Tungsten Oxidation AeroSol Transport
TOAST

for HPTW-7

Per Nilsson, ESS
Anders Gudmundsson, Jens Klingmann, Karin Lovén, Lund University

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Contributions

LTH Energy Sciences	Laboratory, Manufacturing, Temperature measurements, Seeding, Project management, etc Prof. Jens Klingmann, Martin Carlsson
LTH Ergonomics and Aerosol Technology	Aerosol measurements Prof. Anders Gudmundsson, Karin Lovén, Louise Gren
LTH Production and Materials Engineering	Inductive heating Adj. Prof. Tord Cedell, Fredrik Lundström, Ville Akujärvi
ESS Bilbao	Tungsten samples

Outline

- Background
  Accident scenario
- Experiments
  Setup
  Results
- Implications
- Lessons learned
- Open issues

Background

ESS Target

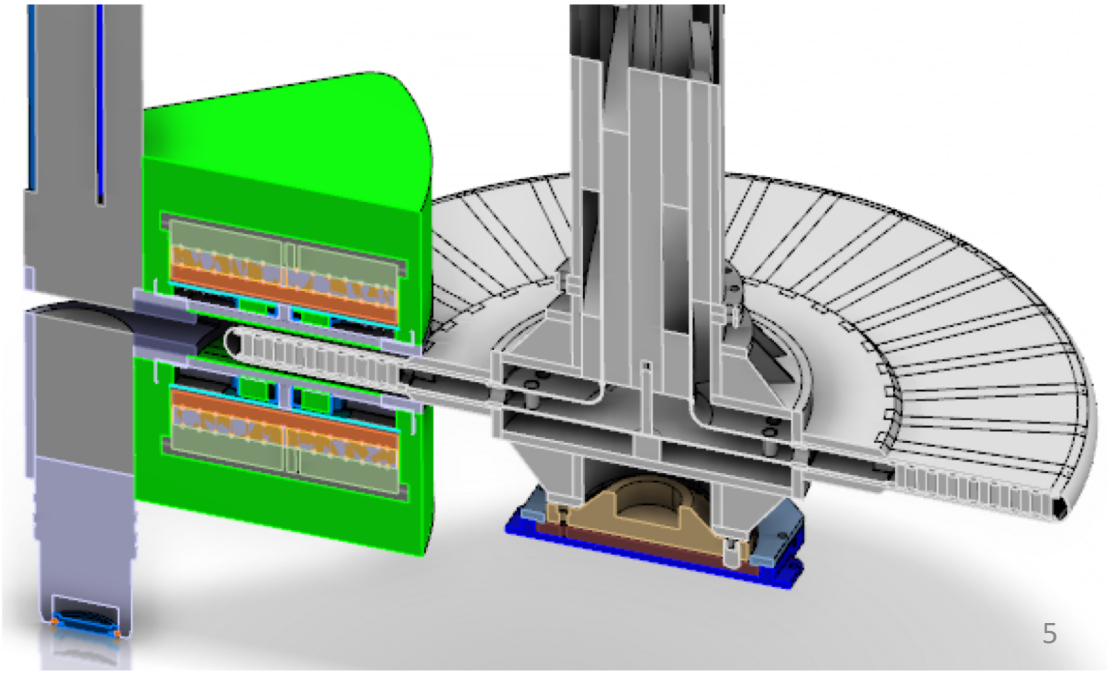
P_{mean} = 5 MW

f = 14 Hz

ΔT_{max}/pulse = 100 °C

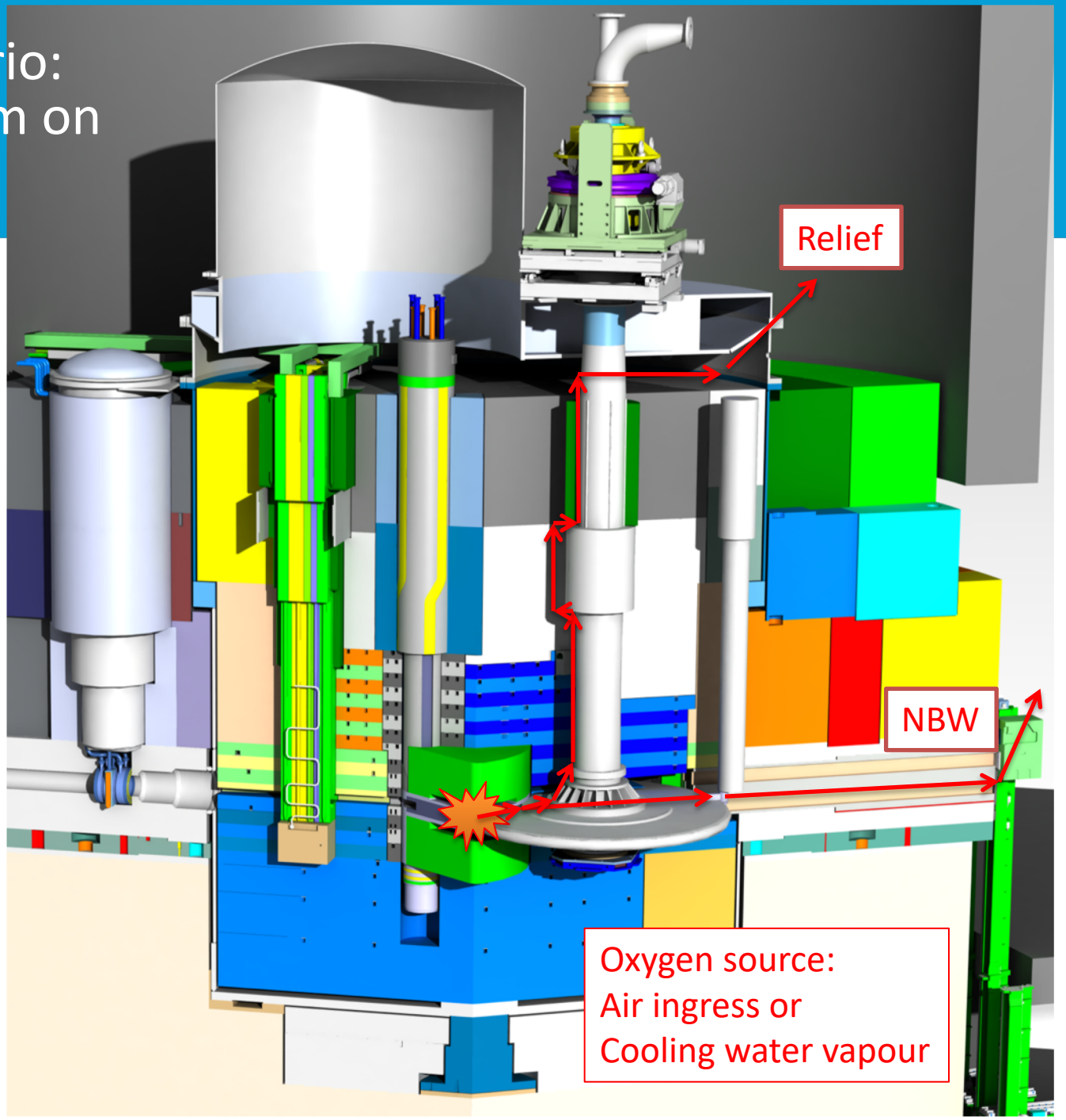
36 sectors

=> 2300 °C / min



Postulated scenario: Lost cooling, beam on No safety system

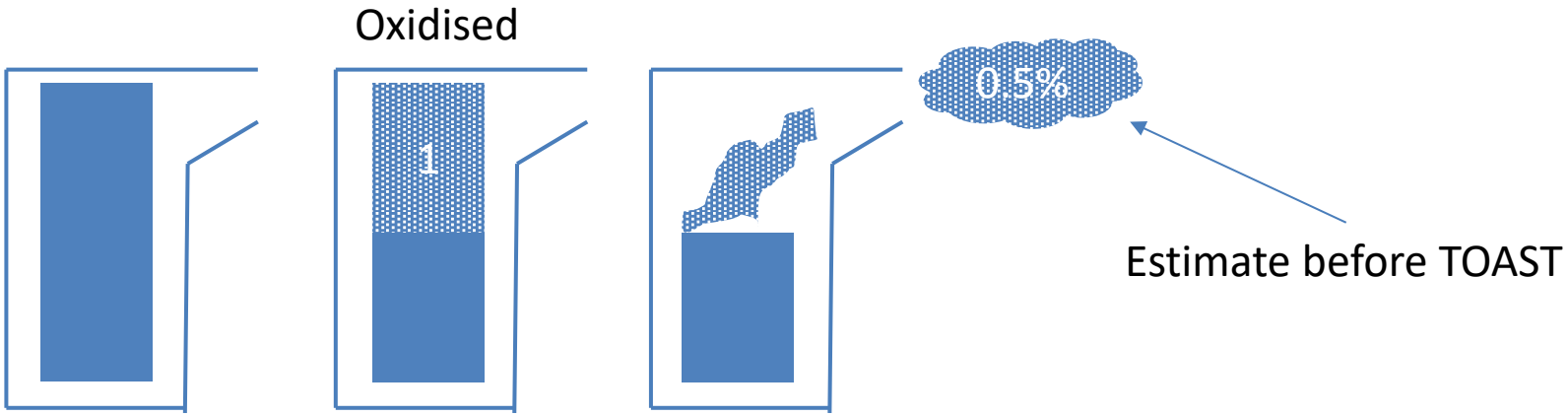
1. Cooling lost
2. Temp increases
   Target opens
   He coolant lost
3. Pressure breaks
   monolith vessel
   confinement
4. Moderator water
   released & evaporates
5. Tungsten exposed
   Oxidises and release
6. Loss of PBW cooling
   -> Failure, beam stop



