The Impact of Americium on the Transient Analysis of the European Lead System (ELSY)

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Why LFR?

GEN IV objectives

- Sustainability
  - Improved fuel utilization (breeding)
  - Waste minimization (reprocessing)
- Safety
  - Excellent safety and reliability
  - Low probability for core damage
  - Elimination of need for off-site emergency response
- Economics
  - Comparable to other energy sources
- Proliferation
  - Least attractive

Six concepts

- Fast reactors
  - Sodium cooled fast reactor (SFR)
  - Lead cooled fast reactor (LFR)
  - Gas cooled fast reactor (GFR)
- Breading ratio < 1 (U-Pu cycle)
  - Very high temperature reactor (VHTR)
  - Super critical water reactor (SCWR)
  - Molten salt reactor (MSR)

Why LFR?

How about sodium?

+ Excellent breeding ratio
+ Mature technology (BN-600, Phénix)
+ Prototype in operation within 10-15 years (ASTRID)

- High cost for prevention of sodium leaks
- Questionable safety (coolant boiling, severe accident scenario)

Violent exothermic reaction 2 Na + 2 H_2O → 2 NaOH + H_2

Why LFR?

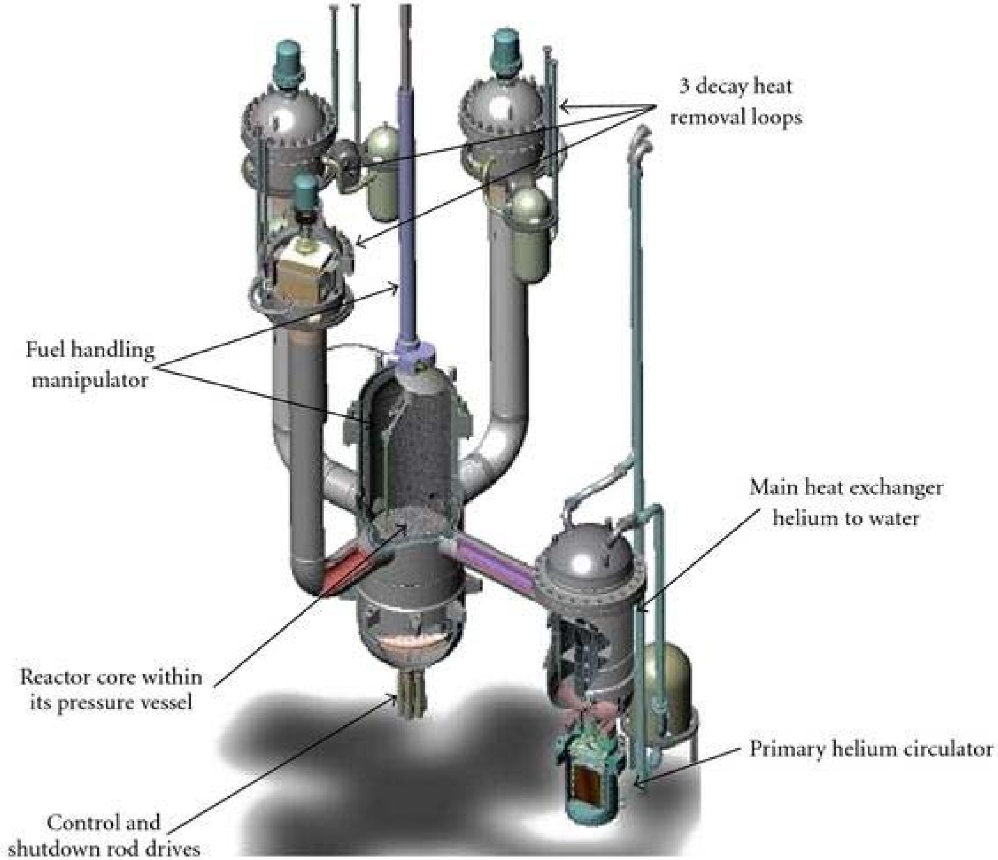
How about gas coolant?

\+ Relatively simple design

\+ Inert gas coolant (He)

– Decay heat removal under loss of pressure

– No operational experience



Proposed layout of ALLEGRO, the GFR demonstrator.

Why LFR?

