

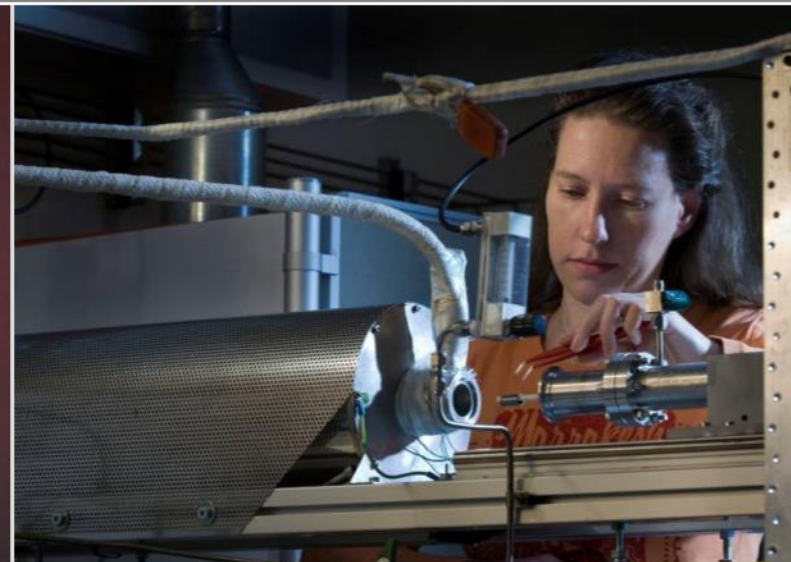
Potential KIT contributions to ATF research

Martin Steinbrück

Second Meeting on Increased Accident Tolerance of Fuels for LWRs

28-29 October 2013, OECD-NEA Headquarters, Issy-les-Moulineaux, France

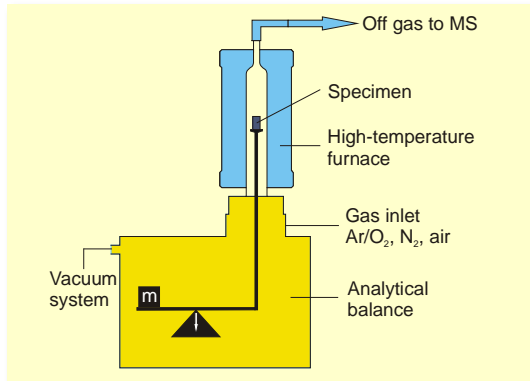
Institute for Applied Materials IAM-AWP & Program NUKLEAR



Outline

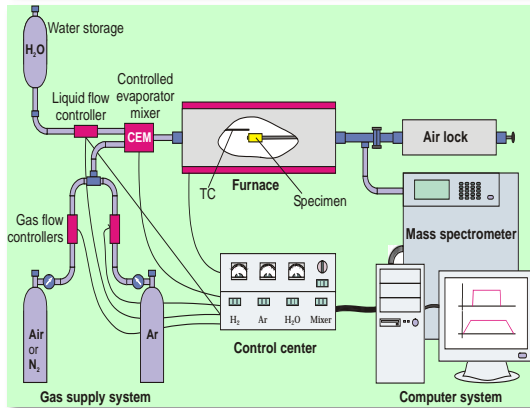
- Experimental infrastructure
- Current work on high-temperature oxidation of SiC materials
- Potential KIT contributions

