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

\[ P_{\text{mean}} = 5 \text{ MW} \]
\[ f = 14 \text{ Hz} \]
\[ \Delta T_{\text{max}/\text{pulse}} = 100 \text{ °C} \]

36 sectors

\[ \Rightarrow 2300 \text{ °C} / \text{min} \]
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

Oxygen source: Air ingress or Cooling water vapour
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

Estimate before TOAST
Experiment Setup
Vessel configuration

- Air Inlet
- Insulation Pipe
- Window cooling
- Heating coil
- Sample
- Stainless Sacrifice
- Thermocouple
- Outlet
- IR thermometer
- ~0.5 m/s
TOAST setup

- Pressurised air
- Flange
- Sample
- 3 * 1 m, 1.5"
- TC1
- DMS1
- TC2
- Flange
- DMS2 Aerosol Measurements
- Impactor
- Filter
- Flow control
- Inductive Heating
- Sample
- Pressurised air
- T IR
Experimental Results
After Test 11 (~1700 C)

Looking down onto block

30 g in vessel

Settling in horizontal pipe

116 g recession

55 g in filter -> 38 %

ARF up to 0.46
Comparing recession to literature (Test 3)

(120 s + 260 s) * 5 mg/cm²s * 35 cm² ~ 66 g  ➔  (74 g measured)

Saturation, rarely above 100 g/m³
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 conservatism, 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?
The End