Thorium

By Anonymous MIT Student #3

Since the beginning of the nuclear age, there have been promises of amazing technology like nuclear cars and effectively unlimited batteries. As time went on, none of these really came to fruition, and the rumors died off for the most part. However, with an article about a nuclear car published as recently as late 2013, a certain Asgardian nuclear fuel hasn't received the same treatment. Thorium has long been praised as a miracle fuel by its proponents, and has a history of misinformation and supposed conspiracy surrounding it. Though it is certainly a powerful source of energy, and quite possibly the next step in the realm of nuclear energy, Thorium is not the perfect fuel it is made out to be.

So what does thorium have going for it? Primarily, it's a valid nuclear fuel, well suited for a group of reactors known as molten salt reactors. Thorium occurs almost entirely as the 232 isotope, which when in neutron flux absorbs a neutron, becoming Th233, which decays into Pa233 and then U233, a fissile isotope of Uranium. Because of this, Thorium is considered a "fertile" fuel. (1) This U233 can also be extracted and used as fuel uranium reactors, which can expand the lifetime of uranium fuel reserves. On top of this, another benefit of the Thorium fuel cycle is its waste profile- Thorium waste is much shorter lived than Uranium waste- though Thorium produces higher-radiation waste at first, it produces far fewer transuranic elements, making long term waste storage much safer.(2)

Generally, the legitimate benefits end there, but there are a ton of misconceptions about Thorium that lead people to tout it as a perfect fuel source. One such misconception has to do with Uranium supply vs Thorium. It is often touted that there is far more Thorium available to us than uranium, but that isn't entirely true. Thorium is certainly more common in Earth's crust than Uranium, about three times as common, but what's often forgotten is how much Uranium is in seawater- a staggering 4.5 billion tons is theoretically obtainable, 10000 times as much as there is Thorium. Of course, compared to mining, seawater extraction isn't commercially viable at the moment, but the concept has been proven and the cost will likely fall once a demand exists.(3) However, this half-truth of abundance isn't the thing most often praised, but rather the fact that Thorium isn't capable of nuclear weapon proliferation. Except, of course, that it is. The thought that the Thorium fuel cycle can't be used to make nuclear weapons comes from the fact that no plutonium isotopes are produced, which is correct, but it ignores the fact that U-233, which is the direct decay product of Pa-233, which can be chemically separated during operation, is a great material for making nuclear weapons. In a report from the Hanford site published 1966, it is expressed that U-233 is "highly satisfactory as a weapons material" and it is even stated that if U-233 weapons were engineered first, there would likely have been no interest in switching to plutonium-based weapons.(4)

And, of course, many strong proponents don't tend to mention the negatives of Thorium fuel. One of these cons is tied very tightly with something often considered an

upside. The short half-life of Thorium waste corresponds with a high radioactivity early on, making the waste very dangerous at first. (2) Beyond this, there are several engineering challenges standing in the way of Thorium. Among these challenges is Thorium's high melting point, which can make the raw fuel difficult to work with. Another hurdle is more specific to MSR's, which is that salts often very corrosive, and at high working temperatures they tend to be even more so. Really though, these challenges just come down to time and money, which sums it up pretty nicely- figuring out Thorium will be expensive.(5)

So, when you really look into it, Thorium isn't everything it's cracked up to be. It's got some definite benefits, and may be worth getting figured out, but it's no miracle fuel, and shouldn't be talked about as if it were. Doing so spreads misconceptions and can lead to crackpot conspiracy theories, which is bad for all of us.

Technical Note

1) Thorium is actually fertile, not fissile- it technically is not the primary energy source in the reactor. Transmutation trains: Th-232 + n -> Th-233 -> Pa-233 -> U-233[4]

2) Thorium waste is highly radioactive at first, but in the long term is much safer than Uranium waste [4]

3) Thorium is about three times as abundant as uranium in Earth's crust, but Uranium is nearly 10000 times as abundant in oceans.[1] The most common source of Thorium in the crust is monzonite [2] Uranium in ocean's is not currently commercially viable, but the concept has been proven.[5]

4) Thorium products are suitable for nuclear weapons. The reason this path wasn't taken is simply because plutonium was found and developed first. [3]

5) Thorium has a fairly high melting point [1], and the fuel salts used in molten salt reactors have corrosion problems that pose engineering challenges. [6]

[1] https://ptable.com
[2] https://www.intechopen.com/books/descriptive-inorganic-chemistry-researches-of-metal-compounds/nature-sources-resources-and-production-of-thorium

[3]https://www.osti.gov/servlets/purl/79078

[4]https://web.archive.org/web/20110525091426/http://lpsc.in2p3.fr/gpr/english/NEWNRW/NEWNRW.html#foot284

[5] https://www.pnnl.gov/news/release.aspx?id=4514

[6]http://www.vtt.fi/inf/pdf/workingpapers/2008/W90.pdf (F22 is stated generally, but it is discussed throughout the paper)

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