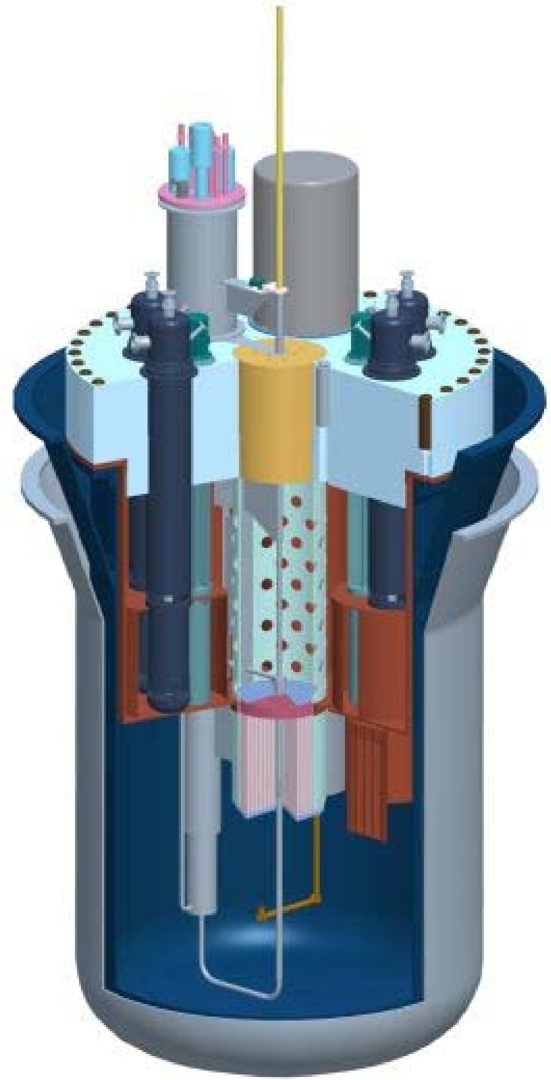
K 705, Alfa-class Soviet submarine

- \+ Lead does not react with water rapidly
- \+ Coolant boiling virtually impossible
- \+ High degree of natural circulation (high thermal expansion)
- \+ Chemically retains Cs and I in the core (in case of an accident)

- – Technology used only in military applications
- – Material issues (corrosion & erosion)

LFR projects in Europe

- **BREST**
  - 300 MW_e
  - NIKIET, Russia
- **SVBR-100**
  - LBE; 100 MW_e
  - Rosatom, Russia
- **MYRRHA**
  - LBE; 100 MW_t
  - SCK-CEN, Belgium
- **ALFRED**
  - 120 MW_e
  - LEADER project, Romania
- **ELECTRA**
  - 0.5 MW_t
  - KTH, Sweden



MYRRHA design

LFR projects in Europe

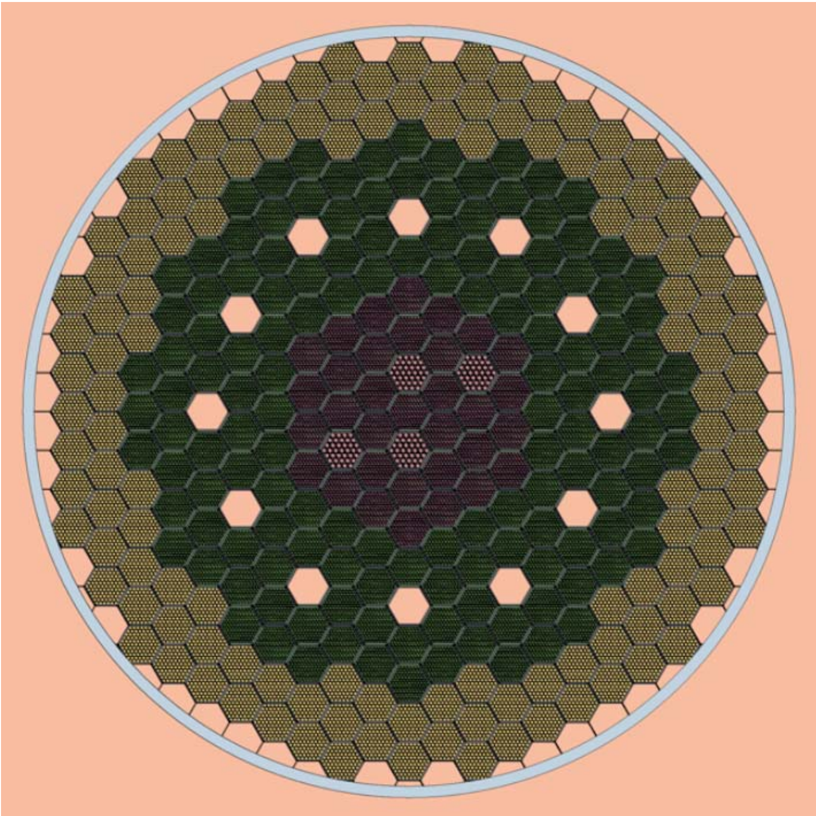
ELECTRA – European Lead Cooled Training Reactor

ELECTRA design

- Test reactor for education and training (suited also for liquid-metal reactor-dynamics research)
- Thermal power 0.5 MW
- Core size: 30 x 30 cm (vessel size 1.5 x 3.0 m)
- Pump-free design; 100% natural circulation
- U-free nitride fuel: (Pu,Zr)N

