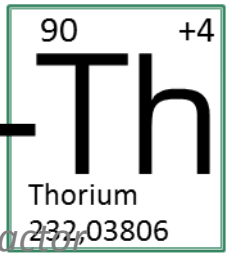
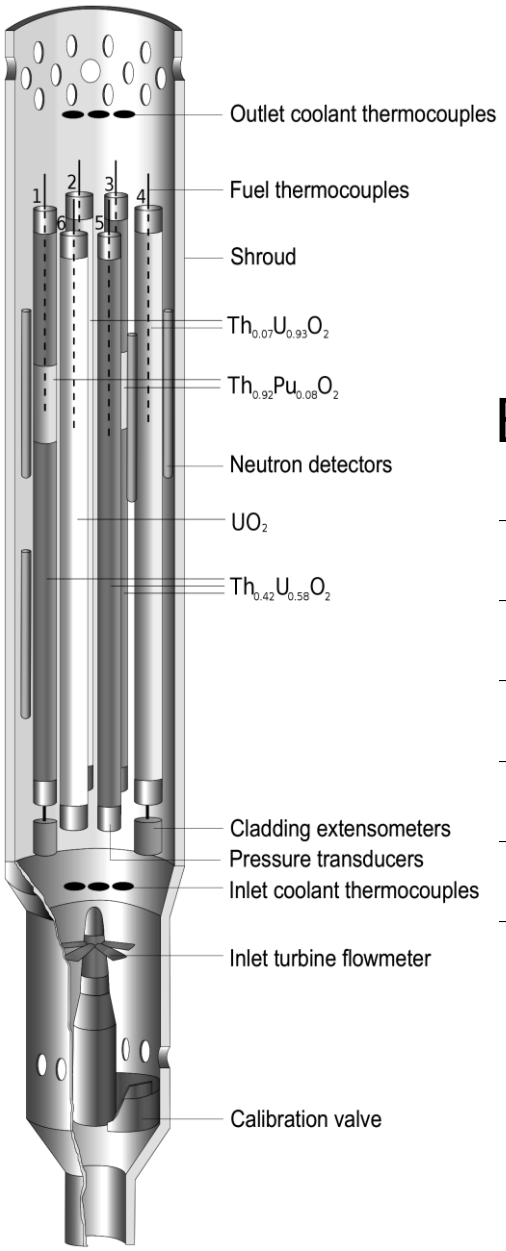
Seven-Thirty



The Thorium Irradiation Campaign in the Halden Reactor

Thor Energy
Scandinavian Advanced Technology



Overview

Testing ceramic (Th,**U/Pu**)O_2 fuel for LWR use.

Experiment producing new & valuable data

- high Pu content for high burnup
- high density
- including some Th-U OX pellets
- flexibly designed experiment
- microstructure dependence
- support to other Th development projects

Thor Energy
Scandinavian Advanced Technology

Why?

To commercialize an attractive new fuel for LWR utilities

Thorium-Plutonium LWR Oxide Fuel

- Power from stockpile Pu
- Thorium energy share
- ThO_2 robust fuel matrix
- 'Familiar' oxide material
- Reactor-operable
- Safety margin benefit
- Optimizable (BU, CR)
- Achievable in forseeable future
- Slot-in to existing LWR infrastructure

Technology development option

HI-CONVERSION Thorium Fuels

using *breeding* potential of Th
(*eg*, RBWRs, PHWRs)

