Thor-bores and uro-sceptics: thorium's friendly fire

Author: *Jim Green − Nuclear Monitor editor*

NM801.4458 Many *Nuclear Monitor* readers will be familiar with the tiresome rhetoric of thorium enthusiasts− let's call them thor-bores. Their arguments have little merit but they refuse to go away.

Here's a thor-bore in full flight − a science journalist who should know better:

"Thorium is a superior nuclear fuel to uranium in almost every conceivable way ... If there is such a thing as green nuclear power, thorium is it. ... For one, a thorium-powered nuclear reactor can never undergo a meltdown. It just can't. ... Thorium is also thoroughly useless for making nuclear weapons. ... But wait, there's more. Thorium doesn't only produce less waste, it can be used to consume existing waste."1

Thankfully, there is a healthy degree of scepticism about thorium, even among nuclear industry insiders, experts and enthusiasts (other than the thor-bores themselves, of course). Some of that 'friendly fire' is noted here.

Readiness

The World Nuclear Association (WNA) notes that the commercialization of thorium fuels faces some "significant hurdles in terms of building an economic case to undertake the necessary development work." The WNA states:

"A great deal of testing, analysis and licensing and qualification work is required before any thorium fuel can enter into service. This is expensive and will not eventuate without a clear business case and government support. Also, uranium is abundant and cheap and forms only a small part of the cost of nuclear electricity generation, so there are no real incentives for investment in a new fuel type that may save uranium resources.

"Other impediments to the development of thorium fuel cycle are the higher cost of fuel fabrication and the cost of reprocessing to provide the fissile plutonium driver material. The high cost of fuel fabrication (for solid fuel) is due partly to the high level of radioactivity that builds up in U-233 chemically separated from the irradiated thorium fuel. Separated U-233 is always contaminated with traces of U-232 which decays (with a 69-year half-life) to daughter nuclides such as thallium-208 that are high-energy gamma emitters. Although this confers proliferation resistance to the fuel cycle by making U-233 hard to handle and easy to detect, it results in increased costs. There are similar problems in recycling thorium itself due to highly radioactive Th-228 (an alpha emitter with two-year half life) present."2

A 2012 report by the UK National Nuclear Laboratory states:

"NNL has assessed the Technology Readiness Levels (TRLs) of the thorium fuel cycle. For all of the system options more work is needed at the fundamental level to establish the basic knowledge and understanding. Thorium reprocessing and waste management are poorly understood. The thorium fuel cycle cannot be considered to be mature in any area."3

Fiona Rayment from the UK National Nuclear Laboratory states:

"It is conceivable that thorium could be introduced in current generation reactors within about 15 years, if there was a clear economic benefit to utilities. This would be a once-through fuel cycle that would partly realise the strategic benefits of thorium.

"To obtain the full strategic benefit of the thorium fuel cycle would require recycle, for which the technological development timescale is longer, probably 25 to 30 years.

"To develop radical new reactor designs, specifically designed around thorium, would take at least 30 years. It will therefore be some time before the thorium fuel cycle can realistically be expected to make a significant contribution to emissions reductions targets."4

Thorium is no 'silver bullet'

Do thorium reactors potentially offer significant advantages compared to conventional uranium reactors?

Nuclear physicist Prof. George Dracoulis states: “Some of the rhetoric associated with thorium gives the impression that thorium is, somehow, magical. In reality it isn’t.”[5]

The UK National Nuclear Laboratory report argues that thorium has “theoretical advantages regarding sustainability, reducing radiotoxicity and reducing proliferation risk” but that “while there is some justification for these benefits, they are often over stated.” The report further states that the purported benefits “have yet to be demonstrated or substantiated, particularly in a commercial or regulatory environment.”[3]

The UK National Nuclear Laboratory report is sceptical about safety claims:

“Thorium fuelled reactors have already been advocated as being inherently safer than LWRs [light water reactors], but the basis of these claims is not sufficiently substantiated and will not be for many years, if at all.”[3]

False distinction

Thor-bores posit a sharp distinction between thorium and uranium. But there is little to distinguish the two. A much more important distinction is between conventional reactor technology and some ‘Generation IV’ concepts − in particular, those based on repeated (or continuous) fuel recycling and the ‘breeding’ of fissile isotopes from fertile isotopes (Th-232>U-233 or U-238>Pu-239).