LFR projects in Europe

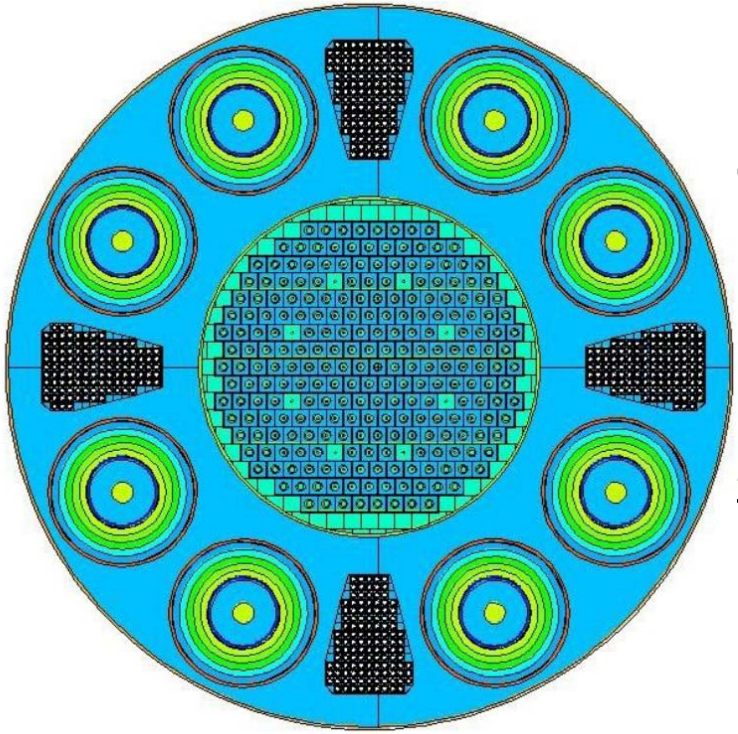
ALFRED – Advanced Lead Fast Reactor Demonstrator



ALFRED, the son of ELSY

- Under development within the LEADER project (coordinated by ANSALDO)
- Energy production 120 MW
- MOX fuel
- Steel protection – GESA method (aluminum oxide coating)
- Expected hosting country Romania
- Operational in late 20’s

ELSY



ELSY design

ELSY - European Lead SYstem

Objectives

- Demonstration of the technical feasibility of an LFR
- Demonstration of the ability to fully comply with the GEN IV objectives

Successfully finished in 2010

Basis for LEADER (LEad-cooled European Advanced DEmonstration Reactor)

- MOX fuel
- Electric power 600 MW
- Open square assembly
- 8 x 190 MW spiral-tube heat exchangers

This work

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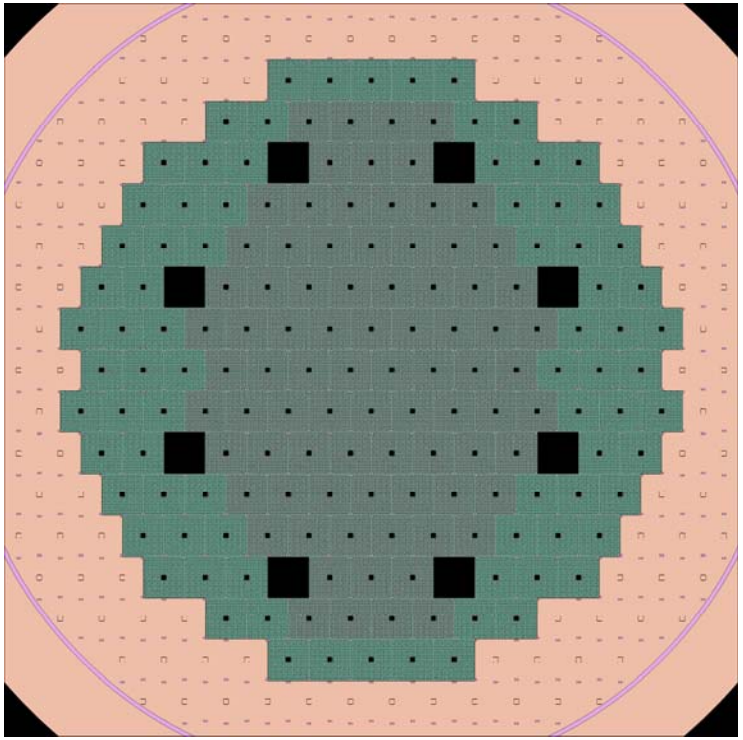


The core of ELSY used in this work

Americium atomic fraction 0-10% in steps of 2%

Two states

- 2 years cooling -> BOC (beginning of cycle)
- ⅔ of a 5-year cycle -> EOEC (end of equilibrium cycle)

6 x 2 = 12 cases; 2 transients for each case

<u>Collaboration</u>

- Reactivity feedbacks by Monte Carlo code SERPENT
  Milan Tesinsky
- Transients by deterministic codes SAS4A/SASSYS
  Youpeng Zhang

Transients Definitions

UTOP

Unprotected Transient Over Power

- Insertion of +1$ within 20 s
- Example: Unpredicted withdrawal of the control rod with the highest worth