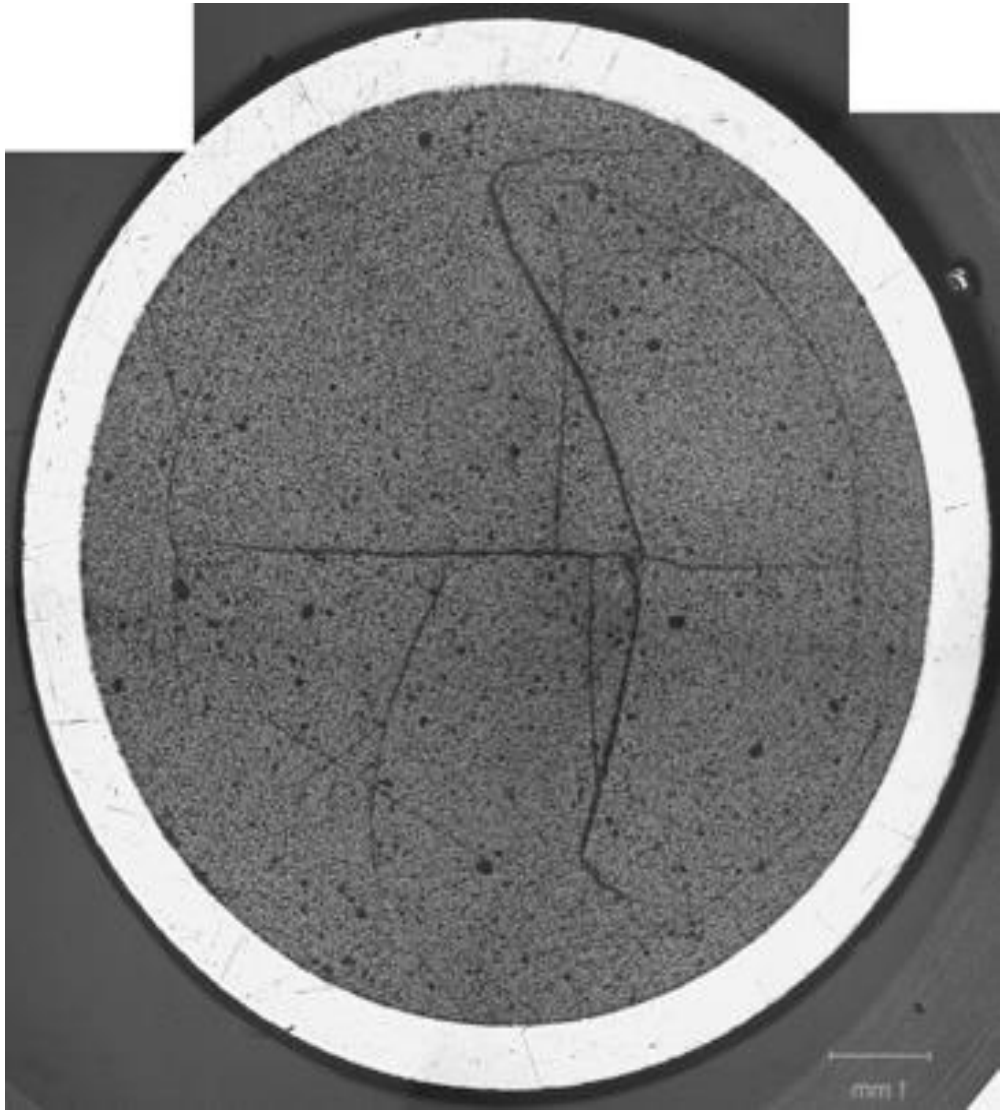
Technology development option

Hi-BURNUP Thorium Fuels

using *matrix* properties of ThO2

eg, deep burn Th fuels, SiC clad option, actinide transmutation focus (2nd gen MOX Pu, WG-Pu, MAs)

Thor Energy
Scandinavian Advanced Technology



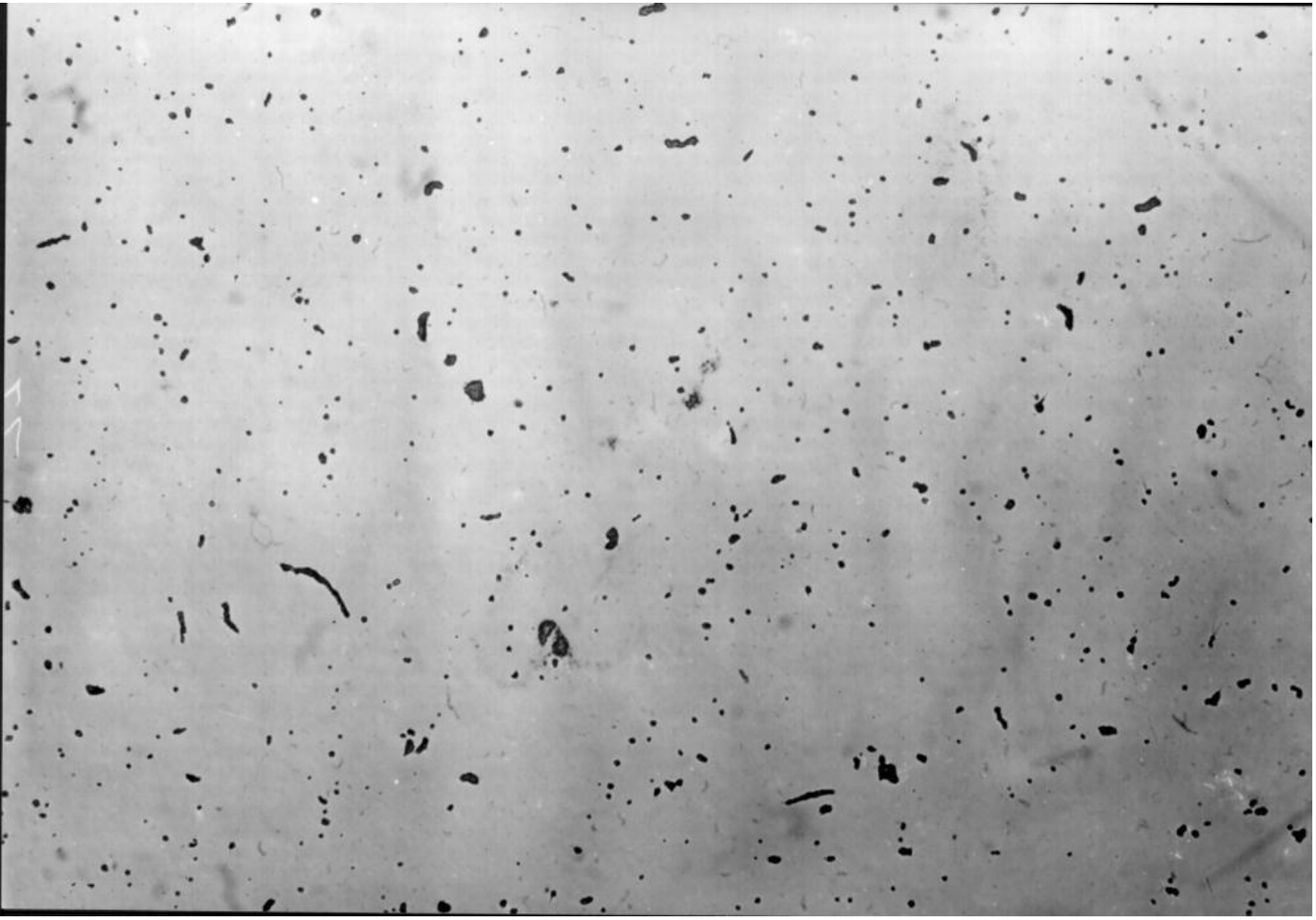
Safety assessment of Plutonium Mixed Oxide Fuel irradiated up to 37.7 GWd/tonne (JNM 2013)

J. Somers1,, D. Papaioannou1, J. McGinley1, D. Sommer2*

1. Joint Research Centre – Institute for Transuranium Elements, Postfach 2340, D76125 Karlsruhe, Germany

2. EnBW Kernkraft GmbH, Postfach 1161, 74843 Obrigheim and Böhmerwaldstraße 15, 74821 Mosbach, Germany*

Thor Energy
Scandinavian Advanced Technology



Safety assessment of Plutonium Mixed Oxide Fuel irradiated up to 37.7 GWd/tonne (JNM 2013)

J. Somers1,, D. Papaioannou1, J. McGinley1, D. Sommer2*

1. Joint Research Centre – Institute for Transuranium Elements

Thor Energy

Scandinavian Advanced Technology

What to Measure?: Fuel Behaviours

Pellet properties evolve as fuel burns – the most important changes to know about are:

- Temperature & Thermal Property Changes
  - temperature, conductivity decrease, expansion, heat capacity
- Fission Gas Release
  - amount, onset and composition
- Mechanical Interactions
  - densification, swelling
- Chemical Interactions
  - SCC, oxygen movement

expect later onset for ThO2, more Iodine, Xe. Less released?

less creep but more swelling for ThO2 – characterize re solid/gas FPs

Oxygen-FP behaviour different in ThO2
I yield higher (released?)

