AUSTRALIAN NUCLEAR FORUM INC
INFORMATION PAPER No. 9

Thorium Reactors (Adopted 2/6/06)

Thorium is 3 times more abundant in the Earth's crust than uranium and can be used as fuel with uranium or plutonium in a variety of reactor types for a variety of purposes. Naturally occurring thorium-232 is fertile (like uranium-238) rather than fissile (like uranium-235), i.e. it does not undergo nuclear fission but it is converted in a reactor to a radionuclide which does. Its thermal neutron cross section is about 3 times that for uranium-238 and it is readily converted to fissile uranium-233. Uranium-233 is superior to plutonium-239 as a fuel in thermal reactors (whereas plutonium-239 is superior in fast reactors). Further, thorium oxide (ThO_2) has superior chemical, physical and nuclear properties to uranium oxide (UO_2). It is more chemically inert, has a much higher melting point and a greater thermal conductivity. The formation of higher isotopes by consecutive neutron capture is much less for uranium-233 than for plutonium-239 and it reaches a stable concentration of 1.5% in spent fuel (up to 1% plutonium isotopes in high burn-up uranium fuel). Core geometries can be designed to favour the production of uranium-233 and the burn-up of plutonium isotopes.

Thorium reactors have been built in 9 countries but all but India closed them, due largely to plentiful supplies of cheap uranium. Molten salt (mixed metal fluorides) and light water coolants have been used experimentally in thermal breeder reactors with mixed thorium/uranium fuels. Early Indian reactors mixed the thorium with high-enriched uranium but current designs now have non-homogeneous fuel which reduces plutonium production by 50–80%. One option is to use a central low-enriched (<20% U235) uranium metal alloy "seed" surrounded by a thorium-rich blanket. The seed remains in the reactor for 3 years and the blanket for 10 years. A small amount of uranium can be added to the blanket to make the uranium-233 unsuitable for weapons although it is considered to be proliferation-proof owing to high gamma radiation from uranium-232 (formed by an (*n, 2n*) reaction with uranium-233). A 2-phase operation can be used: (1) production of uranium-233, (2) use of mixed thorium/uranium-233 oxide fuel. A Canadian proposal uses a once-through thorium (OTT) cycle using mixed enriched uranium/thorium oxide fuel in CANDU reactors from which they expect a 1.5% equilibrium yield of uranium-233 (compared to 0.4% plutonium from CANDU natural uranium fuel). India also proposes a mixed uranium/plutonium carbide fuel with a thorium-232 blanket in fast breeder reactors to produce uranium-233 which will then be burned in advanced heavy water reactors with thorium-232 thereby producing 75% of the power from thorium.