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Opportunities and Challenges for Thorium in Commercial MSRs

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Overview

- Advantages of Thorium
- Advantages of MSRs
- Likely deployments & projects considered
- Technical concerns
  - Materials
  - Safety
  - Reprocessing
  - Proliferation
- Commercial considerations
- Conclusions

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What is 'Commercial'

- Should not be taken to imply a particularly sized reactor
- Both large and small reactor deployments can be said to have advantages
- In general, consideration has been given to what issues remain to bring MSRs to market, as a product which could feasibly be licensed and sold
- Majority of development up to this stage should be from national interest programmes – outside the scope of commercial R&D

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Advantages of Thorium

- Enables a decrease in initial fissile loading, which is improved with increasing burnup
- The value of thorium in a thermal spectrum increases with the ability of LWR cladding material to match the required burnup
- The value of thorium is potentially maximised within an MSR because;
  - Cladding does not limit fuel utilisation
  - A steady fissile load can be considered a non-recurring investment
  - The thorium contribution to energy output can be high in proportion to the rate of addition of fissile material, even if breeding is not achieved

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Advantages of MSRs

- Fuel can be added as required
- Troublesome isotopes removed during operation
- Fissile inventory can be removed from the core using passive systems
- High boiling point of molten salts
- Core lifetime dictated by moderator performance, not fuel burnup limit
- Fuel salt density decreases with increasing temperature
- Broad range of fuel options – no fabrication required
- High temperatures compared to LWRs
- Proliferation resistance

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Projects Considered

- Mainly national or international programmes.
- Limited information on small commercial projects
- French
- Russian
- Chinese
- Japanese
- Indian

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Technical Concerns

- The operation of a historical demonstrator does not necessarily ensure current feasibility, nor commercial success
- MSRs are not just 'in competition' with current technology, but also with Gen IV concepts, many of which have more experience

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Comparison with Gen IV

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Materials

- Hastelloy N was proven during MSRE
- Modifications required to prevent embrittlement reduce max operating temperatures to ~650°C
- If a 100°C ΔT is assumed through the core, and the outlet temperature is 50°C below max, then the inlet temperature is close to salt-freezing, and possibly below depending on the salt
- It is likely alternative alloys would be required for commercial licensing

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Safety

- Freeze plug/Drain tank combination is generally described as a key feature of MSR operation
- Concerns regarding
  - Speed of operation
  - Thermodynamics
  - Links to materials concerns
- Mechanical valve or burst disc could provide alternative option

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Reprocessing

- Where reprocessing is required this appears to represent significant technical risk
- Development of suitable processes is likely to require investment beyond that which would be supplied commercially.
- Promising avenues to explore, but need to be proven at required scale to provide confidence in the feasibility of the proposal

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Proliferation

- Recent concerns raised in Nature regarding the proliferation resistance of the Th-U cycle
- In concepts where Pa-233 requires separation this represents a significant safeguarding risk
- Pyroprocessing can be performed on a bench-top scale, much harder to detect
- Risk is less from external access (eg terrorists) than states accessing high purity fissile material undetected

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Commercial Considerations

- For MSRs to be attractive now, they must out-compete existing technology sufficiently that they are worth a significant initial investment
- Possible areas include;
  - Safety
  - Fuel cost
  - Operation
  - Availability
  - Manning
  - Security
  - Proliferation
  - Waste management
  - Disposal

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Conclusions

- Introduction of thorium fuel cycle may be linked to introduction of molten salt reactors
- Further work is required to quantify the commercial benefits that a realistic MSR concept would provide
- It is also necessary to confirm the feasibility of suggested MSR advantages
- Concerns must be addressed regarding materials, safety, reprocessing and proliferation
- Fundamentally, the MSR must provide some benefit to industry above current technology, in order for investment to be attractive
- For MSRs to progress, national programmes must develop a concept to the point at which commercial investment becomes viable