The nitride fuel R&D program of Blykalla

BLYKALLA
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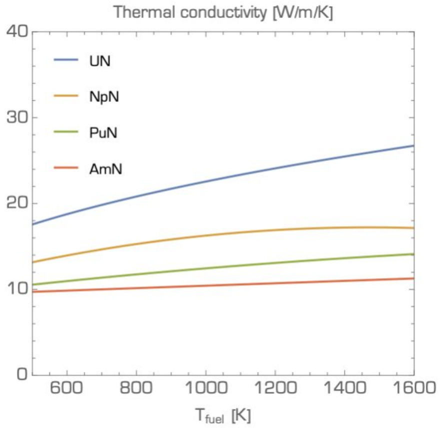
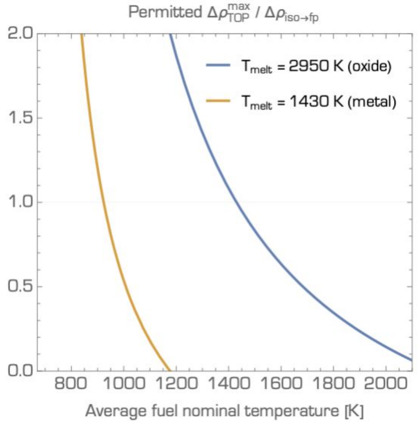
Agenda

- Rationale for the nitride fuel option
- Issues to be addressed
- Fabrication
- Qualification

Rationale for the nitride fuel option: Safety





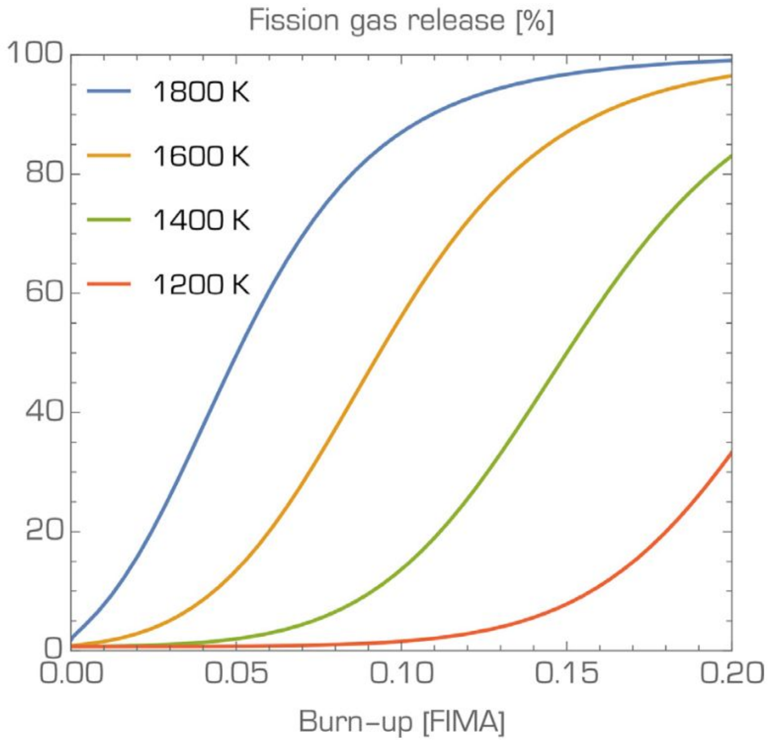
Nitride fuel features a combination of

High thermal conductivity &

High melting temperature

In the case of UTOP transient, fuel is not the limiting factor, as it is for oxide and metal alloy fuels.

