.

References

1. Fast Neutron Reactors, WNA 5/2012.
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3. USDOE Nuclear Energy Research Advisory Committee (2002) *A Technology Roadmap for Generation IV Nuclear Generation Systems*, GIF-002-00