7. China's Thorium - International Relations

China achieves thorium-uranium nuclear fuel conversion in molten-salt reactor. China has achieved a world-first by successfully converting thorium into fissile uranium fuel *inside* its operational 2 MW Thorium Molten Salt Reactor (TMSR). This fourth-generation nuclear technology, which China aims to commercialize by 2035, offers significant advantages in safety (atmospheric pressure operation), efficiency, and fuel abundance, positioning China as a leader in advanced, low-carbon energy.

China's Thorium Reactor Breakthrough

Key Achievement - China has announced the first-ever successful conversion of thorium into uranium fuel *within* an operational Thorium Molten Salt Reactor (TMSR).

About the Achievement

Global First - This marks the first time in the world that scientists have been able to successfully acquire experimental data on thorium-based nuclear operations directly from *inside* a molten salt reactor.

Unique Status - This achievement makes China's 2-megawatt (MW) liquid-fuelled thorium-based molten salt reactor (TMSR) the only operating example of this specific technology in the world.

Key Milestone - It is the only reactor that has successfully loaded and used thorium fuel as part of its operational cycle.

Molten Salt Reactor (MSR)

Reactor Generation - It is classified as an advanced fourth-generation nuclear reactor design.

Core Function - It uniquely uses molten salt to serve two primary functions simultaneously -

1. **Fuel Carrier -** The nuclear fuel (thorium and bred uranium) is dissolved directly into the salt, creating a liquid fuel.
2. **Coolant -** The same molten salt circulates to transfer heat away from the core.

Key Difference - This design fundamentally contrasts with conventional reactors, which use solid fuel rods (like uranium oxide pellets) and water as a coolant.

Operating Conditions - The reactor operates at atmospheric pressure, which enhances safety by eliminating the risk of high-pressure explosions. It operates at very high temperatures (approximately 700°C), increasing its thermal efficiency for electricity generation.

Refuelling - The use of a liquid fuel allows for continuous circulation, which in turn enables on-the-fly refuelling (adding new fuel and removing waste products) without needing to shut the reactor down.

Thorium-to-Uranium Conversion Process

The "Breeding" Process - The reactor "breeds" its own fuel from thorium in a multi-step process -

1. **Neutron Absorption -** Thorium-232 (a *fertile* element) absorbs a neutron.
2. **First Decay -** It becomes Thorium-233, which is unstable.
3. **Second Decay -** Thorium-233 quickly decays into Protactinium-233.
4. **Final Decay -** Protactinium-233 decays into Uranium-233 (U-233).

Fissile Fuel - This resulting Uranium-233 is a fissile material, meaning it can sustain a nuclear chain reaction (fission) to produce energy.

"Burn while Breeding" Cycle - This creates a self-sustaining and highly fuel-efficient cycle where the reactor "burns" the U-233 fuel while it "breeds" new U-233 fuel from the abundant thorium.

In-Situ Conversion - A major advantage is that this entire conversion occurs inside the reactor core itself, which eliminates the need for external fuel fabrication and complex reprocessing plants.

India's Thorium Reserves

Global Rank - India possesses one of the largest reserves of thorium in the world, primarily in monazite sands.

Key Locations - Major thorium deposits are found in the coastal states of Kerala, Odisha, Tamil Nadu, and Andhra Pradesh.

Concentration - Together, Kerala and Odisha account for over 70% of India's total thorium reserves.

National Strategy - India has been developing a three-stage nuclear program, which is strategically designed to eventually utilize these vast thorium reserves.

Role of Thorium - Thorium-based reactors are the critical component of the third and final stage of this long-term national energy plan.

Challenges

Extraction - Extracting thorium from its ores requires high amounts of energy and creates significant waste.

Implementation Hurdles - Despite having large reserves, India has faced challenges in utilizing them for nuclear energy.

Specific Hurdles - These include the need for advanced reactor technology (like MSRs, which are still developmental) and ensuring the entire fuel cycle is economically viable.

Key Advantages of TMSR

Safety - Operates at atmospheric pressure, reducing the risk of explosive meltdowns associated with high-pressure systems. The molten salts chemically trap radioactive materials (fission products) if a leak occurs, preventing their release. Features an automatic passive drain system for leak containment, where the fuel salt can drain into passively cooled tanks.

Efficiency - The continuous fuel circulation and online processing allow for full fuel utilisation. This results in minimal nuclear waste compared to solid-fuel reactors, where only a small percentage of the fuel's energy is used.

Low Water Requirement - It does not require large volumes of water for cooling, unlike conventional reactors. This makes it highly suitable for deployment in inland or arid areas where water is scarce.

Reduced Radioactive Waste - The thorium fuel cycle produces significantly less long-lived nuclear waste (transuranic elements) than the standard uranium fuel cycle.

Fuel Abundance - Thorium is estimated to be 3 to 4 times more abundant in the Earth's crust than uranium, offering a near-limitless fuel source.

Program Development and Industrial Integration (China)

Initiation - The TMSR program was launched in 2011 under China's strategic nuclear energy program.

Key Milestones -

2023 - The 2 MW liquid-fuelled TMSR achieved its first criticality (the first sustained nuclear chain reaction).

2024 - The reactor successfully achieved full-power operation.

2024 - The first thorium-fuelled test (the current achievement) was successfully conducted.

Future Goal - The ultimate aim is to design and build a 100 MW demonstration plant by 2035, planned for location in the Gobi Desert.

Industrial Collaboration - This is a massive national effort, involving nearly 100 Chinese institutions specializing in design, materials science, and reactor engineering.

Self-Reliance - A key strategic point is that all core components and the entire supply chain for the reactor are 100% domestically developed by China.

Strategic Significance for China

Energy Security - China's domestic thorium reserves could potentially supply its energy needs for tens of thousands of years. This enables a path to complete energy independence by ending its reliance on imported uranium.

Resource Utilisation - Thorium can be extracted from existing industrial waste. It is estimated that one mine tailings site in Inner Mongolia holds enough thorium to power China entirely for more than 1,000 years.

Climate and Carbon Goals - TMSR provides a stable, 24/7 low-carbon energy system that complements variable renewables like solar and wind. The high-temperature heat (≈700°C) from the reactor can also be used for industrial processes, such as green hydrogen production.

Technological Leadership - With this achievement, China now leads the world in operational thorium MSR technology. This positions China at the forefront of fourth-generation nuclear innovation.

Future Strategic Sectors - China is already exploring the use of this technology for other advanced applications, including thorium-powered ships and compact lunar reactors to power future moon bases.

Challenges and Limitations

Material Durability - The molten salts used as fuel and coolant are highly corrosive at extreme temperatures. Developing reactor materials that can withstand these conditions for decades is a primary challenge.

Radioactive Handling - The in-situ "breeding" process creates a complex mix of isotopes. Managing protactinium and uranium isotopes safely within the liquid fuel is a complex engineering task.

Economic Viability - The technology currently has high initial R&D (Research & Development) and infrastructure costs.

Regulatory Framework - Because MSRs are a new class of reactor, global safety and licensing standards are still evolving, which can slow down widespread commercial deployment.

Way Forward

China's Goal - China is aiming for commercial-scale deployment of its TMSR technology by the year 2035.

Global Impact - This success could reshape the global nuclear energy landscape by providing a sustainable, safe, and low-carbon alternative to both fossil fuels and conventional uranium reactors.

Climate Goals - If the technology proves to be scalable and economically viable, thorium MSRs could be pivotal in helping nations achieve net-zero targets and ensuring long-term energy security.

Source - http - //www.china.org.cn/china/Off_the_Wire/2025-11/01/content_118154313.shtml