- ultimately, will cladding integrity be challenged?

Thor Energy
Scandinavian Advanced Technology

What is Achieved?: So Far

A fuel testing campaign requires a lot of preparatory work

Pellet Procurement

- Difficult, due to Pu. Three types of (Th,Pu)O_2 ceramic ... v good news
- Contingency & compromise
- Fabrication of 'Phase 1a' material underway in Norway

Technical

- Rig design & manufacture complete
- Instrumentation – rig shuffling

Irradiating & Collecting Data

- On-line readings....
- Info derived from scrams

Phase 1B Fuel Manufacture:

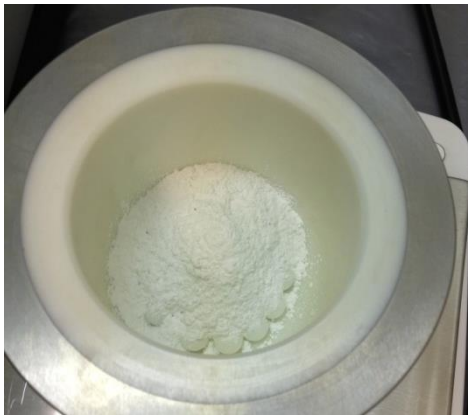
Equipment commissioning:
- Mill
- Press
- Furnace

Thor Energy
Scandinavian Advanced Technology

Phase 1B Fuel Manufacture:

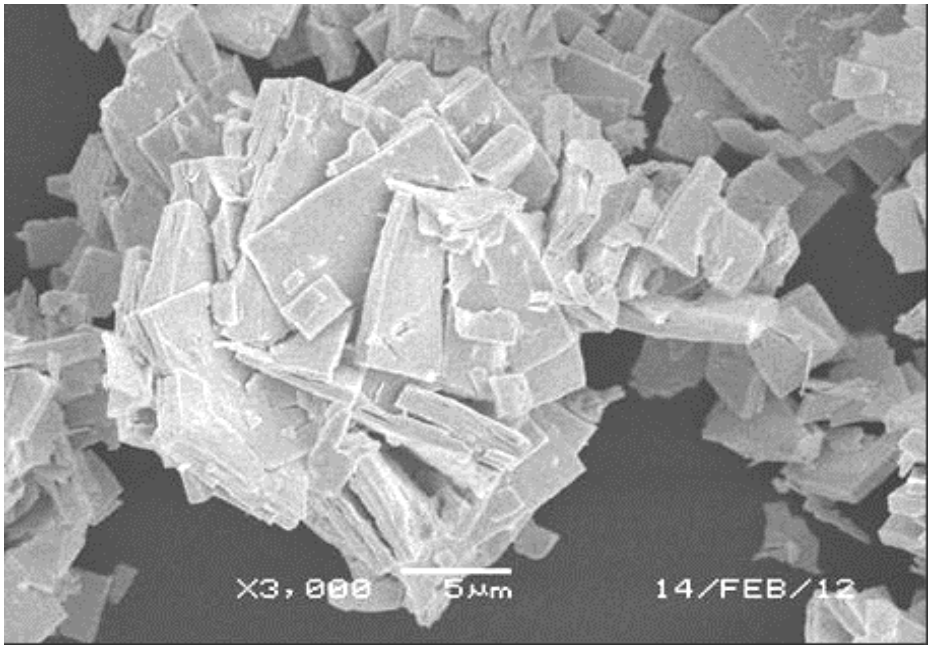
Equipment commissioning:
- Mill
- Press
- Furnace

Thor Energ
Scandinavian Advanced Technology



Phase 1B Fuel Manufacture:

Equipment commissioning:
- Mill
- Press
- Furnace

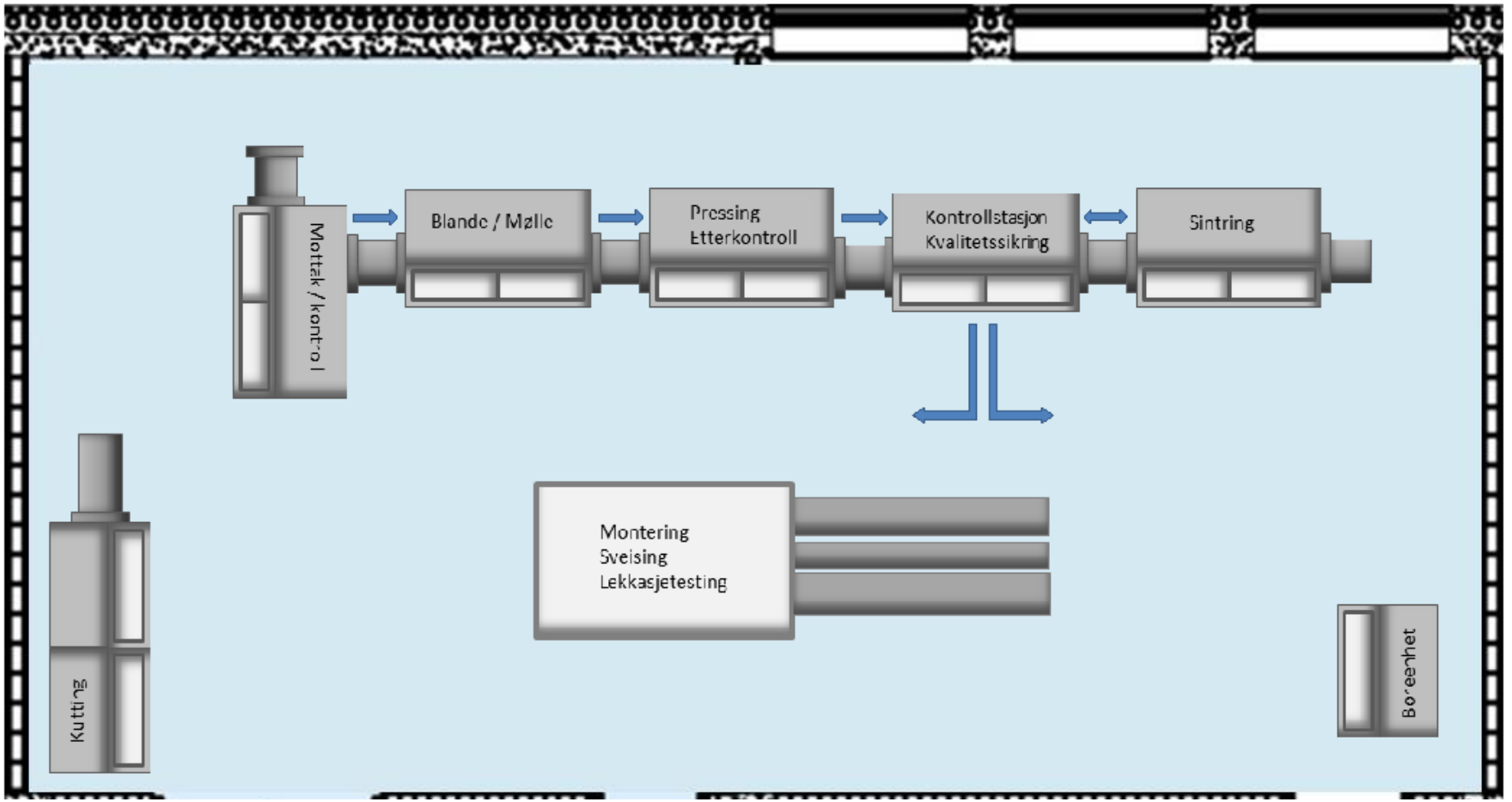


Thor Energy
Scandinavian Advanced Technology

The Thor Energy Alpha Lab

Pellet Manufacturing Phase 1b

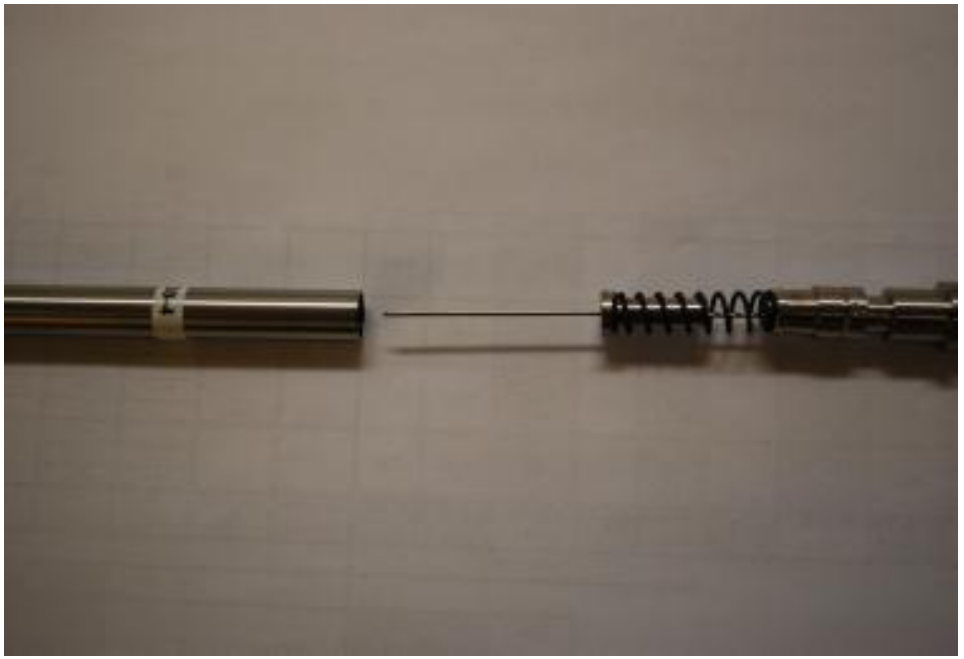
PuO_2ThO_2 Pellets

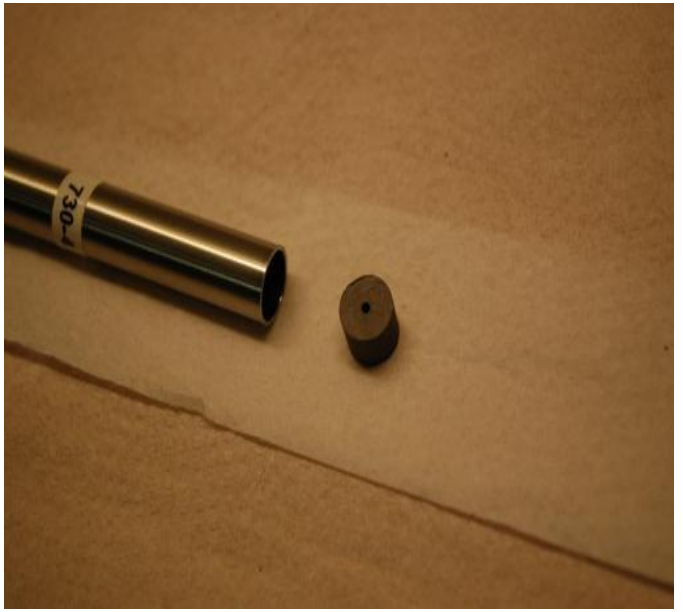


Thor Energy
Scandinavian Advanced Technology

IFE Seven-Thirty

90 +4
Thorium
232,03806





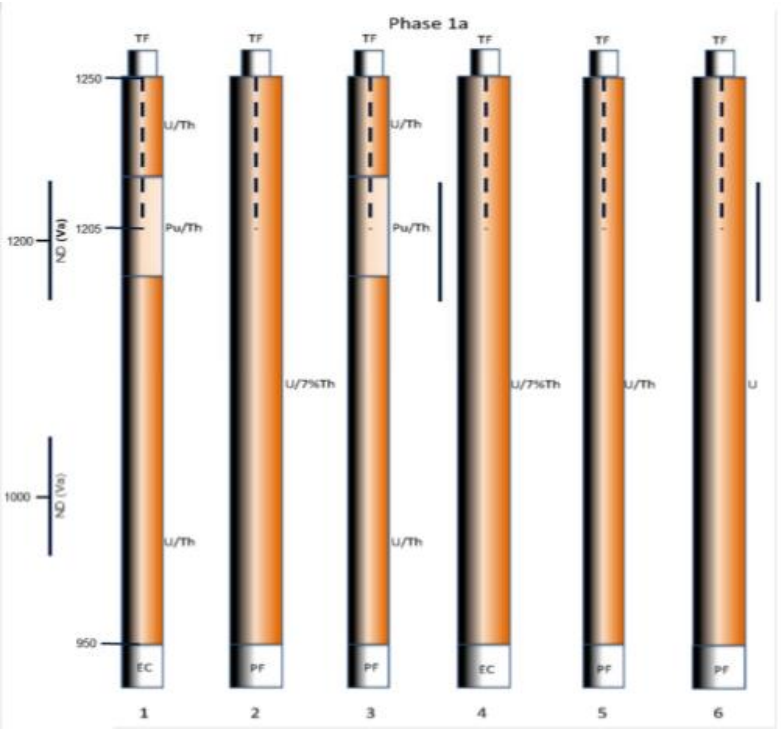
Thor Energy
Scandinavian Advanced Technology

Seven-Thirty
90 +4
Thorium
232,03806