Separate-effects tests: Main setups



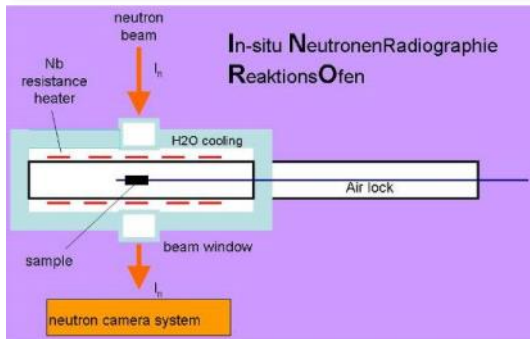
Thermobalance

1600 °C
1250 °C (steam)
Specimens: 0-2 cm
MS coupling



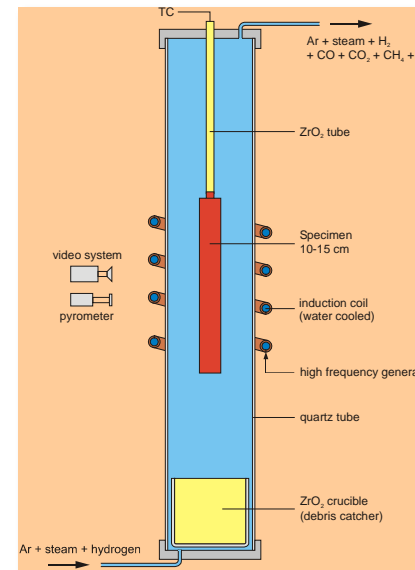
BOX Facility

1700 °C
Oxidising, reducing atmosphere (incl. steam)
Specimens: 1-2 cm
MS coupling



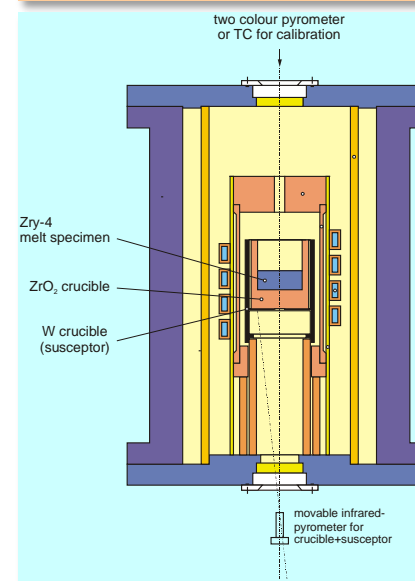
INRRO Facility

1500°C
Specimens: 1-2 cm
Transparent for neutrons



QUENCH-SR Rig

2000 °C
Induction heating
Oxidising, reducing atmosphere (incl. steam)
Specimens: 15 cm
MS coupling



LAVA Furnace

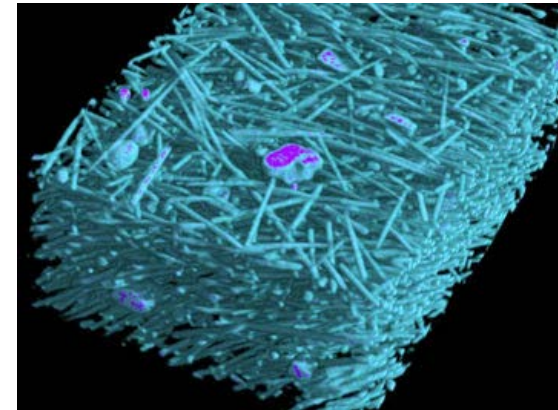
2300 °C
Induction heating
Inert, reducing atmosphere
Specimens: 1-2 cm
MS coupling

X-Ray and neutron radiography/tomography

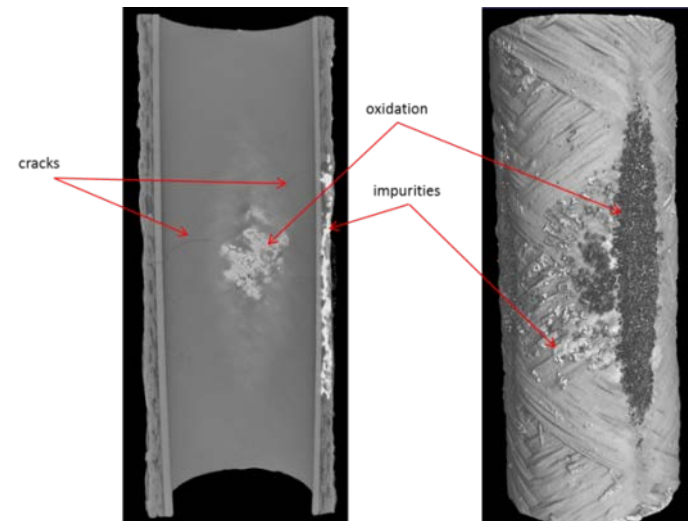


GE phoenix v|tome|x s

- For 2D X-ray inspection and 3D computed tomography
- Max. sample size: 200 x 150 mm
- Resolution down to 1 μm



