Indian scientists designing thorium reactor

A team of scientists at a premier Indian nuclear facility has made a theoretical design of an innovative reactor that can run on thorium - available in abundance in the country - and will eventually do away with the need for uranium.

But the success of the project largely depends on the US playing ball.

The novel Fast Thorium Breeder Reactor (FTBR) being developed by V. Jagannathan and his team at the Bhabha Atomic Research Centre (BARC) in Mumbai has received global attention after a paper was submitted to the International Conference on Emerging Nuclear Energy Systems (ICENES) held June 9-14 in Istanbul.

Power reactors of today mostly use a fissile fuel called uranium-235 (U-235), whose 'fission' releases energy and some 'spare' neutrons that maintain the chain reaction. But only seven out of 1,000 atoms of naturally occurring uranium are of this type. The rest are 'fertile', meaning they cannot fission but can be converted into fissionable plutonium by neutrons released by U-235.

Thorium, which occurs naturally, is another 'fertile' element that can be turned by neutrons into U-233, another uranium isotope. U-233 is the only other known fissionable material. It is also called the 'third fuel'.

Thorium is three times more abundant in the earth's crust than uranium but was never inducted into reactors because - unlike uranium - it has no fissionable atoms to start the chain reaction.

But once the world's uranium runs out, thorium - and the depleted uranium discharged by today's power reactors - could form the 'fertile base' for nuclear power generation, the BARC scientists claim in their paper.

They believe their FTBR is one such 'candidate' reactor that can produce energy from these two fertile materials with some help from fissile plutonium as a 'seed' to start the fire.

By using a judicious mix of 'seed' plutonium and fertile zones inside the core, the scientists show theoretically that their design can breed not one but two nuclear fuels - U-233 from thorium and plutonium from depleted uranium - within the same reactor.

This totally novel concept of fertile-to-fissile conversion has prompted its designers to christen their baby the Fast 'Twin' Breeder Reactor.

Their calculations show the sodium-cooled FTBR, while consuming 10.96 tonnes of plutonium to generate 1,000 MW of power, breeds 11.44 tonnes of plutonium and 0.88 tonnes of U-233 in a cycle length of two years.

According to the scientists, their FTBR design exploits the fact that U-233 is a better fissile material than plutonium. Secondly, they were able to maximise the breeding by putting the fertile materials inside the core rather than as a 'blanket' surrounding the core as done traditionally.

'At present, there are no internal fertile blankets or fissile breeding zones in power reactors

operating in the world,' the paper claims.

The concept has won praise from nuclear experts elsewhere. 'Core heterogeneity is the best way to help high conversion,' says Alexis Nuttin, a French nuclear scientist at the LPSC Reactor Physics Group in Grenoble.

Thorium-based fuels and fuel cycles have been used in the past and are being developed in a few countries but are yet to be commercialised.

France is also studying a concept of 'molten salt reactor' where the fuel is in liquid form, while the US is considering a gas-cooled reactor using thorium. McLean, Virginia-based Thorium Power Ltd of the US, has been working with nuclear engineers and scientists of the Kurchatov Institute in Moscow for over a decade to develop designs that can be commercialised.

But BARC's FTBR is claimed to be the first design that truly exploits the concept of 'breeding' in a reactor that uses thorium. The handful of fast breeder reactors (FBRs) in the world today - including the one India is building in Kalpakkam near Chennai - use plutonium as fuel.

These breeders have to wait until enough plutonium is accumulated through reprocessing of spent fuel discharged by thermal power reactors that run on uranium.

Herein lies the rub.

India does not have sufficient uranium to build enough thermal reactors to produce the plutonium needed for more FBRs of the Kalpakkam type. The India-US civilian nuclear deal was expected to enable India import uranium and reprocess spent fuel to recover plutonium for its FBRs. But this deal has hit a roadblock.

'Jagannathan's design is one way of utilising thorium and circumventing the delays in building plutonium-based FBRs,' says former BARC director P.K. Iyengar.

Meanwhile, India's 300,000 tonnes of thorium reserves - the third largest in the world - in the beach sands of Kerala and Orissa states are waiting to be tapped. The BARC scientists say that thorium should be inducted into power reactors when the uranium is still available, rather than after it is exhausted.

But the FTBR still needs an initial inventory of plutonium to kick-start the thorium cycle and eventually to generate electricity. A blanket ban on India re-processing imported uranium - a condition for nuclear cooperation with the US - could make India's thorium programme a non-starter.

Iyengar has one suggestion that he says must be acceptable to the US if it is serious about helping India to solve its energy problem.

'The US and Russia have piles of plutonium from dismantled nuclear weapons,' Iyengar told IANS, adding: 'They should allow us to borrow this plutonium needed to start our breeders. We can return the material after we breed enough.'

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