Experiment Scope

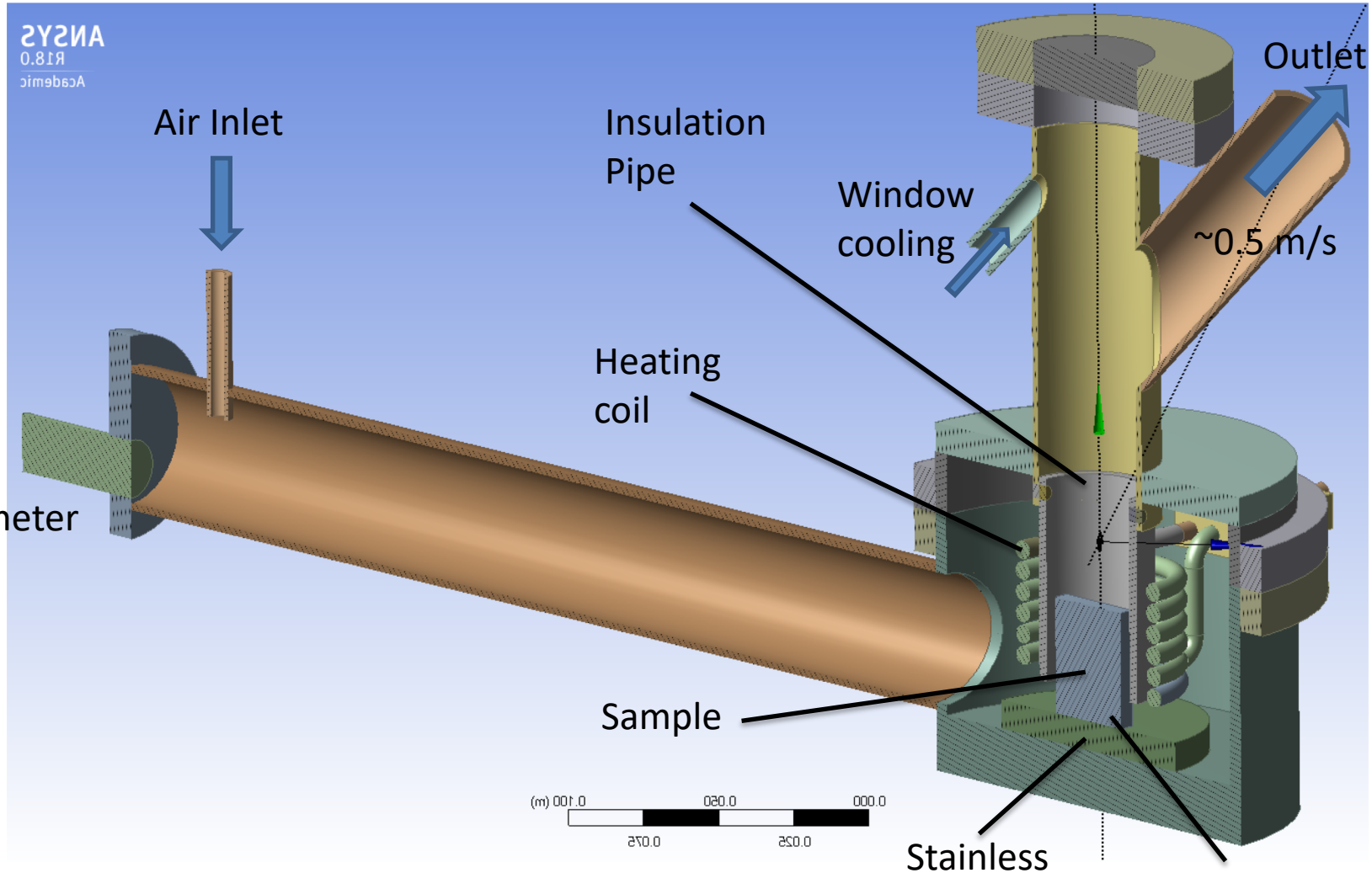
- How much tungsten becomes airborne by tungsten oxidation at high temperatures, > 1400 C?