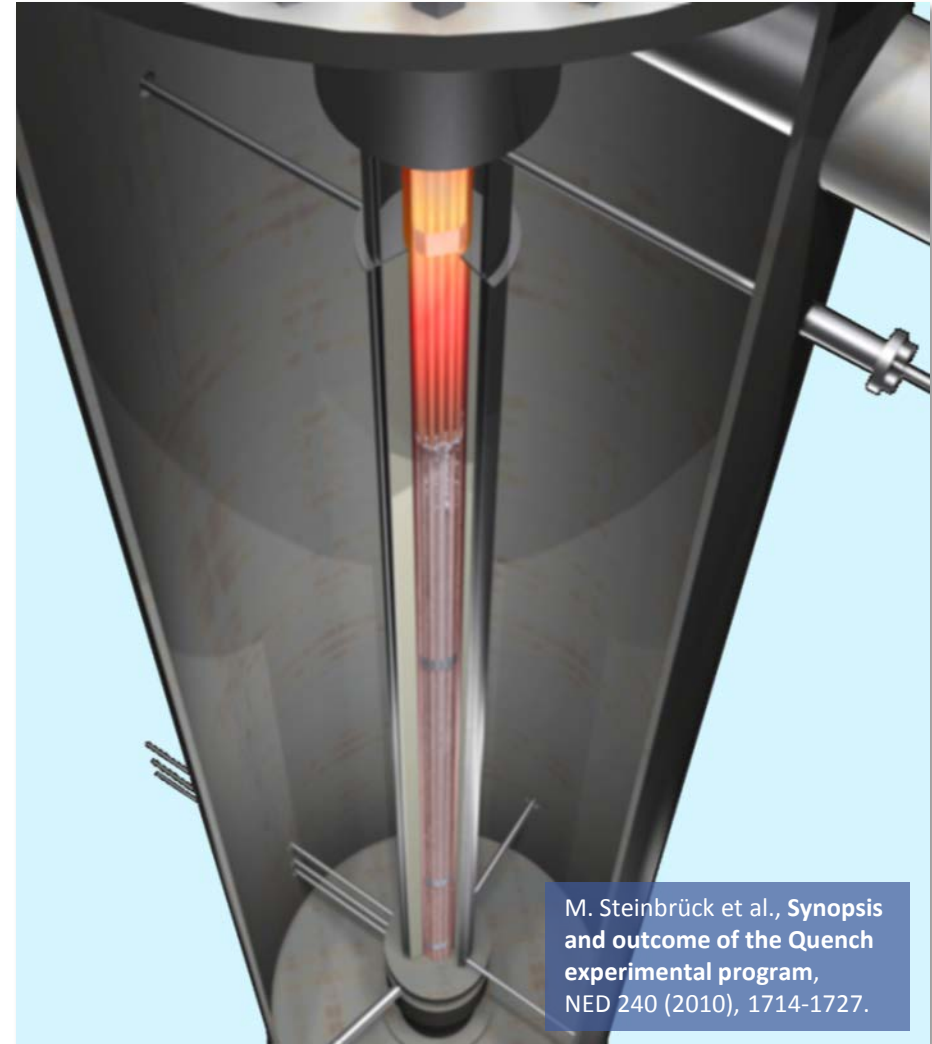
glass fiber-reinforced plastic



SiC/SiCf cladding

QUENCH Facility

- Unique out-of-pile bundle facility to investigate reflood of an overheated reactor core
- 21-31 electrically heated fuel rod simulators; T up to $>2000^{\circ}\text{C}$
- Extensive instrumentation for T, p, flow rates, level, etc.
- So far, 17 experiments on SA performed (1996-today)
 - Influence of pre-oxidation, initial temperature, flooding rate
 - B_4C , Ag-In-Cd control rods
 - Air ingress
 - Advanced cladding alloys
- DBA LOCA experiments with separately pressurized fuel rods



M. Steinbrück et al., *Synopsis and outcome of the Quench experimental program*, NED 240 (2010), 1714-1727.

High-temperature oxidation of SiC materials

- PhD thesis started 04/2012 “**High temperature oxidation in corrosive atmospheres and quenching of silicon carbide**”
- Partner of the EC MatISSE program
- Materials:
 - Commercial α -SiC cylindrical samples (ESK Ekasic F-plus)
 - SiC-SiC triplex cladding tubes provided by CEA and CTP
- Atmospheres:
 - Argon-oxygen mixtures
 - Helium-impurities mixtures
 - Steam
- Experiments with final quench phase from up to 2000°C

