The DMSR: Keeping it Simple

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What factors differentiate between various Liquid Fluoride designs?

- R&D required and level of technological uncertainty
- Start up requirements of fissile material and thus deployability
- Whether fission product removal is required and if so, its degree of difficulty
- Reactivity coefficients
- Degree of Proliferation Resistance
  - All very good but still major differences

Breeder or Converter?

- Breeders offer the ultimate in minimising resource usage but at the capital and R&D cost of fuel processing
- Converters require an outside fissile source but greatly simplify development and operation

DMSR Converter Reactors

- Starting Premise is Oak Ridge`s *30 Year Once Through Design* (1980)
- 1000 MWe output
- Startup with LEU (20% ^{235}U) + Th
- No salt processing, just add small amounts of LEU annually
- Low power density core gives 30 year lifetime for graphite (8m x 8m)
- Lower fissile startup load than LWR (3450 kg/GWe)
- No reactivity coefficient issue like MSBR

HOLD ON NOW!

- Won't using LEU hurt the conversion ratio, produce much more transuranics and rely on natural uranium which will run out in just a few decades!!!
- Drop in conversion ratio is only minor and LEU fissile is much cheaper than U233 or spent fuel Pu
- Inventory of transuranics comparable to a pure Th-U233 breeder. The DMSR can actually be superior in regards to TRUs going to waste
- We WILL NOT run out of uranium despite the claims of AntiNuclear groups and Breeder supporters. We CAN run out of cheap uranium (hard on LWRs but little effect on DMSRs)

Denatured Molten Salt Reactors

- At end of 30 years
  - Uranium easily removed and reused which would drop the lifetime ore to under **1000 t**
  - Transuranics should also be recycled
  - ~1000 kg TRUs in salt at shutdown
  - Assuming typical 0.1% processing loss, just 1 kg in 30 years! As good or better radiotoxicity as pure Th-^{233}U cycle
- Reducing the Earth`s Radioactivity?
  - After 300 years, a net reduction of radiotoxocity (from reducing nat U234)
  - No other reactor can make this claim

Reactor	Lifetime Uranium Ore (t)	Annual Uranium Ore (t)	Annual Ore Costs **50$/kg U**	Annual Fuel Costs **50$/kg U**	Annual Fuel Costs **5000$/kg U**
LWR	**6400**	200	8.5 million	~40 0.006$/kwh	~880
LWR with U-Pu Recycle	**4080**	125	5.3		
Sodium Fast Breeder	**~4000** **If start up on ^{235}U**	2.5			
DMSR Converter	**1800**	35	1.5	~6 0.001$/kwh	~155 <0.02$/kwh
DMSR single U recycle	**1000**	35	1.5	~6	~155