- Measure Airborne Release Fraction, ARF
  = mass fraction of the *oxidised* amount that is airborne after passage through the system

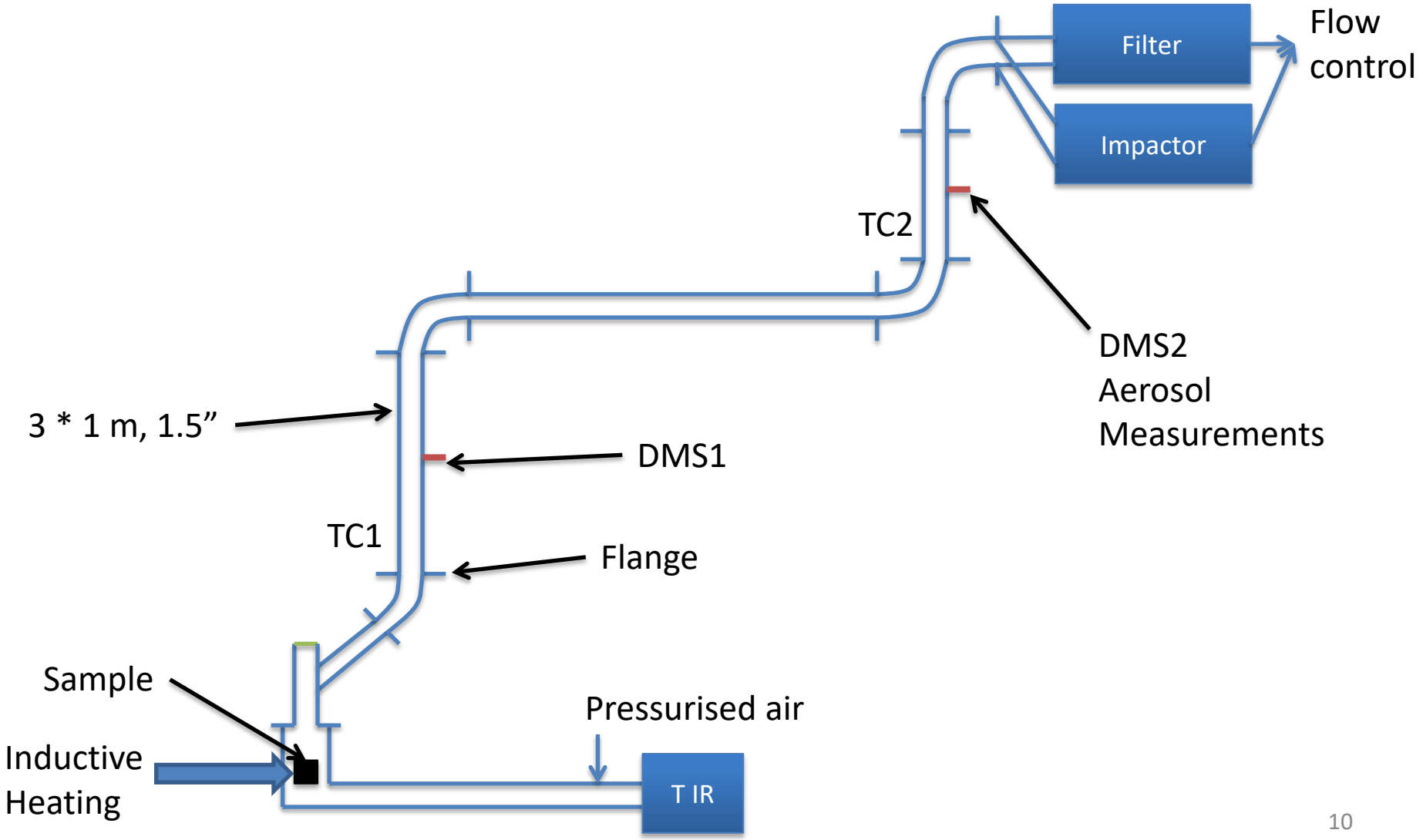


Experiment Setup

Vessel configuration

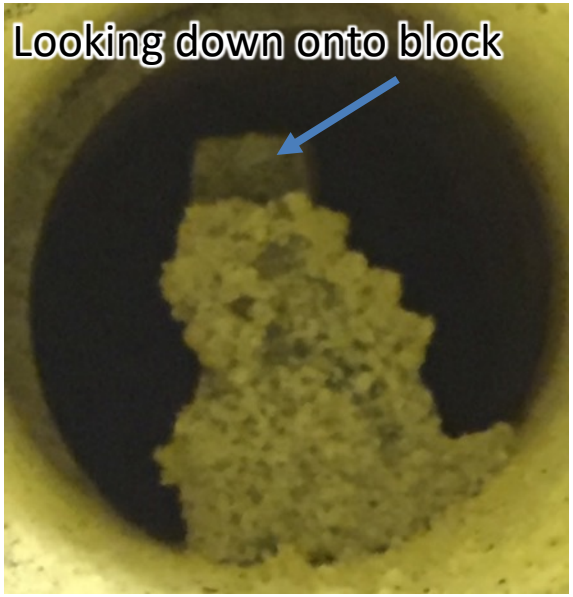


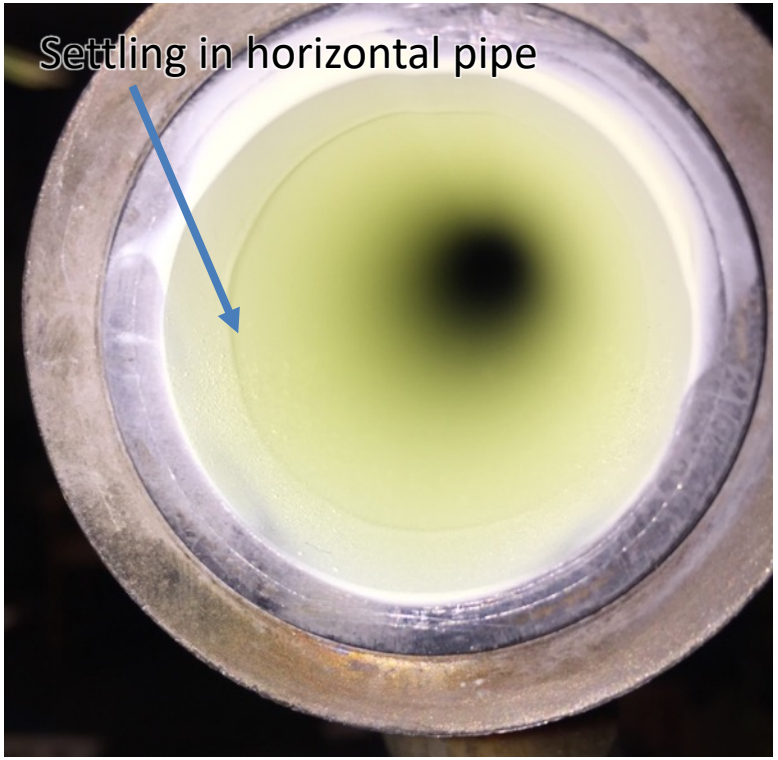