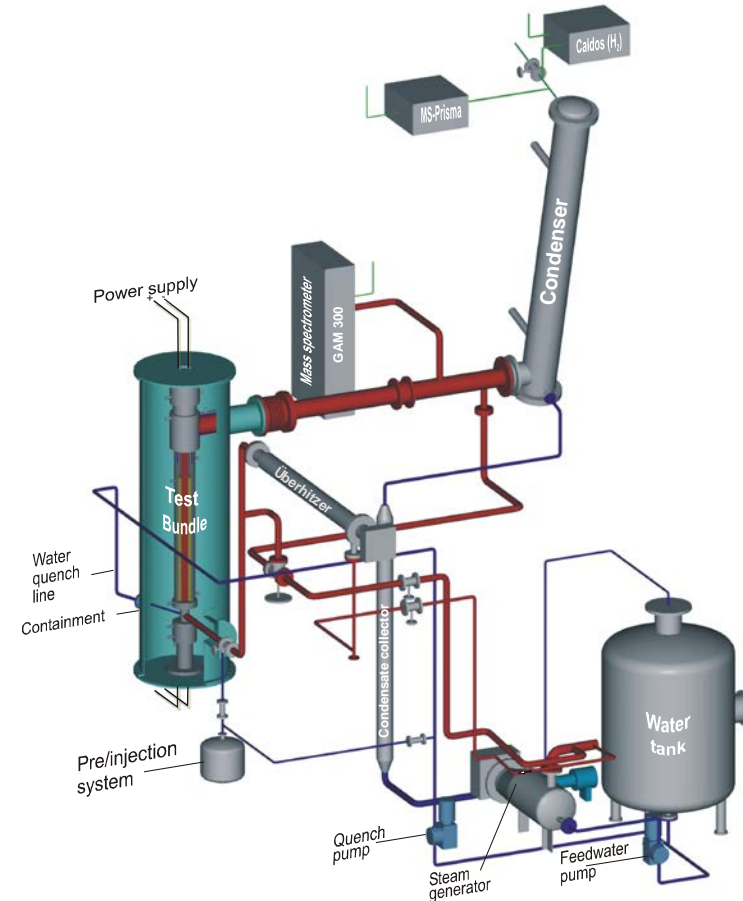


SiC oxidation in steam and quenching from 2000°C



Potential KIT contributions to ATF research

- Separate-effects tests on high-temperature oxidation, quenching and mechanical behavior of AT claddings
- Bundle tests with prototypic LOCA and BDBA scenarios
- One bundle experiment with SiC-SiC claddings (if available) already planned within the next evaluation period of KIT

