LeadCold

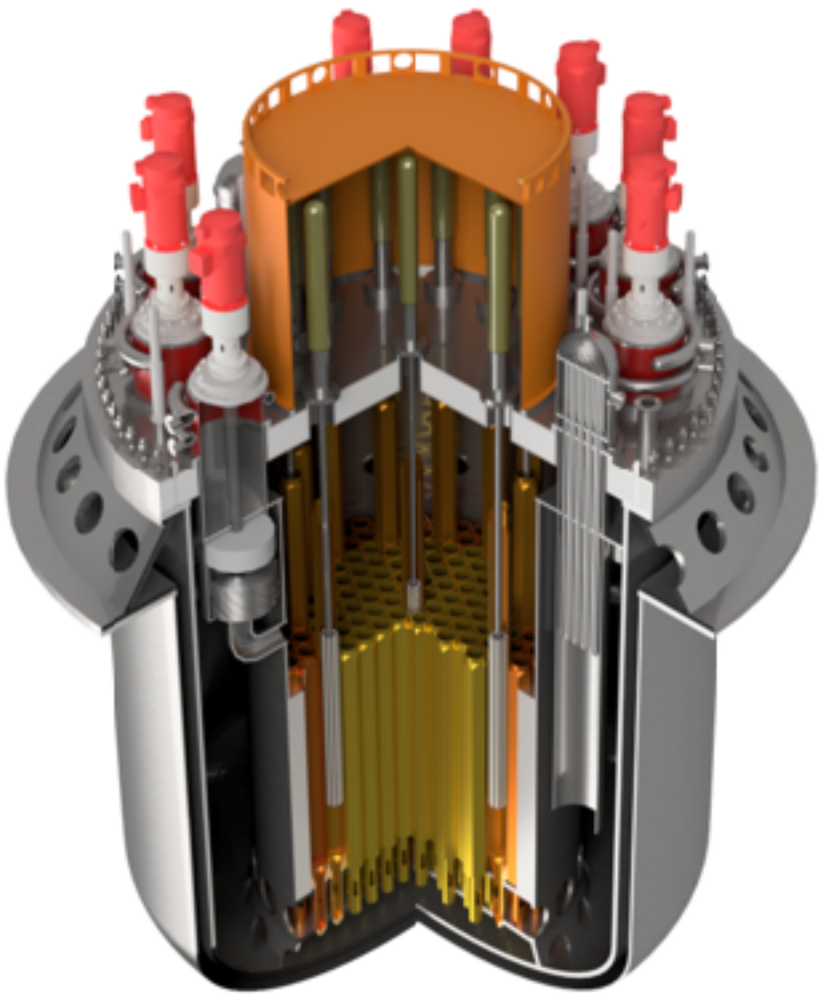
Atomic simplicity

www.leadcold.com

Fuel cycle of SEALER-55

- **Background**
  - Specifics of technology
  - Primary system design
  - Core design and performance
- **Front end**
- **Back-end options**

Background



- 55 MWe SMR developed in Sweden
- Lead coolant provides passive safety in compact format
- Alumina forming steels ensures corrosion tolerance
- Uranium nitride fuel enhances economics

Lead coolant: The good

- Low pressure system
- Does not react violently with other liquids/materials
- Eliminates risk for loss of coolant by boiling (T_{boil} = 1740 C)
- Allows for residual heat removal by natural convection in compact format
- Forms stable, low vapour pressure compounds with Iodine and Caesium
- Functions as in-situ gamma shielding