ULOF

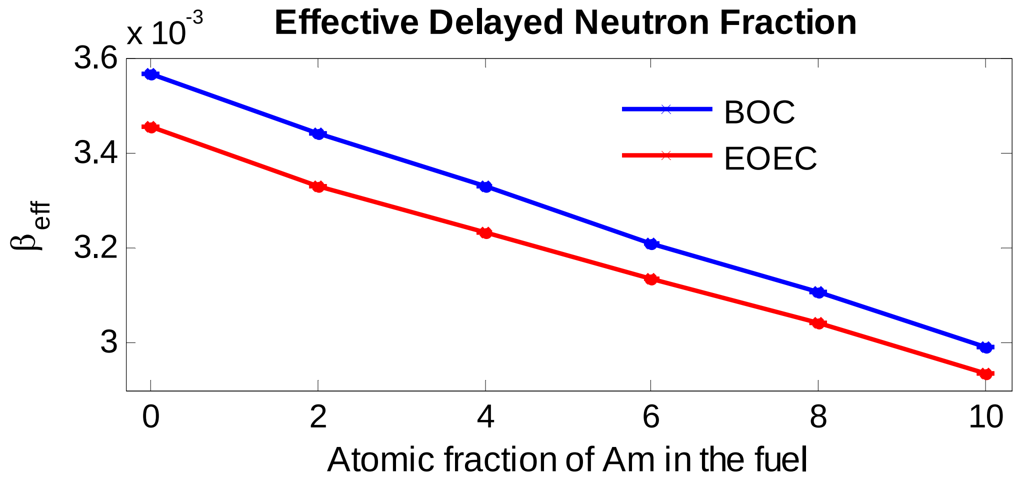
Unprotected Loss of Flow

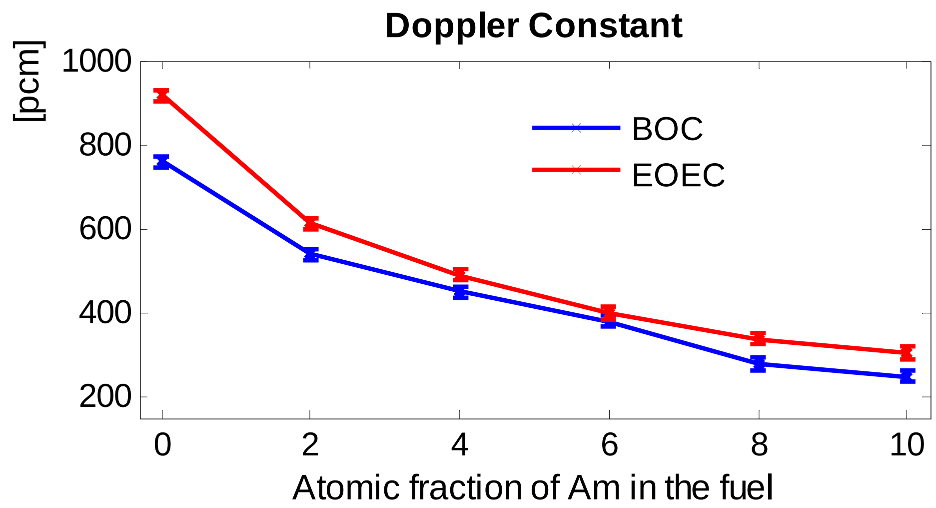
- Reduction of flow rate to 30% within 10 s
- Example: All primary pump trip