TOAST setup

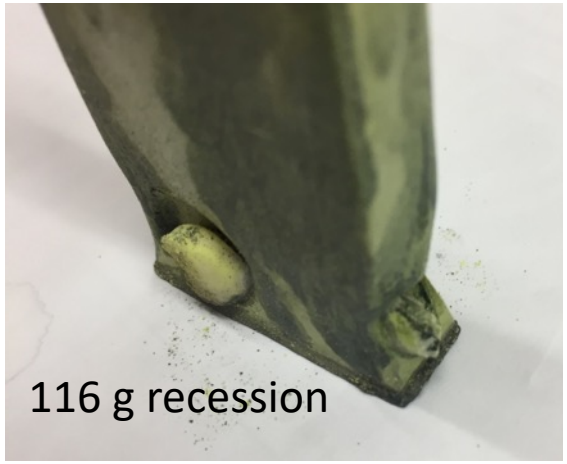

Filter
Impactor
Flow control
TC2
DMS2
Aerosol
Measurements
3 * 1 m, 1.5”
DMS1
TC1
Flange
Sample
Pressurised air
Inductive
Heating
T IR

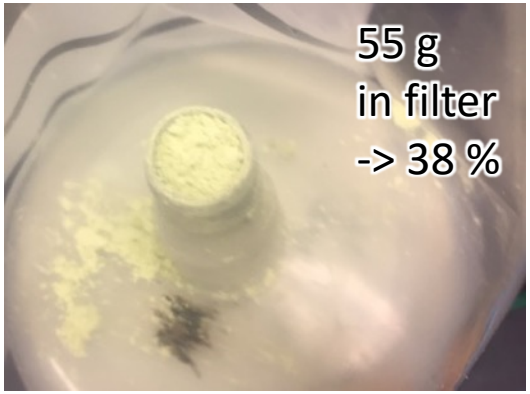
Experimental Results

After Test 11 (~1700 C)