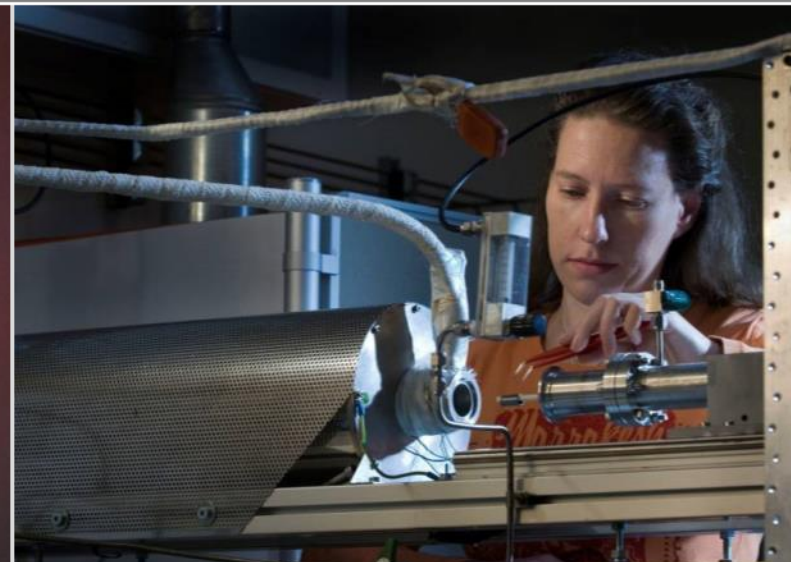


Potential KIT contributions to ATF research

Martin Steinbrück