Thor Energy
Scandinavian Advanced Technology

IFA-730 Test matrix

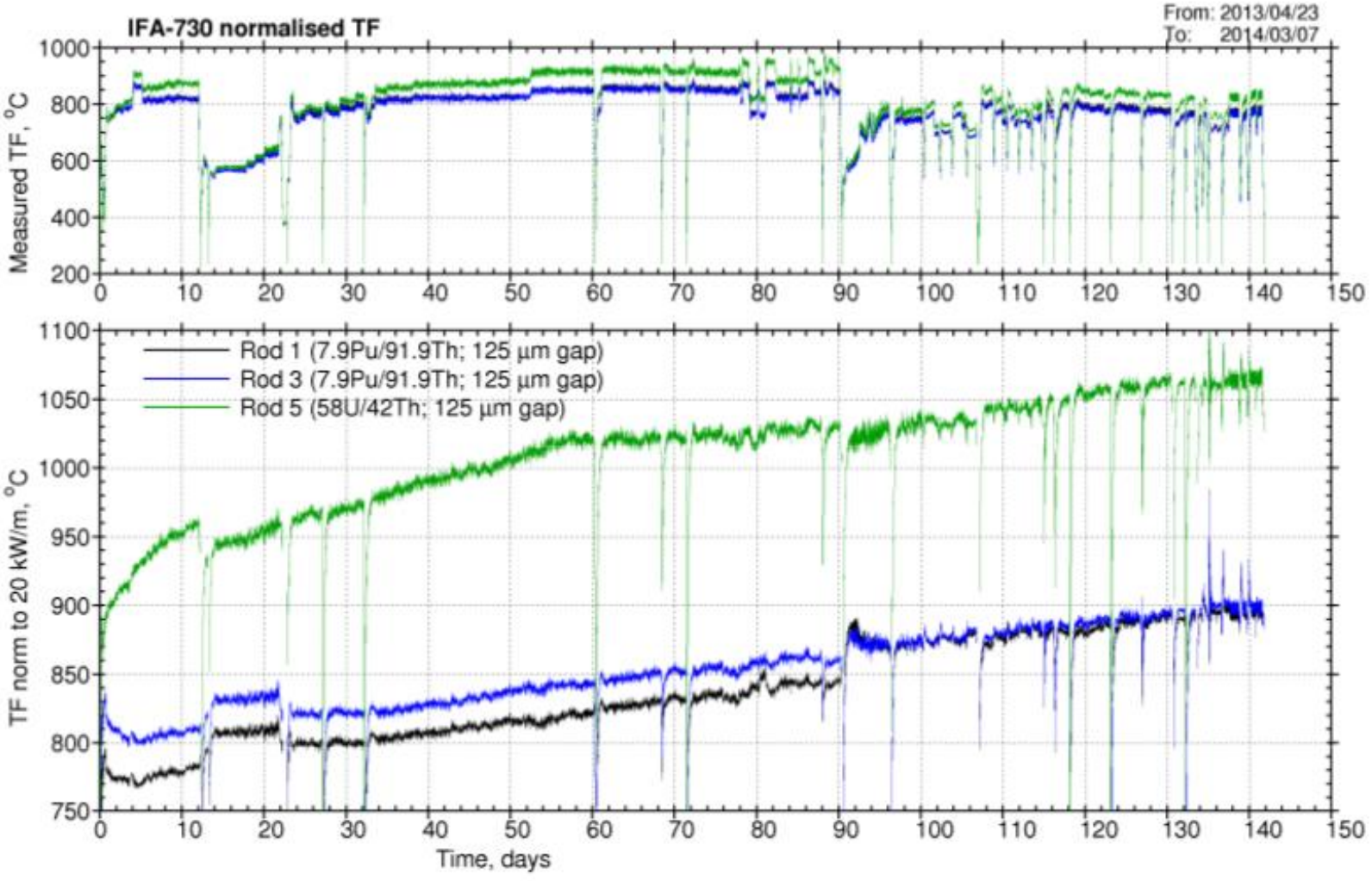
Rod ID	730-1	730-2	730-3	730-4	730-5	730-6
Fuel	58% U / 42% Th 8% Pu / 92%Th (OMICO pellets)	93% U / 7% Th	58% U / 42% Th 8% Pu / 92%Th (OMICO pellets)	93% U / 7% Th	58% U / 42% Th	UO_2
Pellet OD [mm]	5.90	8.48	5.90	8.48	5.90	8.48
Diam. gap [μm]	125	150	125	150	125	150
Instr.	TF*) / EC	TF1) / PF	TF*) / PF	TF / EC	TF / PF2)	TF / PF3)
Power [kW/m]	20	32	20	30	20	32
Burnup [MWd/Ox]	9.8	6.8	9.6	6.7	9.6	6.8