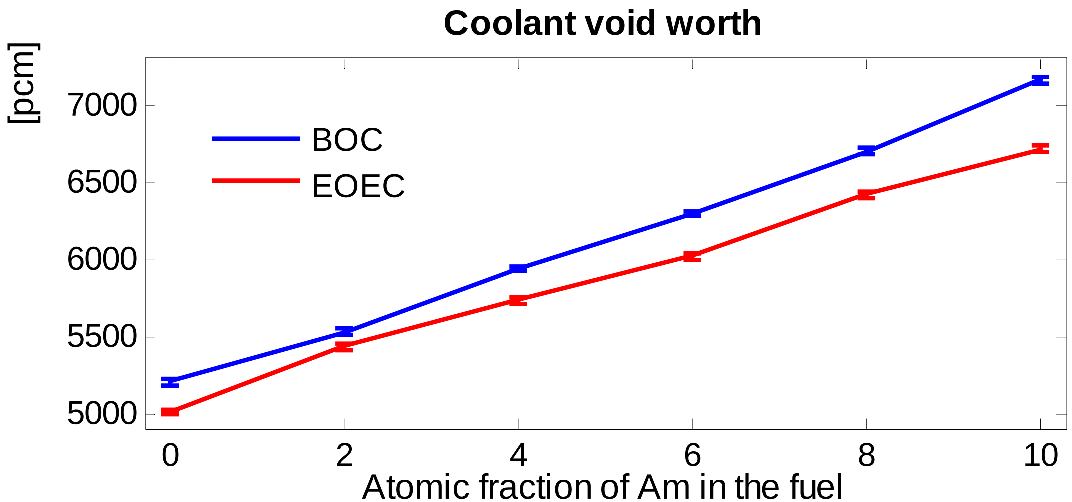
Unprotected = no SCRAM

Reactivity feedbacks

A number of feedbacks has been investigated for each case, such as





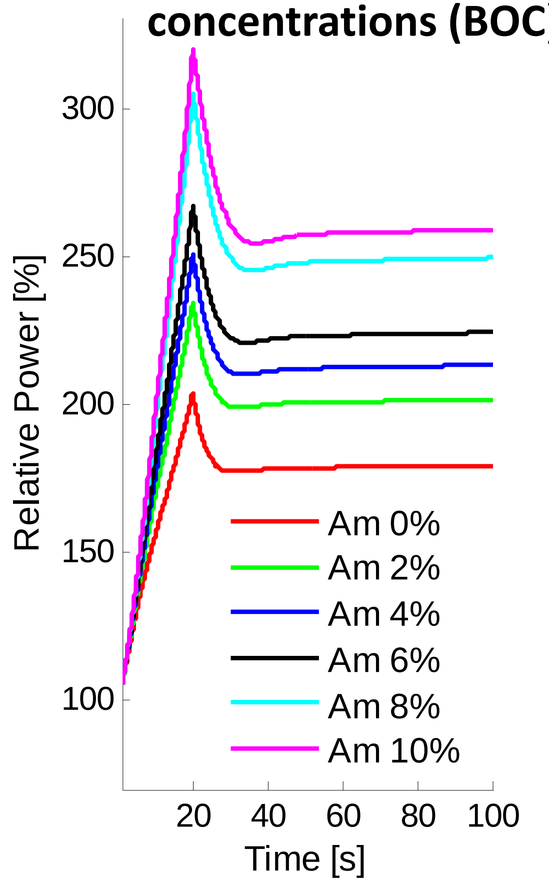


$$\mathrm{DC} = \frac{k_1 - k_2}{\ln \frac{T_2}{T_1}}$$

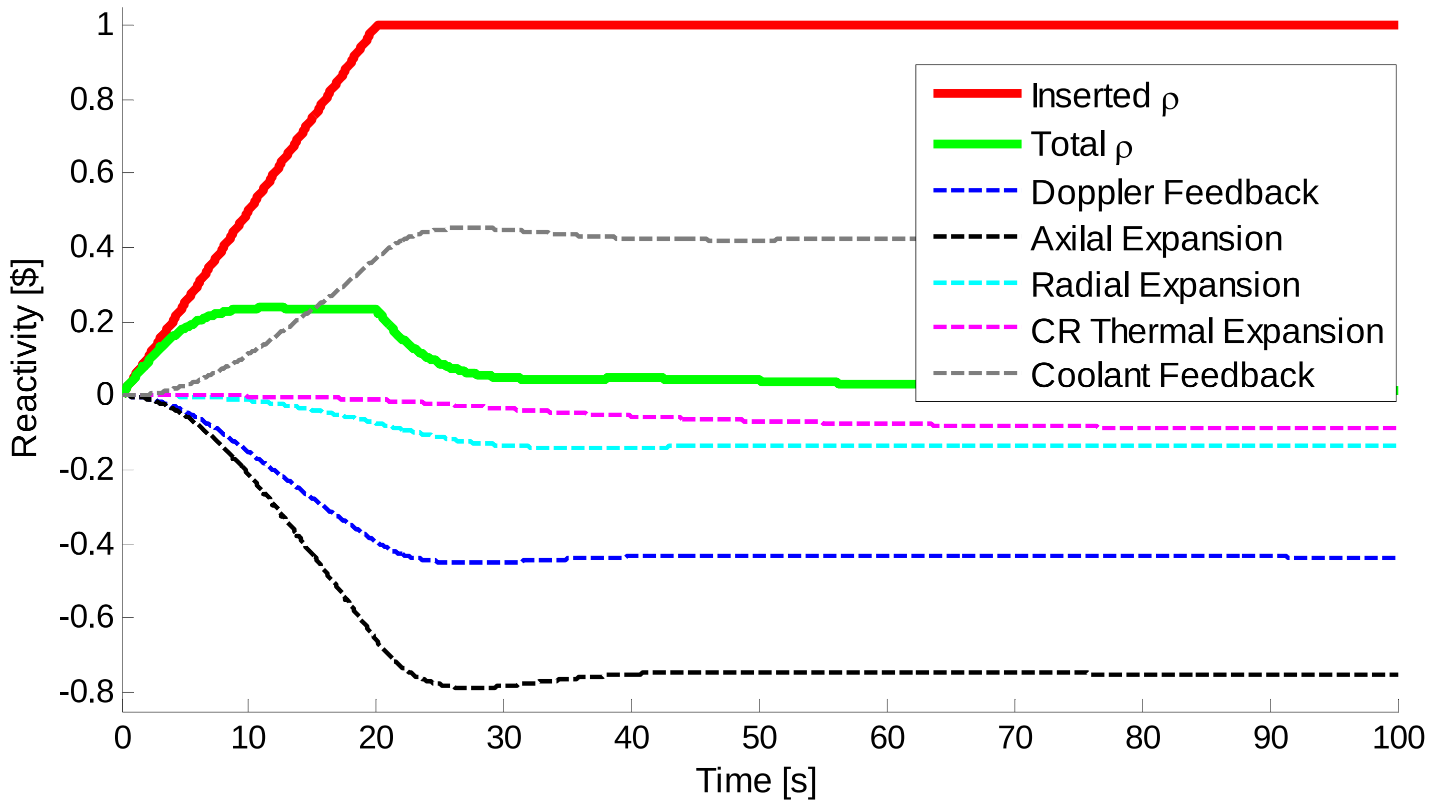
UTOP

Unprotected Transient Over Power

Relative power during ULOF for different Am concentrations (BOC)