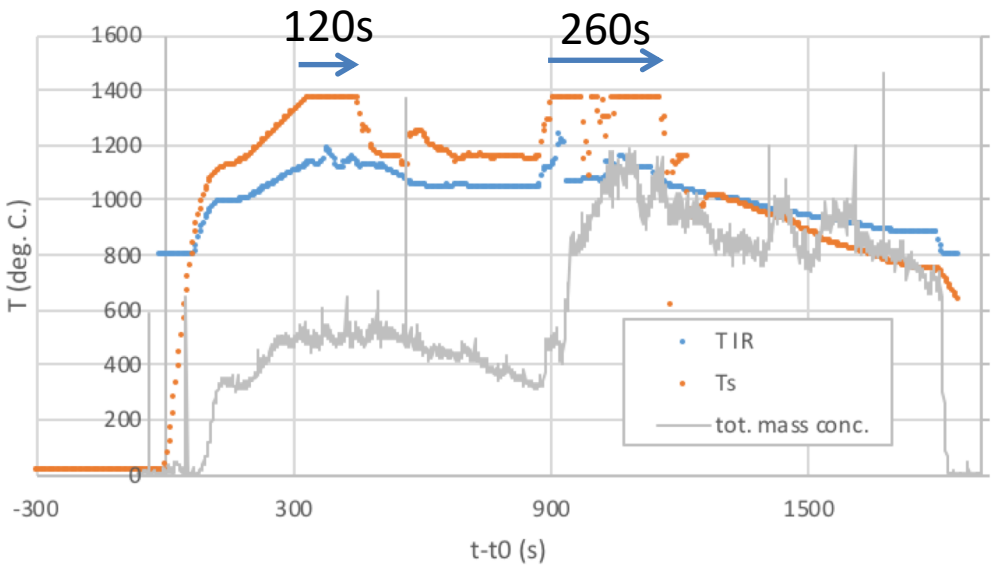


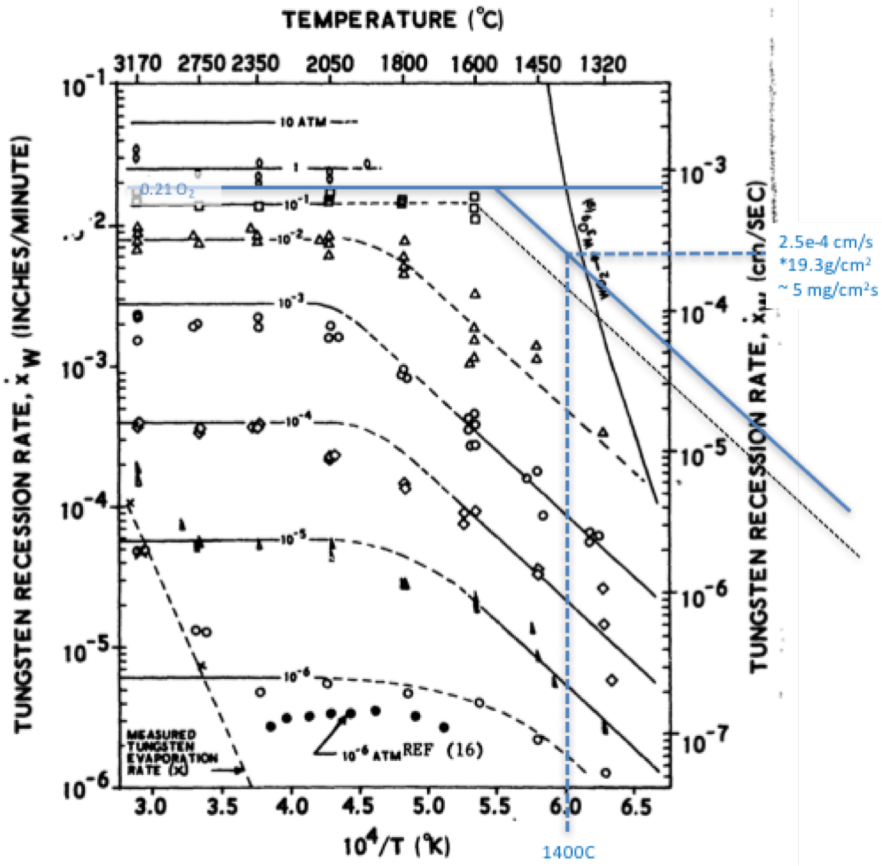




ARF up to 0.46

Comparing recession to literature (Test 3)