Thor Energy
Scandinavian Advanced Technology

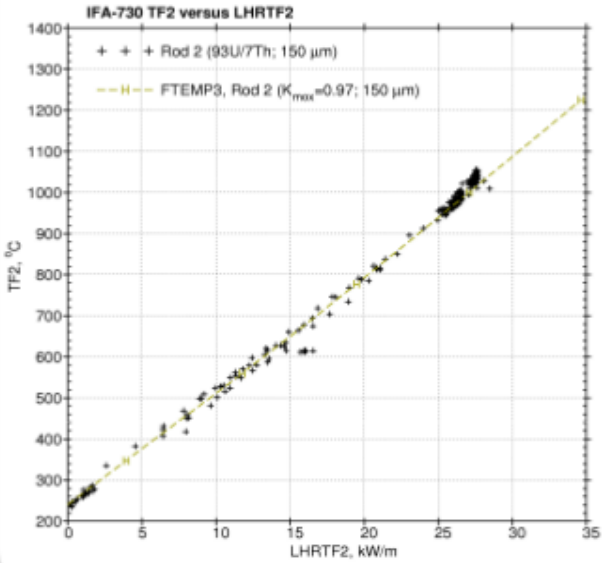
Seven-Thirty
90 +4
Thorium
232,03806

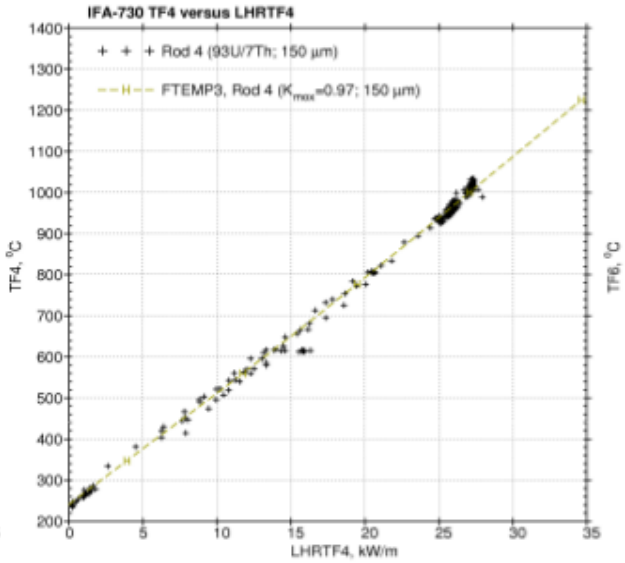
IFA-730 Normalised temperature 2/2

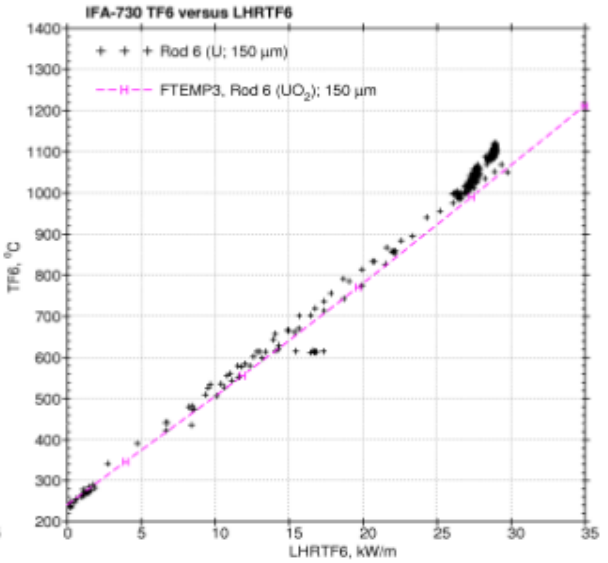


IFA-730 Results: Fuel temperature

- Comparison with temperature calculations, start-up data: large diameter rods
  - In general good agreement between measured temperature and calculations
  - Temperature in Th fuel slightly lower than reference UO_2 fuel