A report by the Idaho National Laboratory states:

“For fuel type, either uranium-based or thorium-based, it is only in the case of continuous recycle where these two fuel types exhibit different characteristics, and it is important to emphasize that this difference only exists for a fissile breeder strategy. The comparison between the thorium/U-233 and uranium/Pu-239 option shows that the thorium option would have lower, but probably not significantly lower, TRU [transuranic waste] inventory and disposal requirements, both having essentially equivalent proliferation risks.

“For these reasons, the choice between uranium-based fuel and thorium-based fuels is seen basically as one of preference, with no fundamental difference in addressing the nuclear power issues.

“Since no infrastructure currently exists in the U.S. for thorium-based fuels, and processing of thorium-based fuels is at a lower level of technical maturity when compared to processing of uranium-based fuels, costs and RD&D requirements for using thorium are anticipated to be higher.”[7]

George Dracoulis takes issue with the “particularly silly claim” by a science journalist (and many others) that almost all the thorium is usable as fuel compared to just 0.7% of uranium (i.e. uranium-235), and that thorium can therefore power civilization for millennia. Dracoulis states:

“In fact, in that sense, none of the thorium is usable since it is not fissile. The comparison should be with the analogous fertile isotope uranium-238, which makes up nearly 100% of natural uranium. If you wanted to go that way (breeding that is), there is already enough uranium-238 to ‘power civilization for millennia’.”[5]

Some Generation IV concepts promise major advantages, such as the potential to use long-lived nuclear waste and weapons-usable material (esp. plutonium) as reactor fuel. On the other hand, Generation IV concepts are generally those that face the greatest technical challenges and are the furthest away from commercial deployment; and they will gobble up a great deal of R&D funding before they gobble up any waste or weapons material.

Moreover, uranium/plutonium fast reactor technology might more accurately be described as failed Generation I technology. The first reactor to produce electricity − the EBR-I fast reactor in the US, a.k.a. Zinn’s Infernal Pile − suffered a partial fuel meltdown in 1955. The subsequent history of fast reactors has largely been one of extremely expensive, underperforming and accident-prone reactors which have contributed far more to WMD proliferation problems than to the resolution of those problems.

Most importantly, whether Generation IV concepts deliver on their potential depends on a myriad of factors − not just the resolution of technical challenges. India’s fast reactor / thorium program illustrates how badly things can go wrong, and it illustrates problems that can’t be solved with technical innovation. John Carlson, a nuclear advocate and former Director-General of the Australian Safeguards and Non-Proliferation Office, writes:

“India has a plan to produce [weapons-grade] plutonium in fast breeder reactors for use as driver fuel in thorium reactors. This is problematic on non-proliferation and nuclear security grounds. Pakistan believes the real purpose of the fast breeder program is to produce plutonium for weapons (so this plan raises tensions between the two countries); and transport and use of weapons-grade plutonium in civil reactors presents a serious terrorism risk (weapons-grade material would be a priority target for seizure by terrorists).”[8]

Generation IV thorium concepts such as molten salt reactors (MSR) have a lengthy, uncertain R&D road ahead of them − notwithstanding the fact that there is some previous R&D to build upon.[4,9]

Kirk Sorensen, founder of a US firm which aims to build a demonstration ‘liquid fluoride thorium reactor’ (a type of MSR), notes that “several technical hurdles” confront thorium-fuelled MSRs, including materials corrosion, reactor control and in-line processing of the fuel.[4]

George Dracoulis writes:

“MSRs are not currently available at an industrial scale, but test reactors with different configurations have operated for extended periods in the past. But there are a number of technical challenges that have been encountered along the way. One such challenge is that the hot beryllium and lithium “salts” – in which the fuel and heavy wastes are dissolved – are highly reactive and corrosive. Building a large-scale system that can operate reliably for decades is non-trivial. That said, many of the components have been the subject of extensive research programs.”[10]

Weapons proliferation

Claims that thorium reactors would be proliferation-resistant or proliferation-proof do not stand up to scrutiny.[11] Irradiation of thorium-232 produces uranium-233, which can be and has been used in nuclear weapons.