Rationale for the nitride fuel option: low gas release

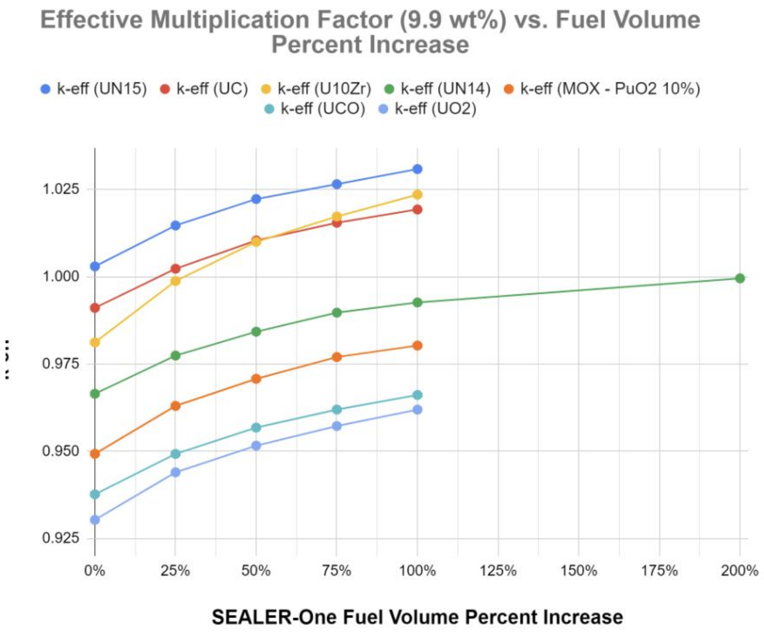


Operating a fuel below ⅓ of its melting point is only possible for a nitride fuel

Gas release is limited to recoils (< 1%)

No volatile release - no pellet clad chemical interaction

Rationale for the nitride fuel option: economy

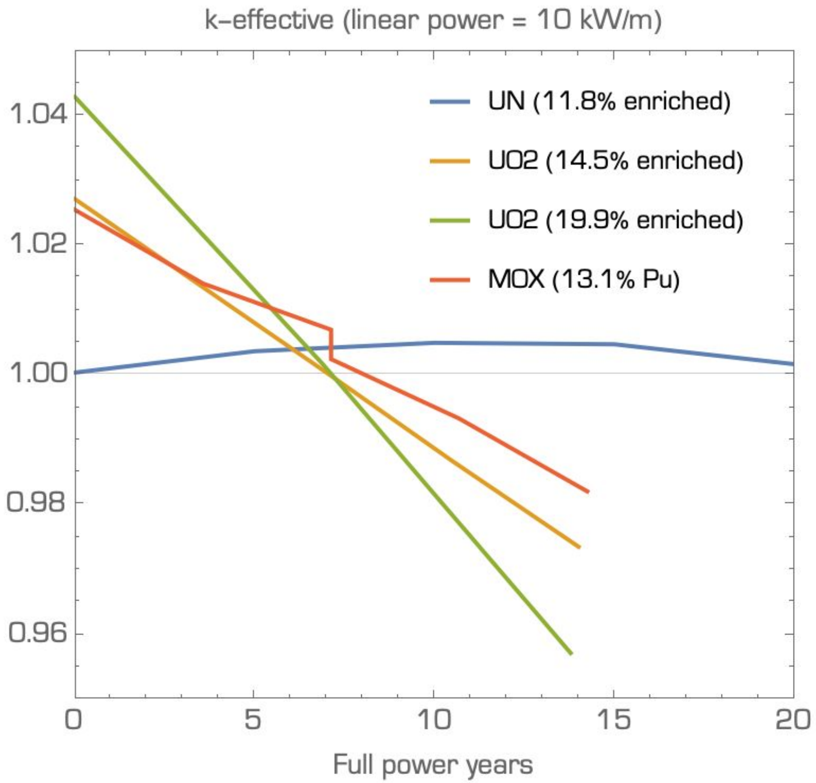


Nitride fuel made with N-15 features the best neutron economy

Smallest core for any enrichment

For currently commercially available enrichment (9.9%), UO_2 cannot be used to operate a fast reactor.

Reactivity evolution



UN + core operating at 150 MWth

6% burn-up reached in 20 full power years

Reactivity swing 400 pcm

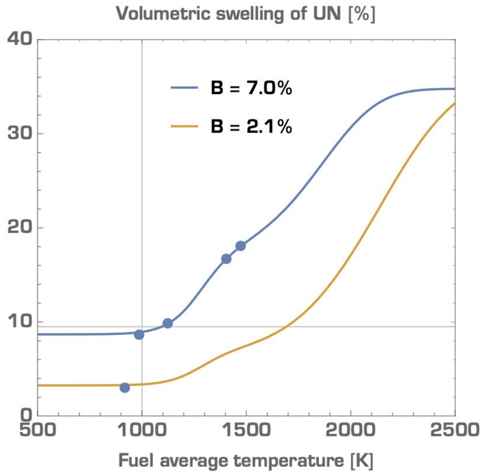
Oxide core with same fuel height/linear power:

- **Enrichment: 14.5%**
- **Reactivity loss: 400 pcm/year**
- **6 assemblies replaced every year**

MOX core with same fuel height/linear power

- **Pu fraction: 13.1%**

Issue: Swelling



At high temperatures, nitride fuel swell rapidly

Cause of failure in 2nd core of BR-10 due to pellet-clad mechanical interaction.