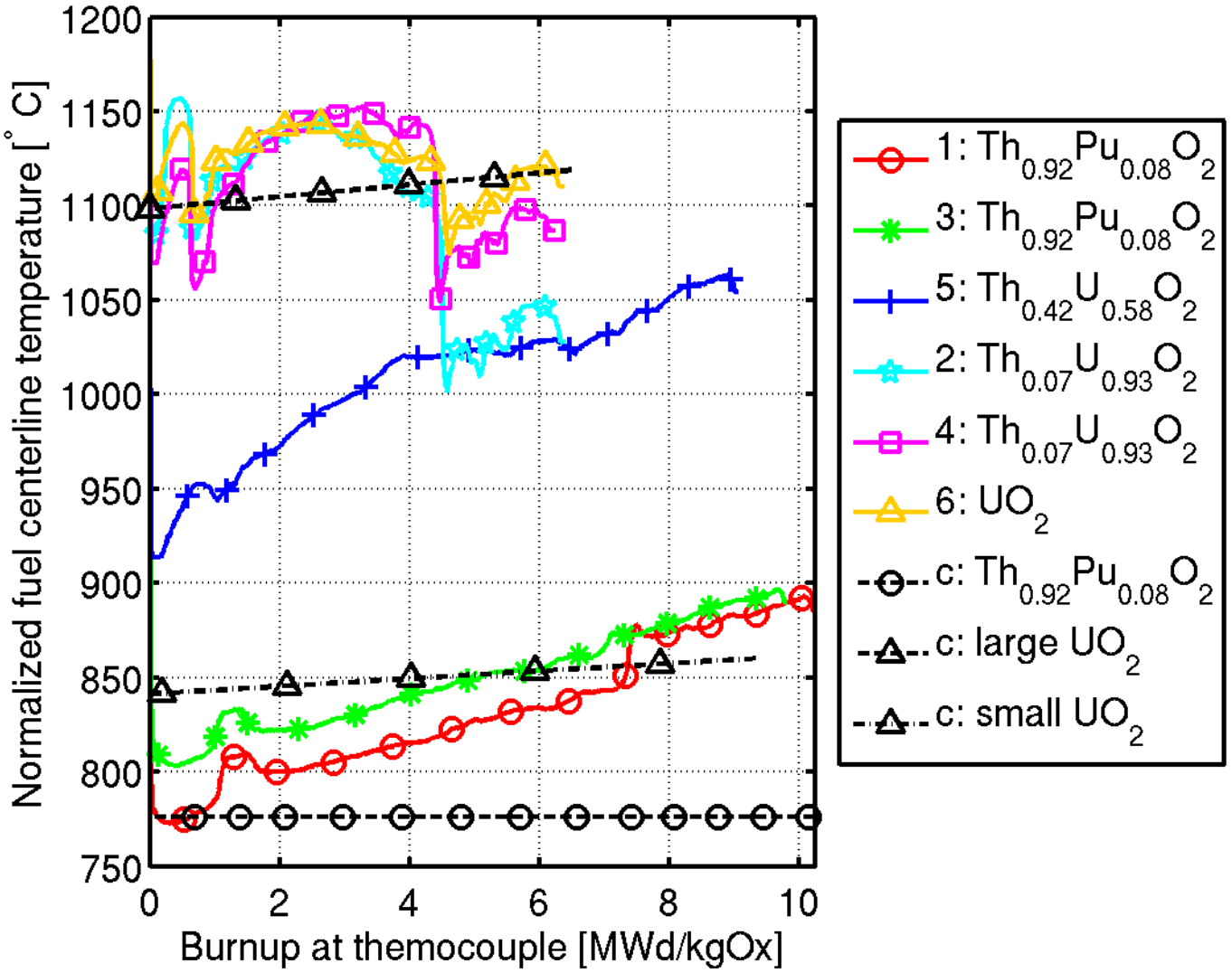






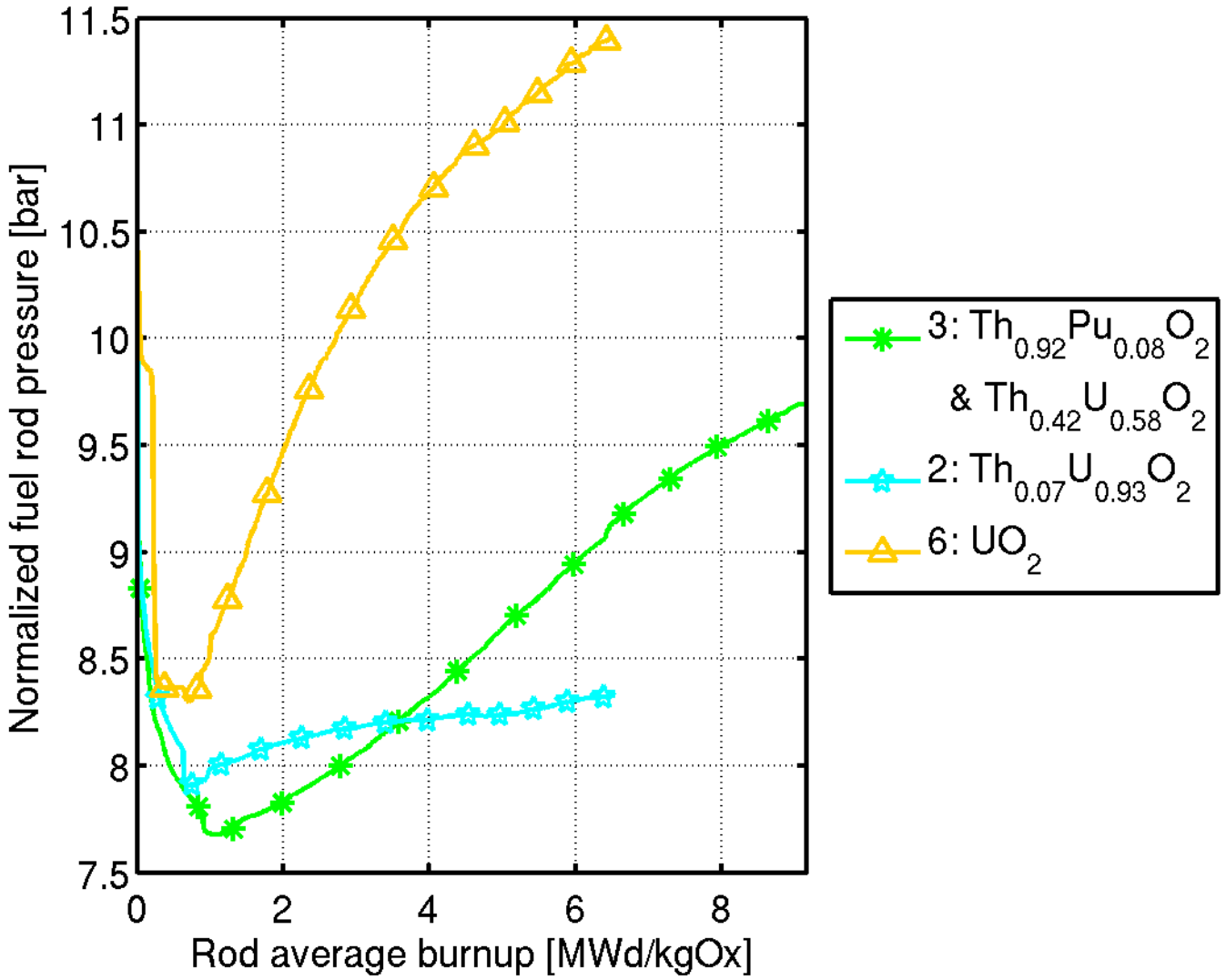
Thor Energy
Scandinavian Advanced Technology