The World Nuclear Association states:

"The USA produced about 2 tonnes of U-233 from thorium during the 'Cold War', at various levels of chemical and isotopic purity, in plutonium production reactors. It is possible to use U-233 in a nuclear weapon, and in 1955 the USA detonated a device with a plutonium-U-233 composite pit, in Operation Teapot. The explosive yield was less than anticipated, at 22 kilotons. In 1998 India detonated a very small device based on U-233 called Shakti V."[2]

According to Assoc. Prof. Nigel Marks, both the US and the USSR tested uranium-233 bombs in 1955.[6]

Uranium-233 is contaminated with uranium-232 but there are ways around that problem. Kang and von Hippel note:

"[J]ust as it is possible to produce weapon-grade plutonium in low-burnup fuel, it is also practical to use heavy-water reactors to produce U-233 containing only a few ppm of U-232 if the thorium is segregated in "target" channels and discharged a few times more frequently than the natural-uranium "driver" fuel."[12]

John Carlson discusses the proliferation risks associated with thorium:

"The thorium fuel cycle has similarities to the fast neutron fuel cycle – it depends on breeding fissile material (U-233) in the reactor, and reprocessing to recover this fissile material for recycle. ...

"Proponents argue that the thorium fuel cycle is proliferation resistant because it does not produce plutonium. Proponents claim that it is not practicable to use U-233 for nuclear weapons.

"There is no doubt that use of U-233 for nuclear weapons would present significant technical difficulties, due to the high gamma radiation and heat output arising from decay of U-232 which is unavoidably produced with U-233. Heat levels would become excessive within a few weeks, degrading the high explosive and electronic components of a weapon and making use of U-233 impracticable for stockpiled weapons. However, it would be possible to develop strategies to deal with these drawbacks, e.g. designing weapons where the fissile "pit" (the core of the nuclear weapon) is not inserted until required, and where ongoing production and treatment of U-233 allows for pits to be continually replaced. This might not be practical for a large arsenal, but could certainly be done on a small scale.

"In addition, there are other considerations. A thorium reactor requires initial core fuel – LEU or plutonium – until it reaches the point where it is producing sufficient U-233 for self-sustainability, so the cycle is not entirely free of issues applying to the uranium fuel cycle (i.e. requirement for enrichment or reprocessing). Further, while the thorium cycle can be self-sustaining on produced U-233, it is much more efficient if the U-233 is supplemented by additional "driver" fuel, such as LEU or plutonium. For example, India, which has spent some decades developing a comprehensive thorium fuel cycle concept, is proposing production of weapons grade plutonium in fast breeder reactors specifically for use as driver fuel for thorium reactors. This approach has obvious problems in terms of proliferation and terrorism risks.

"A concept for a liquid fuel thorium reactor is under consideration (in which the thorium/uranium fuel would be dissolved in molten fluoride salts), which would avoid the need for reprocessing to separate U-233. If it proceeds, this concept would have non-proliferation advantages.

"Finally, it cannot be excluded that a thorium reactor – as in the case of other reactors – could be used for plutonium production through irradiation of uranium targets.

"Arguments that the thorium fuel cycle is inherently proliferation resistant are overstated. In some circumstances the thorium cycle could involve significant proliferation risks."[13]

Sometimes thor-bores posit conspiracy theories. Former International Atomic Energy Agency Director-General Hans Blix said "it is almost impossible to make a bomb out of thorium" and thorium is being held back by the "vested interests" of the uranium-based nuclear industry.[14]

But Julian Kelly from Thor Energy, a Norwegian company developing and testing thorium-plutonium fuels for use in commercial light water reactors, states:

"Conspiracy theories about funding denials for thorium work are for the entertainment sector. A greater risk is that there will be a classic R&D bubble [that] divides R&D effort and investment into fragmented camps and feifdoms."[4]

Thor-bores and uro-sceptics

Might the considered opinions of nuclear insiders, experts and enthusiasts help to shut the thor-bores up? Perhaps not − critics are dismissed with claims that they have ideological or financial connections to the vested interests of the uranium-based nuclear industry, or they are dismissed with claims that they are ideologically opposed to all things nuclear. But we live in hope.

Thor-bores do serve one useful purpose − they sometimes serve up pointed criticisms of the uranium fuel cycle. In other words, some thor-bores are uro-sceptics. For example, thorium enthusiast and former Shell executive John Hofmeister states:

"The days of nuclear power based upon uranium-based fission are coming to a close because the fear of nuclear proliferation, the reality of nuclear waste and the difficulty of managing it have proven too difficult over time."[15]

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