Lead coolant: The bad

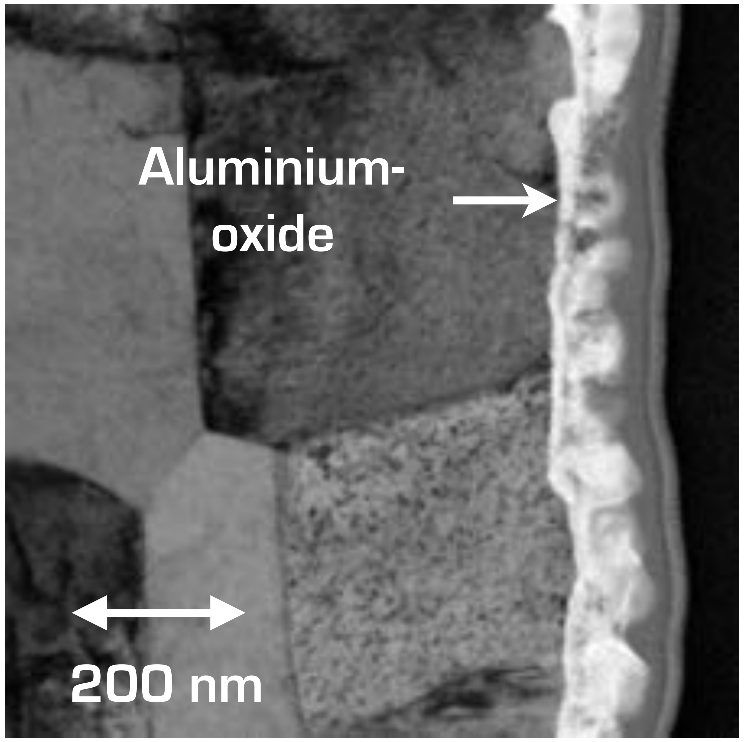
± Mixed experience from operation of nuclear sub-marines (11 reactors)

– Excessive corrosion rate of austenitic stainless steels at T > 450 ºC

– Opaqueness makes inspection and fuel management difficult

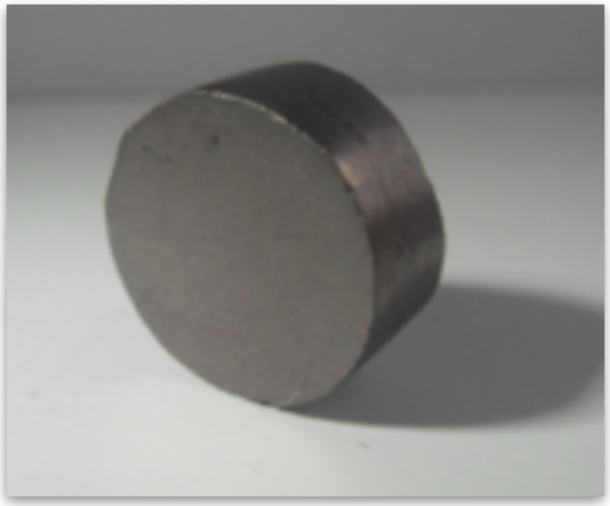
– High melting temperature makes maintenance complex

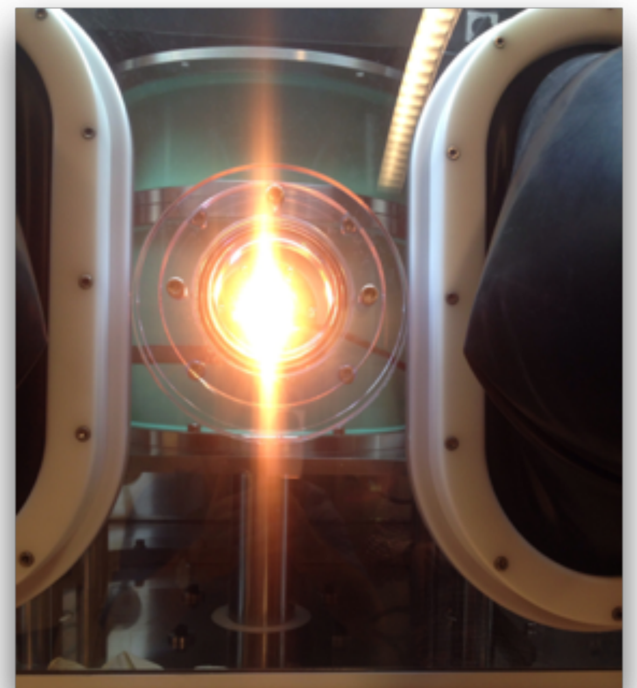
Break-through solution (1)



- Potential show-stopper for commercialisation of lead-cooled reactors: corrosion of stainless steels
- LeadCold's solution: aluminium alloyed steels:
- Fe-10Cr-4Al-RE (RE = Zr, Ti, Nb, Y)
- Alumina forming austenitic steels (AFA)
- Form 100 nm thin, ductile and protective alumina film on surfaces exposed to lead with low oxygen content.
- Fe-10Cr-4Al-RE successfully tested at 550ºC for two years & at 850ºC for ten weeks.
- 10 ton batch fabricated by Sandvik/Kanthal