Seven-Thirty
90 +4
Thorium
232,03806



Thor Energy
Scandinavian Advanced Technology

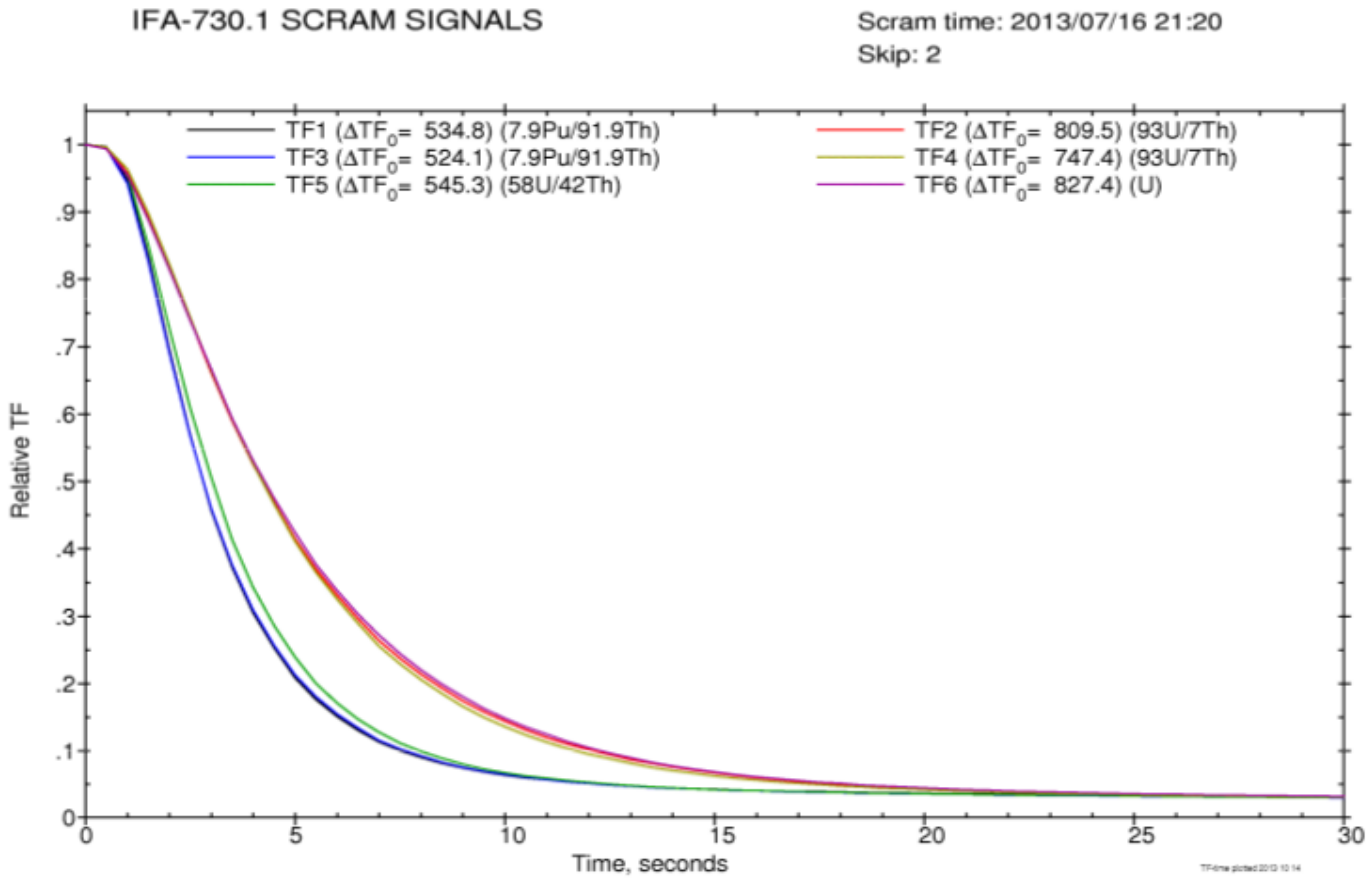
Seven-Thirty
90 +4
Thorium
232,03806



Thor Energy
Scandinavian Advanced Technology

Seven-Thirty
90 +4
Thorium
232,03806

Relative temperature during scram



Thor Energy
Scandinavian Advanced Technology

Seven-Thirty
90 +4
Thorium
232,03806

IFA-730.1 Summary 1/2

- Rig operated since 28.04.2013
  - Power kept at ~30 kW/m for large diam. rods
    ~20 kW/m for small diam. rods
- Collection of irradiation data on
  - **Fuel centre temperature** **Fuel thermal conductivity**
  - Rod pressure Fuel dimensional stability and fission gas release
  - Cladding elongation Pellet-cladding mechanical interaction (fuel dimensional stability)
- Continued operation planned at current power levels

Thor Energy Alpha Fuel Manufacturing Lab

Enables production of advanced, Pu-based fuels

Plans for advanced pellet work for 2015 onwards

Thor Energy

Scandinavian Advanced Technology