Based on 0.2% tails, 75% capacity factor, 30 year lifetime

LWR data from “A Guidebook to Nuclear Reactors” A. Nero 1979

3.9 million$ annual enrichment costs for DMSR at 110$/SWU

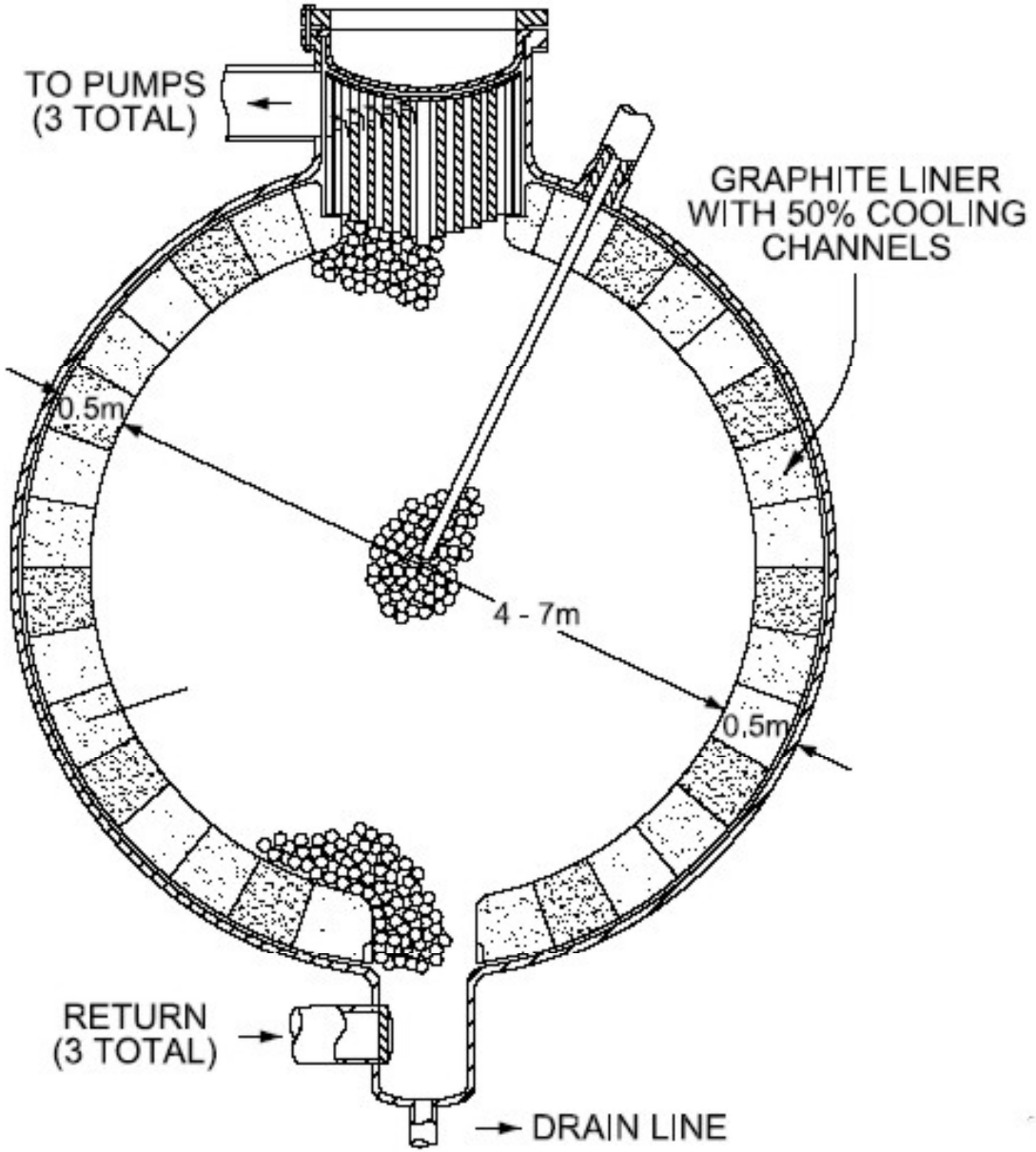
Above $1000/kg uranium resources likely unlimited

Extremely High Proliferation Resistance

- No fuel processing ever required
- Uranium always denatured, at no stage is it weapons usable
- Any Pu present is of very low quality, very dilute in highly radioactive salt and very hard to remove
  - About 3 times the spontaneous fission rate of LWR Pu and 5 times the heat rate (72.5 W/kg)
- No way to quickly cycle in and out fertile to produce fissile

Suggested Improvements

- Extend lifetime to 60 years
  - Simply need more salt+LEU to start
  - Make core larger or replace graphite
- Shorter batch cycles of the salt
  - As long as U is recycled (TRUs can wait) large improvement in U needs. 15 year batches likely 20 t U per year
- Graphite Pebbles as moderator
  - Removes need for flux flattening
  - Can go smaller, higher power density
  - Pyrolytic coatings for increased safety



Proposed Pebble Bed DMSR Converter

Suggested Improvements

- Graphite Free “Tank of Salt” Core
  - Difficult due to ^{238}U resonances but not ruled out
- Alternate carrier salts
  - **NaF-BeF_2** low cost, low melting point
    - May allow stainless steel throughout loop
  - **NaF-RbF** low cost, no tritium production
    - Simplification of entire primary loop
  - **NaF** very low cost, higher melting point
  - Annual uranium needs from 0% to 20% higher

A LEU Only DMSR

- Running without thorium has many interesting advantages
- Neutron economy not as good but resource needs only increase fractionally
- No worry about Pa
  - Run any power density or spectrum
- Much simpler to re-enrich uranium between batches (no U232)

Conclusions

- The DMSR has numerous advantages over proposed MSR breeder designs, especially in terms of R&D and technical uncertainty
- Even ORNL only briefly modeled these designs, help is needed to explore options and potential
- Can be viewed as a 1st generation MSR but might be all we need