COMMENTARY

Burying plutonium: Watt a waste

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Fast reactor is an important constituent of India's nuclear power programme. It is also a bridge to the eventual utilization of large thorium reserves of the country. Fast reactors require plutonium, which is obtained by reprocessing the spent fuel from thermal reactors. One option to expedite the fast reactor (and thorium) programme is to access the global stockpile of separated plutonium. Use of plutonium in thermal reactors has had limited success and immobilization and burying are being considered as an option. However, in a world starved of clean energy, plutonium is too precious an energy source to be buried. India should pursue acquiring access to global stocks of separated plutonium to accelerate its fast reactor programme and expedite thorium programme.

Nuclear power has an important role to play in India's aspirations for achieving energy security. At present, the installed capacity of nuclear power is 5780 MW and it contributes 3% of all electricity generated. However, there are ambitious projections for the growth of nuclear power. Six reactors are presently under construction with a cumulative capacity of 4300 MW and six more are planned with capacity of 4800 MW (ref. 1). In addition, seven new sites have received in principle approval for building new reactors. India's Intended Nationally Determined Contributions (INDCs) mentions an aspiration of 63,000 MW of nuclear power by 2030 (ref. 2).

In recent times, India has made determined efforts to expedite its nuclear power programme in the near term. Following the Indo-US agreement for cooperation in civilian nuclear power, uranium imports have helped increase the plant load factor of reactors to nearly 85%, as against 55% a few years ago. Several leading companies have exhibited interest to build thermal reactors in India. These are positive developments and should be pursued to expedite the thermal reactor programme.

In addition, there is a need to expedite the development of fast breeder reactors (FBRs), which are an important constituent of India's nuclear power programme in the long run. FBRs are also vital for utilization of vast thorium deposits of the country since thorium is not a fissile material and requires plutonium for conversion to fissile U^{233}. At present one 500 MW FBR is under construction in Kalpakkam. There are plans to build at least two more such reactors.

FBRs require plutonium as starting fuel; a 500 MW reactor requires about 4 tonnes initially and is expected to operate thereafter with no further supply over its life. The initial supply is presently obtained by reprocessing the spent fuel from thermal reactors. Reprocessing capacity of India is about 200 tonnes of heavy metal per annum, which if operated to full capacity can recover less than one tonne of plutonium per annum. Clearly the present reprocessing capacity is not adequate to support a large FBR programme. There are reported plans to build new reprocessing plants; however they are time and capital intensive. Therefore, it will take considerable time to accumulate plutonium required for large-scale thorium utilization. In the present scenario, large-scale thorium utilization appears to be at least '3–4 decades after the commercial operation of fast breeder reactors with short doubling time'[3].

Therefore, while India should pursue augmenting reprocessing capacity, one option to accelerate the FBR (and thorium) programme is to access the global stocks of separated plutonium.

Managing plutonium stockpile

Managing the growing global stockpile of separated plutonium has been a subject of considerable debate and concern. The world's stockpile of separated plutonium is estimated to be about 500 tonnes (ref. 4). 'Civilian' plutonium, which is produced by reprocessing the spent fuel from nuclear reactors, accounts for about 260 tonnes. The remaining amount of surplus separated plutonium is 'military', which is obtained from the dismantling of nuclear weapons.

The UK, France and Japan have the largest civilian plutonium stockpiles and they developed this stockpile with the objective of building FBRs. France holds 60 tonnes of civilian plutonium and it has experience in use of plutonium in FBRs as well as light water reactors (LWRs). Japan has about 44 tonnes of plutonium; however a large part of this is located in France and UK, which produced the fuel for Japan[4].

Russia and the US hold the largest stock of military plutonium. The US has declared 43 tonnes of military plutonium and 12 tonnes of impure plutonium (not weapon grade) as surplus and assigned for disposal. The original plan was to turn it into fuel for use in LWRs. However, because of cost considerations, the US is now considering disposal in a geological repository. Russia is the only country to continue to build and operate fast reactors. The US and Russia each decided to reduce 34 tonnes of weapons-released plutonium, which they declared as surplus.

The question now is: what can be done with this stockpile of plutonium? Until recently, the preferred option was to mix it with depleted uranium and make mixed oxide fuel (MOX) for light-water cooled nuclear reactors. In 1997, the US decided to build a MOX fuel fabrication facility in Savannah, which would generate MOX fuel for the utilities. This facility was expected to cost about US$ 1.4 billion and be completed by 2004. However, the cost has now escalated to US$ 7.7 billion and is expected to be operational by 2019 (ref. 5). As of now, the US Congress has provided funding for the year 2015 (ref. 6). However, the Office of Budget and Management raised concerns that 'the current plutonium disposition approach may be unaffordable due to cost growth and fiscal pressure'[7]. The UK built a large plant for producing plutonium-bearing MOX fuel mainly for supplying to other countries for use in

LWRs. This fuel fabrication plant is now shut down due to technical difficulties and the UK is presently not recovering plutonium from spent fuel. Japan was using plutonium as MOX fuel in LWRs. However, following the Fukushima accident in 2011, Japanese electricity utilities stopped procuring the fuel. At this point, it is not clear when they will be licensed for use of plutonium bearing fuel.