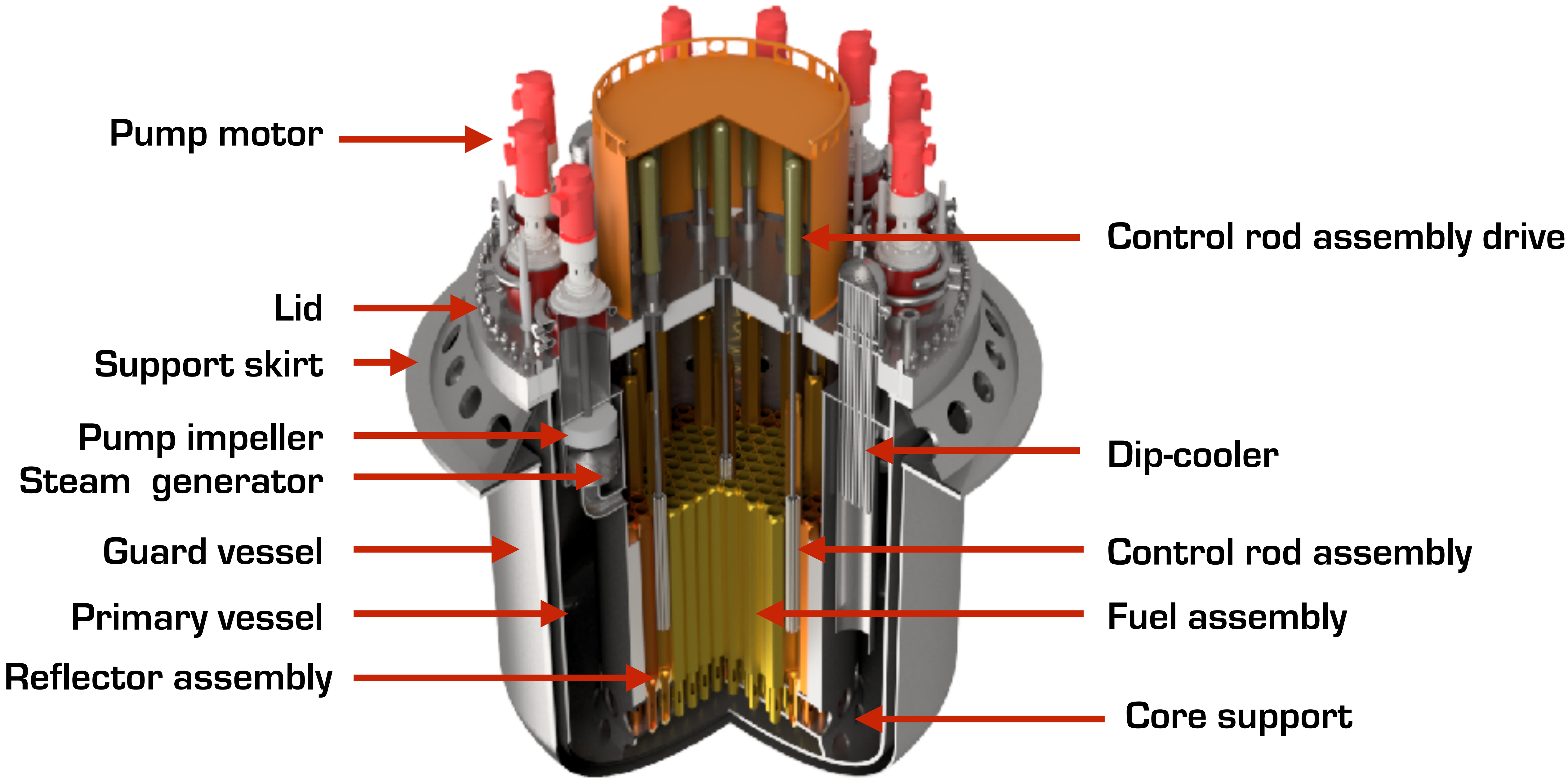
Break-through solution (2)



