American Nuclear Society

Position Statement #78

The Use of Thorium in the Nuclear Fuel Cycle

The American Nuclear Society endorses continued research and development on the use of thorium as an additional option for the worldwide deployment of nuclear energy in a sustainable energy future.

Discovered in Scandinavia in 1828, thorium is three to four times as plentiful as uranium, but it was used in only a few applications, such as the mantles of gas lanterns and experiments on radioactivity by Marie Curie in 1898. It wasn't until Glenn Seaborg's work at the University of California at Berkeley in 1940—and Alvin Weinberg's follow-up work on molten salt reactors (MSR) at Oak Ridge National Laboratory—that thorium's potential as an energy source started to become clear.

The use of thorium as a fertile[a] material in a nuclear reactor leads to the following:

- The production of an alternative fissile uranium isotope, uranium-233.
- The potential for higher conversion rates in the thermal and intermediate neutron energy spectra, thus improving fuel use.
- Enhanced thermophysical properties compared to uranium oxide if used as solid fuel in a fuel matrix (thorium oxide).
- Coproduction of a highly radioactive isotope, uranium-232, which provides challenges for fuel recycling, but may also provide an additional degree of self-protection in certain proliferation threat scenarios.

Various nuclear energy systems—i.e., combining nuclear reactor technology and fuel cycle technology—involving thorium have been investigated since the early days of nuclear energy use, with some developments having materialized, as in India, while others are still under research and development. Thorium utilization has been successfully demonstrated in light-water reactors (LWR), pressurized heavy-water reactors (PHWR), gas-cooled reactors, fast-spectrum reactors, and MSRs, albeit with different objectives for the use of thorium[1,2].

Thorium's characteristics may lead to different uses that can be classified as follows[3]:

- Thorium as an additive to the current uranium–plutonium fuel cycle. The very fissile nature of uranium-233 allows thorium to improve the reuse of reprocessed uranium in PHWRs and/or plutonium in LWRs, or even to replace burnable poisons such as gadolinium in fuel assemblies. India and China are using and/or considering such use of thorium to further improve the fuel cycle of PHWRs.
- Thorium use as a fuel in Generation III+ or Generation IV reactor systems. Thorium solid mixed fuels, such as Th-U, Th-Pu, or even Th-U-Pu, can provide considerable benefits in advanced LWRs and PHWRs and even more so in high-temperature gas reactors.
- Dedicated breeder systems using the Th/U-233 closed fuel cycle. Various options, both with solid fuels in advanced PHWRs (e.g., India's Advanced Heavy Water Reactor) and with liquid fuels in MSRs (e.g., various MSR initiatives in the United States

a. A material, which is not itself fissile (fissionable by thermal neutrons), that can be converted into a fissile material by irradiation in a reactor. There are two basic fertile materials: uranium-238 and thorium-232.

and worldwide, such as the TMSR-LF in China), seek the full deployment of the closed Th/U-233 fuel cycle, with increased resource sustainability from the higher conversion ratios and reduced waste management challenges from forming a lower amount of higher actinides.

In general, the database and industrial experience with thorium fuel and associated fuel cycles, especially for the latter two classes of thorium use, remain limited and must be augmented to support the investment required for expanded use.

References

1. IAEA TECDOC 1450, *Thorium Fuel Cycle—Potential Benefits and Challenges*, Vienna, Austria, 2003.
2. IAEA, STI/PUB/1540, *Role of Thorium to Supplement Fuel Cycles of Future Nuclear Energy Systems*, Vienna, Austria, 2012.
3. OECD Nuclear Energy Agency, *Perspectives on the Use of Thorium in the Nuclear Fuel Cycle*, Paris, France, 2015.

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708-352-6611

askanything@ans.org

ans.org