Clearly, the MOX fuel option has not met with the desired success in eliminating the plutonium stockpile at a reasonable cost. Therefore, direct disposal of plutonium by immobilizing it in the form of ceramic and burying it in geological repositories is gaining traction[8]. Immobilization is expected to be cheaper than MOX fuel fabrication and will permanently bury the excess plutonium for thousands of years. There have been a few limited attempts to explore this option; however it is yet to be demonstrated on a large and commercial level. Nevertheless, this option is being considered to eliminate the plutonium that has been identified as surplus.

Too precious to bury

We argue that in a world starved of clean energy, separated plutonium is too precious an energy source to bury. While it is considered waste in one country, it could be a rich source of energy in other countries. For instance 4 tonnes of plutonium can sustain a 500 MW reactor for its life. Therefore, there is a need to consider a third option of utilizing the plutonium stockpile, namely in FBRs. There was considerable interest in these reactors in the 1960s and 1970s because of the concerns about long-term availability and price of uranium to support a large thermal reactor based nuclear power programme. However, uranium prices have remained low for an extended duration, which has led to the dwindling of interest in fast reactors. Safety has also been a concern with FBRs given that they use liquid sodium as coolant. A sodium leak in the Japanese Monju reactor led to a non-radioactive fire, which resulted in reactor being shut down for many years. As a result, water-cooled thermal reactors have dominated the nuclear power industry.

However, we need to take a relook at fast reactors as part of an advanced nuclear power system. India built and successfully operated a 40 MW (thermal) test reactor in 1985 based on carbide fuel. India is now close to commissioning a 500 MW reactor, using MOX fuel and plans to build at least two more such reactors by 2020. Interestingly, this reactor has a 'breeding ratio' of only 1.04. This implies that the plutonium generated from U^{238} conversion is sufficient to sustain the operation of the reactor over its lifetime, but not enough to start a new reactor. In other words, it does not 'breed' plutonium; instead it 'burns' the plutonium. In future, India has plans to build metal fuel-based fast reactors, which have a higher breeding ratio. These can potentially generate surplus plutonium, which can be used to start new reactors.

As mentioned earlier, India will have to significantly expand its present reprocessing capacity (200 tonnes of heavy metal per annum) to generate enough plutonium required for the ambitious FBR programme. Even then, the use of plutonium for thorium utilization will take at least a few decades.

Give breeders a chance

India should certainly augment its reprocessing capacity. In addition, one option to expedite the fast reactor programme is to access the global surplus of plutonium fuel, which is considered waste. India should procure some of the surplus stockpile of plutonium and use it to build a few fast reactors under international safeguards. We argue this for the following reasons:

1. Subsequent to the signing of the Indo-US agreement, India has access to nuclear material, technologies and fuel. India is already importing natural uranium fuel, which is being used in domestic reactors operating under international safeguards. Further, India reserves the right to reprocess the spent fuel from these reactors and recover plutonium for potential use in FBRs, again under international safeguards. Therefore, this implicitly assumes that India has implemented the necessary mechanisms, which ensure the safety of nuclear fuel, spent fuel and reprocessed fuel. If India could be allowed to import uranium, the same logic should apply to the import of plutonium as well.

2. While several countries are spending large amounts of resources to ensure the safety of separated plutonium stockpile, other countries such as India, Russia and China require plutonium as fuel for their FBR programmes.

3. The present FBRs that are being built in India are based on oxide fuel systems and these are plutonium burners (and not breeders). These systems can also destroy the actinides and lead to lower levels of waste.

4. This proposal assumes that FBR technology for burning plutonium has to be technically and commercially proven. However, the same applies to the other options under consideration for plutonium disposition, namely, use in MOX fuel and immobilization through dilution and disposal. The jury is still out on the more cost-effective option.

Therefore, we propose that the Indian Government make a case for gaining access to the global separated plutonium stock and attempt to use it in its FBRs, which are to be built in the next few years. It will help accelerate the FBR programme and also pave the way for early thorium utilization, which is crucial for India's long-term energy security.

Plutonium is known as the world's most dangerous element. However, in a world grappling with how to provide clean energy to over 3 billion people, it is too precious an energy source to bury.

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