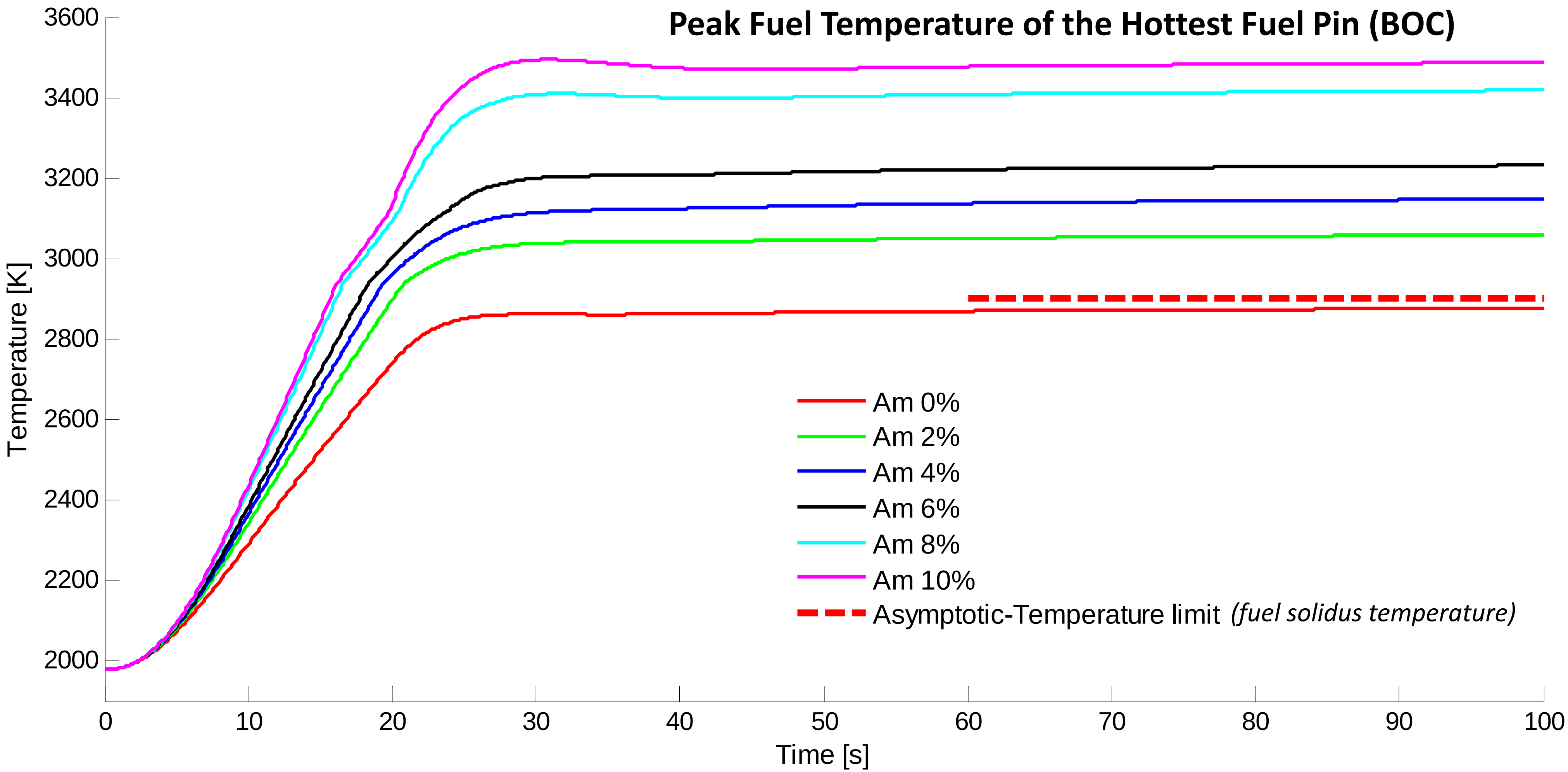


Reactivity as a function of time during ULOF (10% Am, BOC)