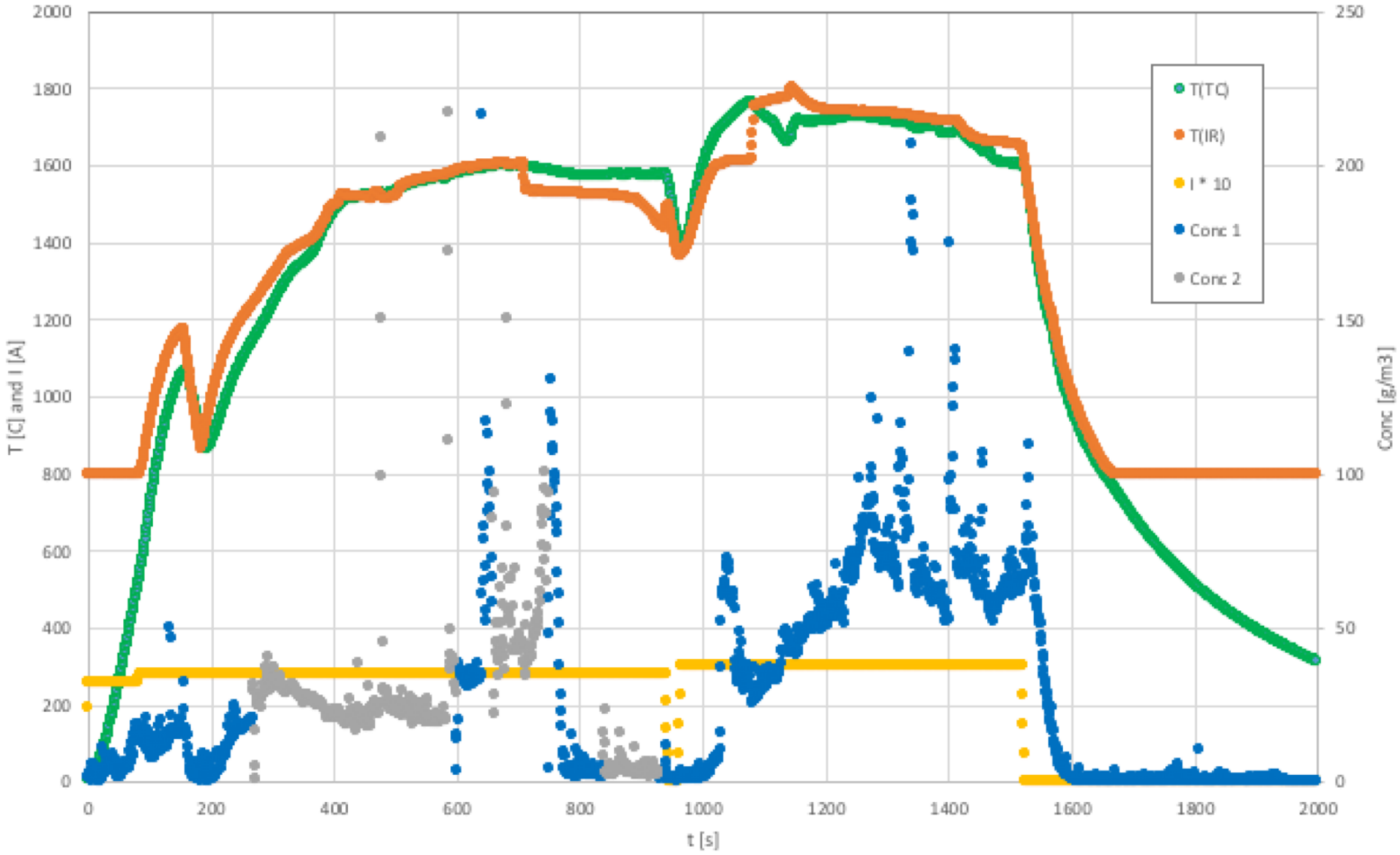


Bartlett, R. W., Tungsten and Molybdenum Oxidation Kinetics at Extremely High Temperatures, US Air Force, ML-TDR-64-290, 1964.

(120 s + 260 s) * 5 mg/cm^{2}s * 35 cm^2 ~ 66 g ⟺ (74 g measured)