Addressed by:

- 15% porosity introduced in fresh fuel (BREST-300)
- Low temperature operation with adequate fuel-clad gap (SEALER).

At T < 1050 K, swelling rate if 1.5±0.2 % per percent FIMA

5 mm pellet radius & burn-up of 10% -> gap size = 250 micron.

Issue: Powder fabrication

3 ways of manufacturing nitride fuel powder may be considered:

Carbothermic nitriding of UO_2

Higher oxygen impurities (> 500 ppm)

Expensive, since we start from UO_2

N-15 recovery more complex

Industrialised in Russia (plant in operation)

Time to production in Europe/US: 2 years.

Hydriding/nitriding of U metal

Purest product (100 ppm oxygen)

Expensive, since we start from metal

N-15 losses are minimal (tested in lab)

Scalability to be proven

Ammonolysis of UF6

Potentially cheapest approach

Simple 2-step gas-gas reaction

N-15 recovery feasible.

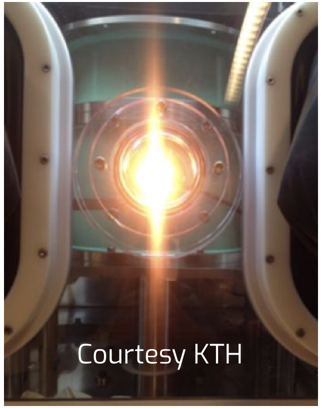
Nitride product catalyses dissociation of ammonia, hence product must be continuously removed from reaction furnace

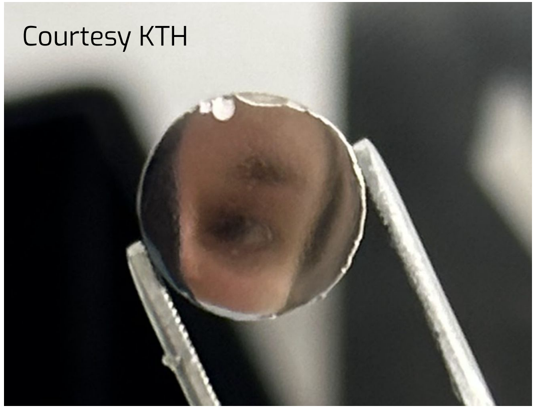
Requires additional R&D

Issue: sintering

Low porosity desired to take advantage of of nitride fuel actinide density

Conventional sintering requires aggressive milling of powders combined with sintering at 2200°C, leading to higher oxygen impurity take-up and larger grain size.





Spark plasma sintering can yield any desired density and microstructure

Current (1000 A) assisted hot pressing at 1600°C, duration a few minutes

Recently industrialised for e.g. space applications

Automated, 0.5 million pellet/year equipment now offered by suppliers.

Issue: N-15

Use of N-15 required to take advantage of high actinide density of nitride fuel

350 m tall cryogenic distillation column for enrichment of Ar-40 under construction in Sardinia

To be commissioned in 2026

Applied to enrichment of NO, capacity of N-15 enrichment is 1 ton/year

May be used for N-15 enrichment from 2027 and onwards

Scalable to capacity of 10 ton/year by increasing diameter of column.

Demand: 1 ton per SEALER-unit

Qualification

Two full cores of UN were used as driver fuel for BR-10, 18 years of operation

24 fuel assemblies with (U,Pu)N rods irradiated in BN-600

(U,Pu)N qualified for use up to 6% FIMA in Russia.

Transient tests up to T = 3000°C carried out in Kazakhstan.

BLYKALLA:

- Verify low swelling rate of UN at irradiation temperature < 1050 K.
- Target burn-up: 0.5 - 2.0% FIMA

Fabrication

Fabrication of ≈ 1 kg of UN for irradiation testing & qualification of process

Funding from EIC & Swedish Energy Agency

- Ammonolysis of UF_6 (2026)
- 100 pellet batch fabrication of UN with spark plasma sintering (2026)

Design of pilot scale plant (10 t/year) within Euratom FREDMANS project

- Safety analysis (2025)
- Economic analysis (2026)

Conclusions

Nitride fuel provides better safety and economics than alternative fuels for LFRs.

Low temperature operation ensures low gas release & acceptable swelling rate

Fabrication of fuel with innovative technology under development

Kilogram scale fabrication to be conducted in 2026

Irradiation testing to modest burnup (0.5-2.0% FIMA) under planning

Pilot plant to fuel first SEALER unit under design.