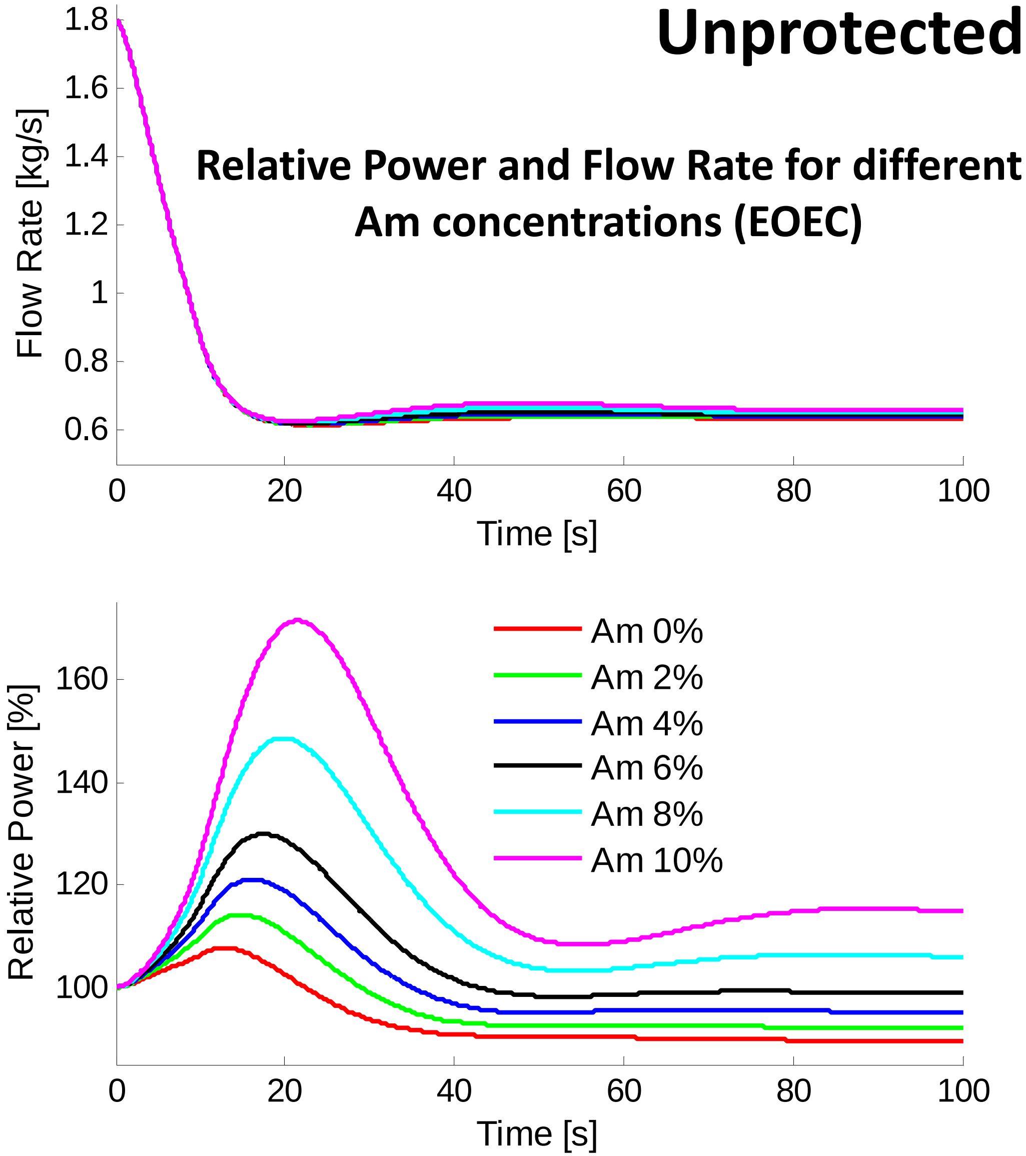
UTOP

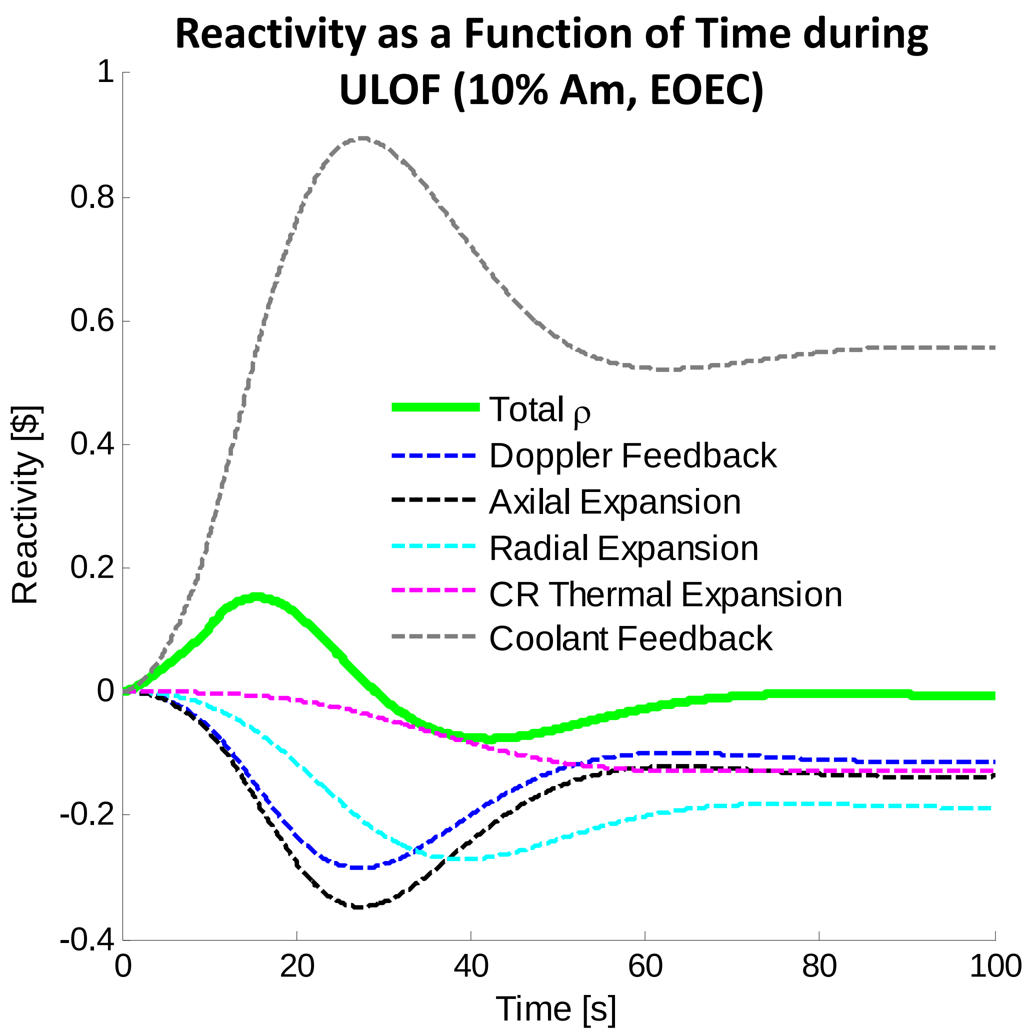
Unprotected Transient Over Power



ULOF

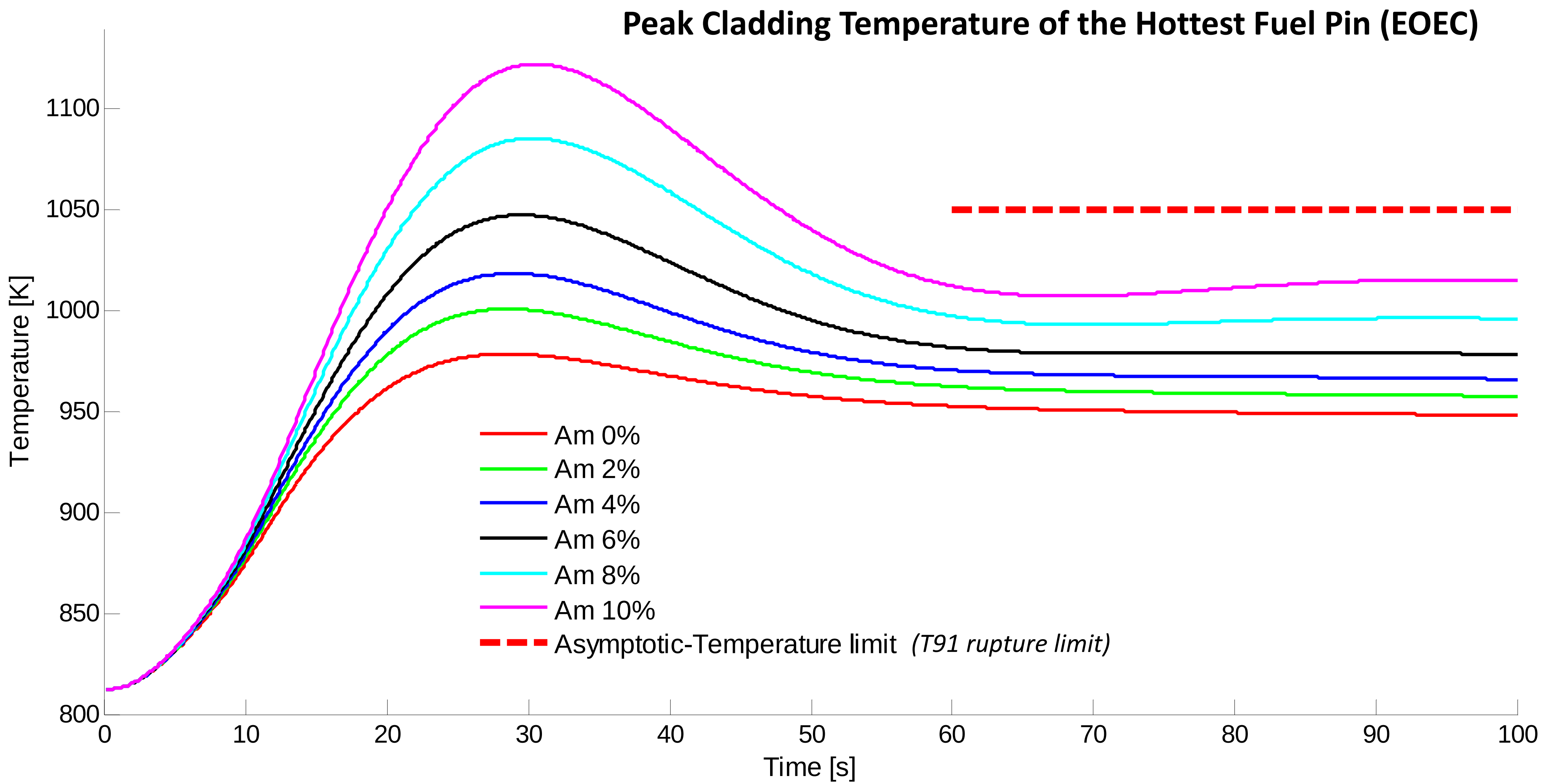
Unprotected Loss of Flow





ULOF

Unprotected Loss of Flow



Conclusions and Outlook

Two transients simulated for the reference ELSY design

UTOP	**ULOF**
Unprotected Transient Over Power	Unprotected Loss of Flow
• Insertion of +1$ within 20 s	• Reduction of flow rate to 30% within 10 s
Am in the core ↓ Fuel temperature above the safety limits	Cladding temperature below safety limits Safety margins?

The reference design of ELSY – not suitable for Am recycling → **Nitride fuel!**

Thank you for your attention