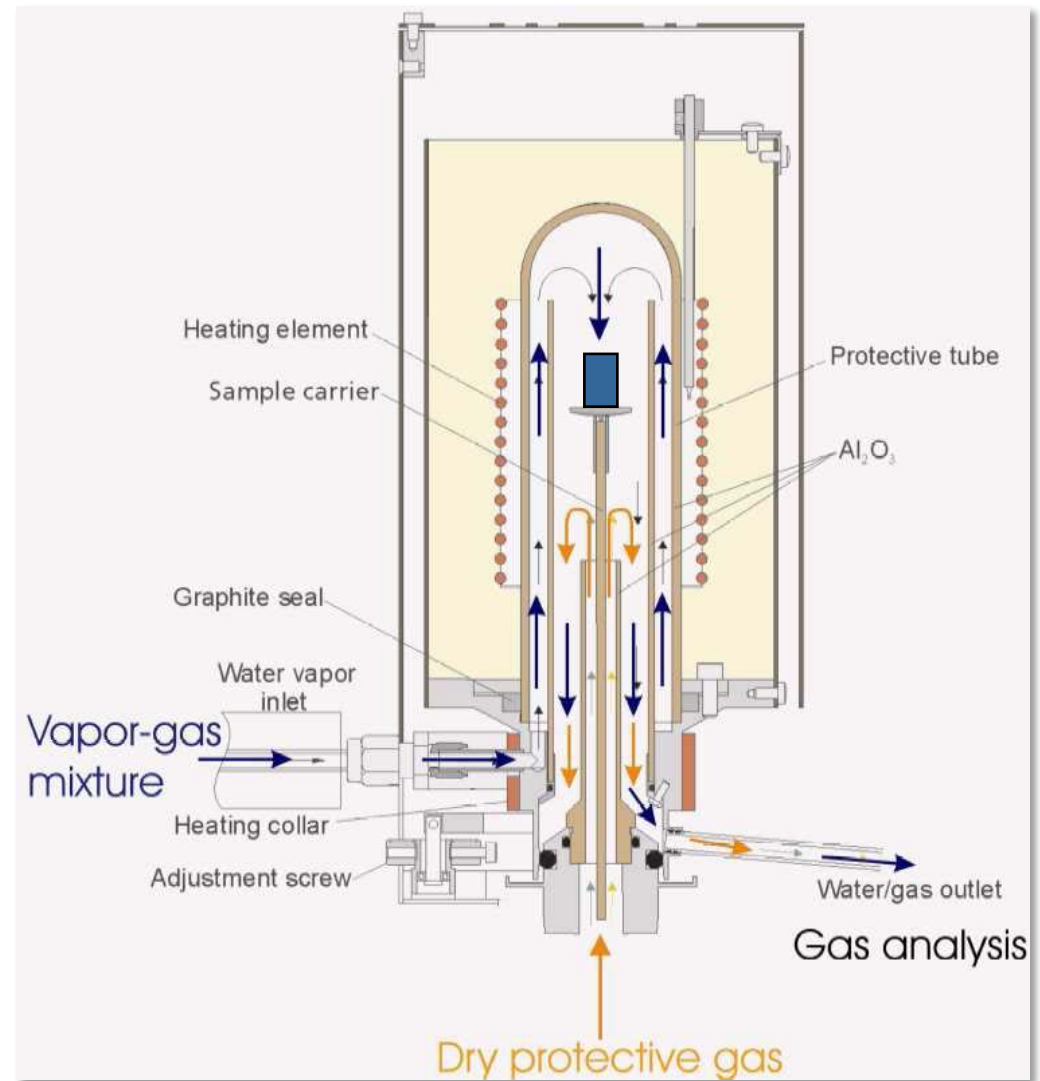
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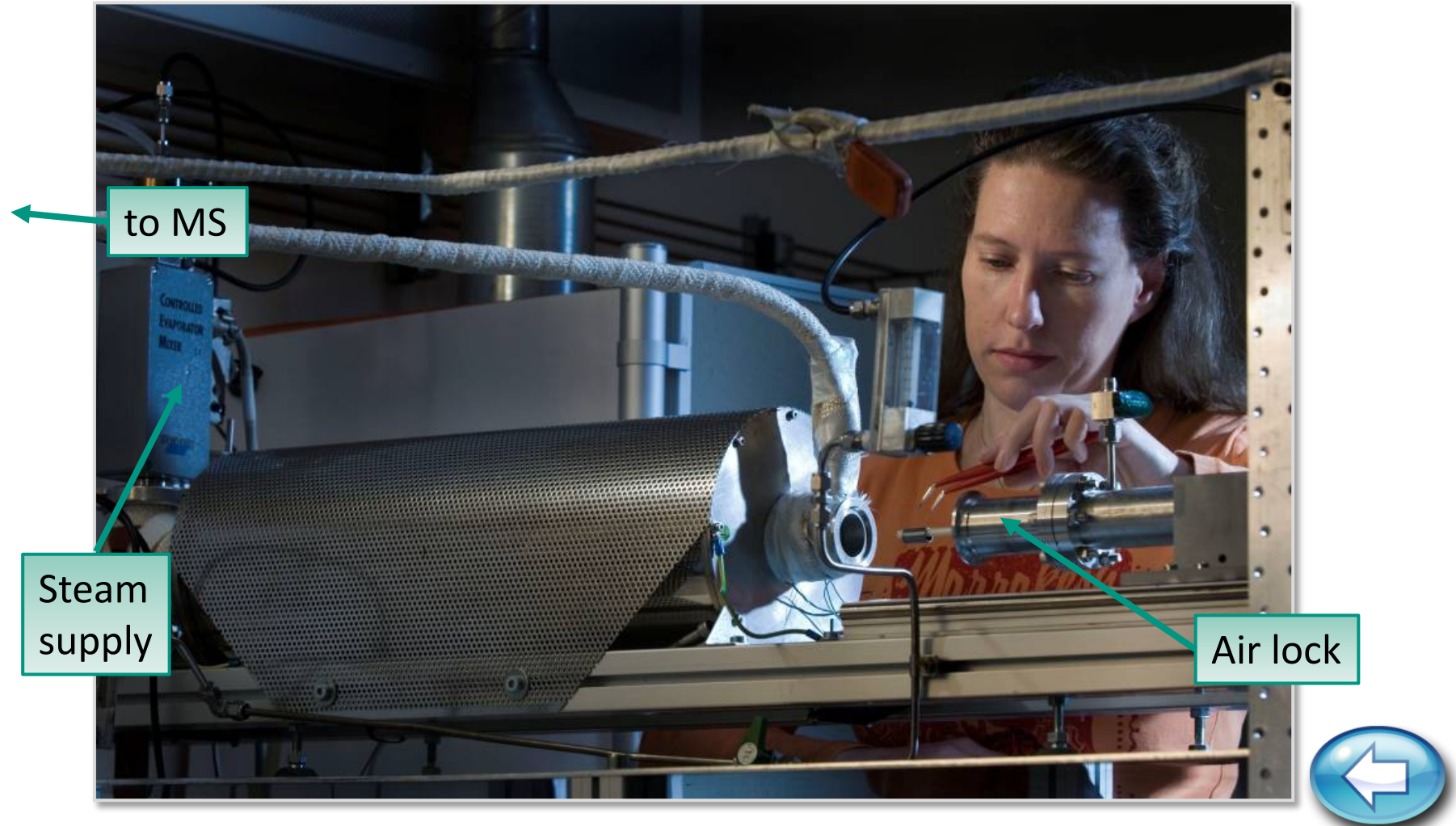