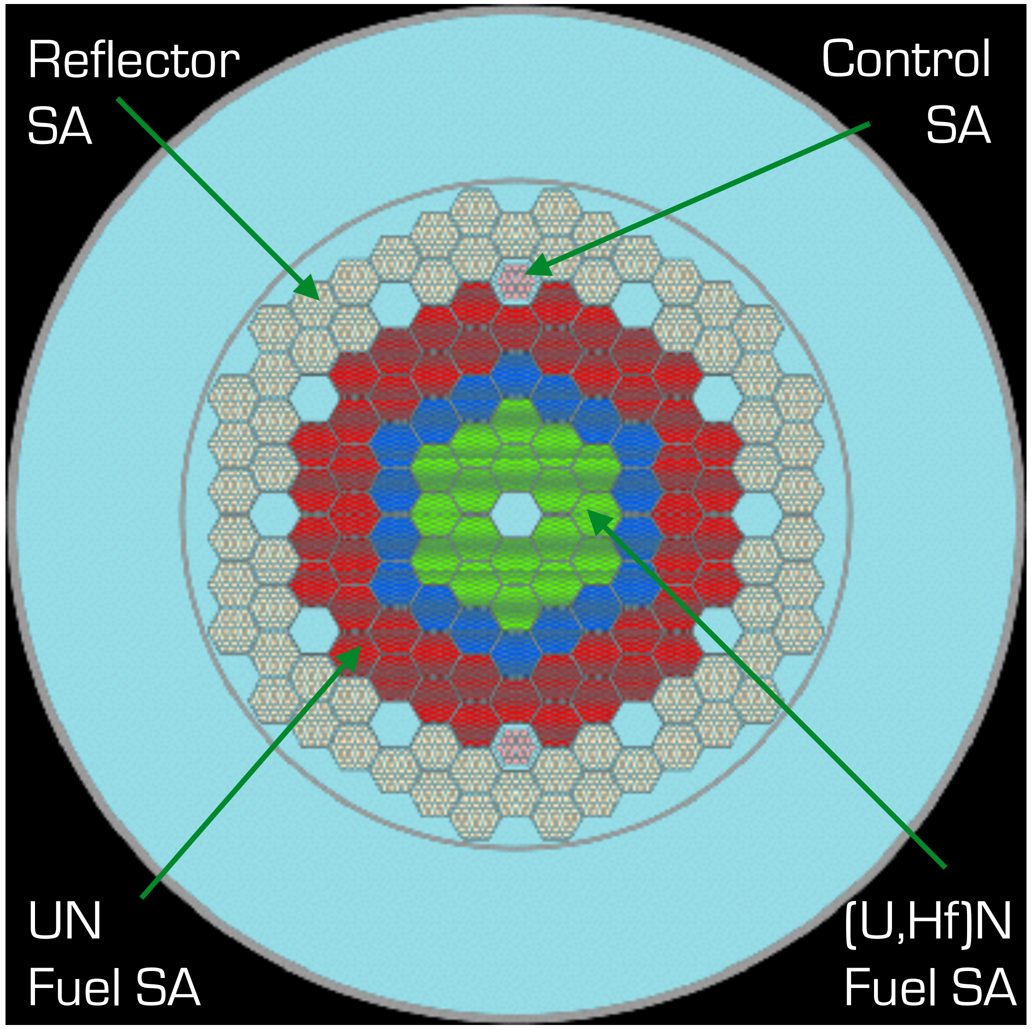


- Fuels with higher density of uranium provide better economy than conventional UO_2.
- Uranium nitride features 40% more uranium per volume unit and 7 times higher thermal conductivity
- Difficult to manufacture using conventional methods
- KTH has developed methods for manufacture of uranium nitride permitting tailor made manufacture of this fuel at industrial scale
- ”Spark Plasma Sintering” - SPS
- Pellet can be sintered in 3 minutes at 1450˚C (8 h at 1900˚C using conventional sintering furnaces)