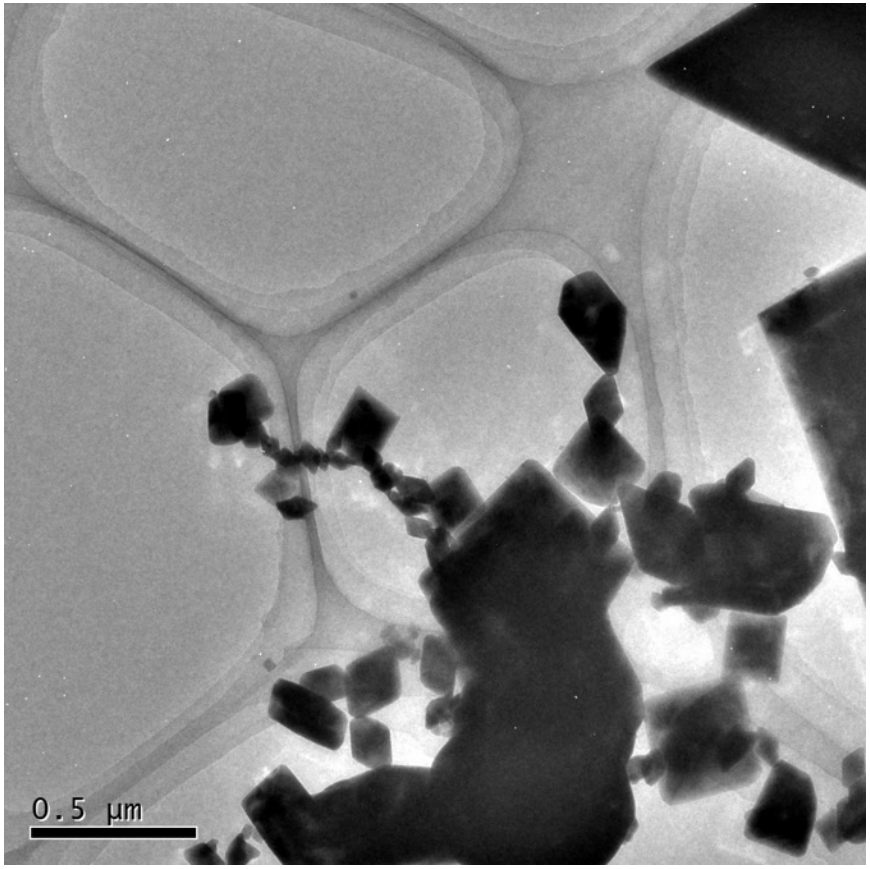
Measurements Test 11

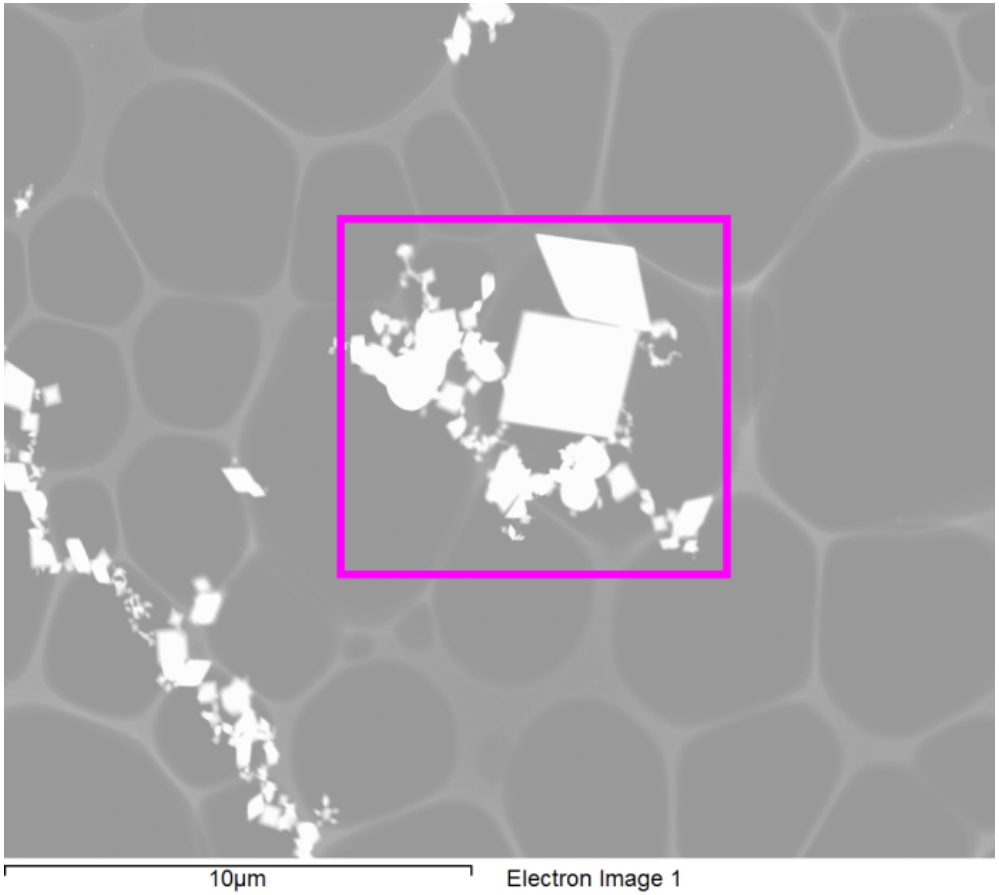
Temperature and particle concentration



Saturation, rarely above 100 g/m^3

Transmission Electron Microscopy (Test 13)





Agglomerates of crystal primary particles
Far from spherical

Implications

Implications in accident analysis

Higher ARFs (from 0.005 to 0.5), gave high doses

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Necessary to remove unnecessary concervatism, e.g.:
- Avoid high temperatures
- Decrease available oxidant
- Limit transport path

Implications in licensing process

- Notified regulators (SSM) immediately
- Delayed decisions on emergency planning
- Continuous updates
- SSM approved source terms for emergency planning

Lessons learned

Lessons learned

- Numerous in technical details
  Steam may e.g. condense

- Do not extrapolate, use experiments at relevant conditions:
  We did, but drew preliminary conclusions to early

- Openness is crucial but difficult:
  The findings may seem alarming, but are results of systematic work and do finally not have major implications.
  This is delicate to communicate during the work, internally as well as externally.

Open issues

Under investigation

- Particle sizes and agglomeration
- Deposition
- Saturation

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Model for application in transport

Questions?

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The End