Primary system

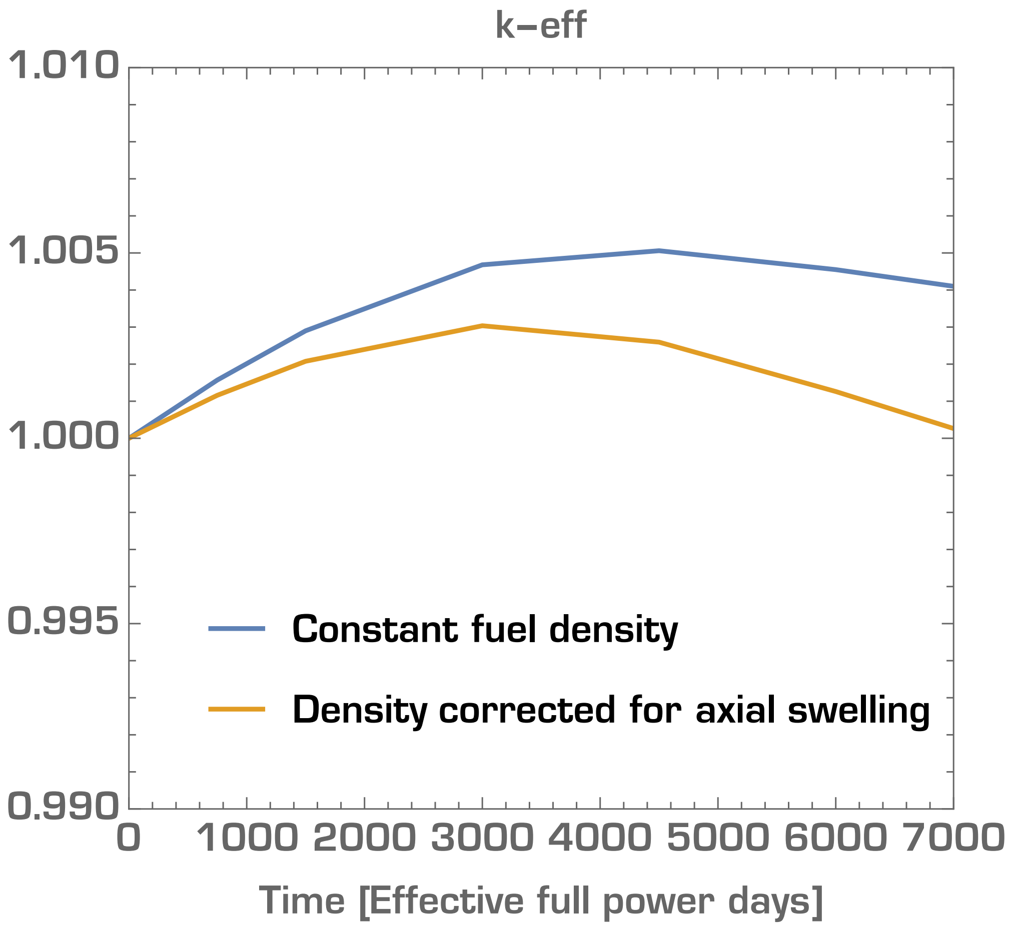


Core



Item	Value
Fuel composition	UN & (U,Hf)N
N-15 enrichment (at%)	99.5
U-235 enrichment (at%)	12.0
Pellet porosity	0.05
UN pellet density (cold)	13.63 g/cm^3
Pellet diameter (cold)	11.00 mm
Clad inner diameter	11.46 mm
Clad outer diameter	12.66 mm
Rod pitch	14.23 mm
Fuel column height	1300 mm
Axial reflector composition	ZrN
Reflector pellet density	6.99 g/cm^3
Lower reflector height	100 mm
Upper reflector height	10 mm
Lower end plug height	50 mm
Upper plenum height	500 mm
Upper end plug height	20 mm
Total rod length	1980 mm
Fuel rods/SA	169
UN/(U,Hf)N fuel assemblies	48/36
Fuel assembly inner FTF	188.3 mm
Fuel assembly outer FTF	193.3 mm
Fuel assembly pitch	194.3 mm

Core performance



- SEALER uses 12% enriched uranium
- Breeding ratio > 1.0
- Thermal power: 140 MW
- Fuel residence time: 25 EFPY
- Peak radiation damage dose: 120 dpa
- Average fuel burn-up: 60 GWd/tom
- Peak fuel burn-up: 90 GWd/ton
- Reactivity swing: < 300 pcm

Front-end of fuel cycle

- Each SEALER requires supply of
  - 21 tons of 12% enriched uranium
  - 1 ton of 99.5% enriched ^{15}N
  - 0.5 ton of hafnium
- Today, single suppler of above 5% enriched U for commercial purposes is Rosatom (TENEX)
- URENCO may start delivering 10% enriched U in 2023-2024, higher enrichments possibly follow later.
- Industrial scale supplier of ^{15}N has been identified
- Hafnium supplier to be identified
- Potential site for fuel fabrication: Studsvik in Sweden

Back-end options

- **Direct disposal of entire UN core in frozen lead**
  - \+ Least amount of processing required
  - \+ Needs container development and R&D for licensing
- **Steam conversion of irradiated UN to UO_2 for direct disposal**
  - \+ Lab scale conversion of fresh UN has been achieved at KTH
  - \+ Least amount of R&D
  - – Probably costly
- **Reprocessing of irradiated UN**
  - \+ UN is soluble in nitric acid at room temperature
  - \+ Spent SEALER fuel contains > 12% ^{235}U reactivity equivalent fissile material, may be commercially competitive
  - – Requires largest amount of R&D