NETZSCH® steam furnace for TGA

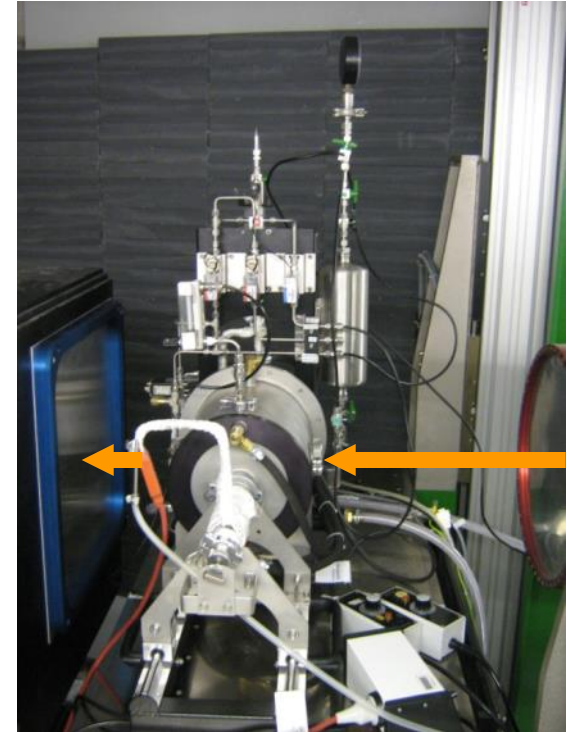
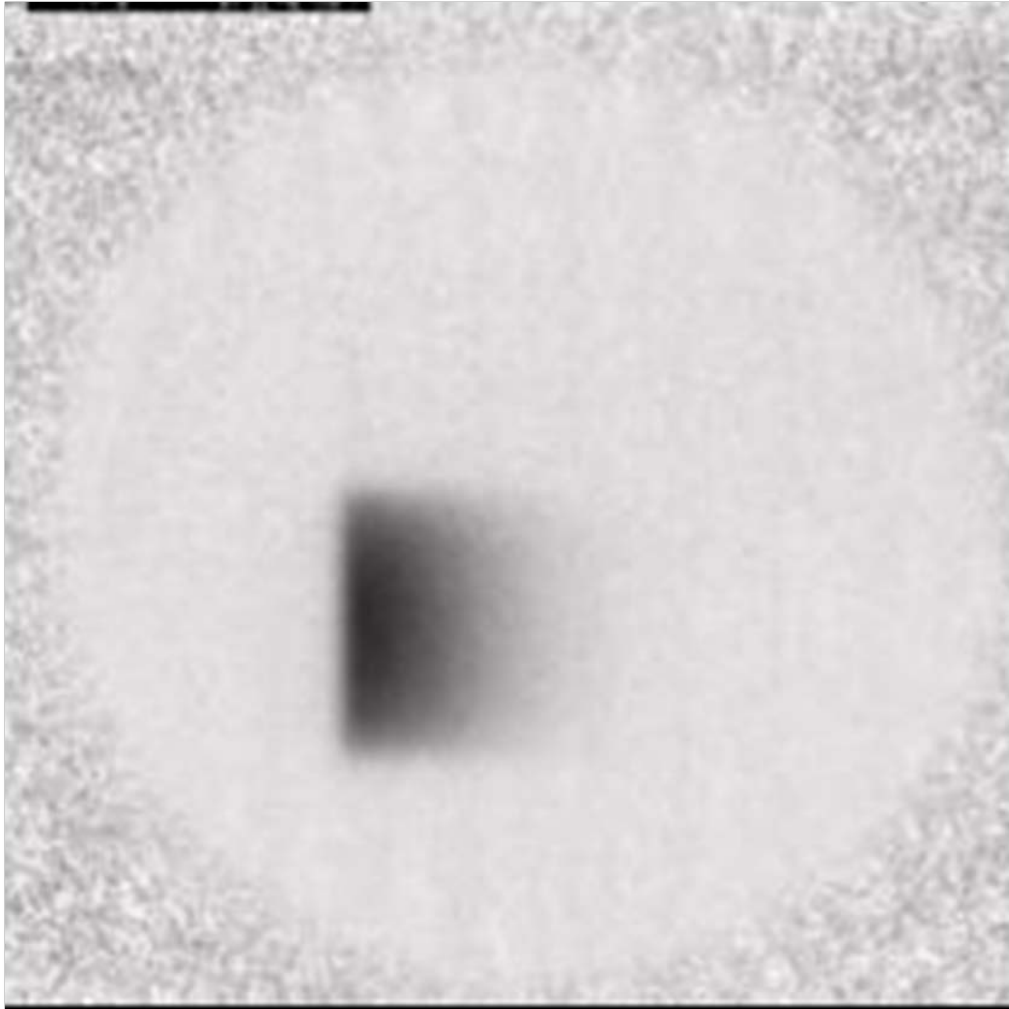
- Up to 100% steam
- Up to 1250°C



BOX rig for investigation of materials at high temperatures (1700°C) in defined atmospheres



In-situ investigation of hydrogen diffusion in Zry



Example:

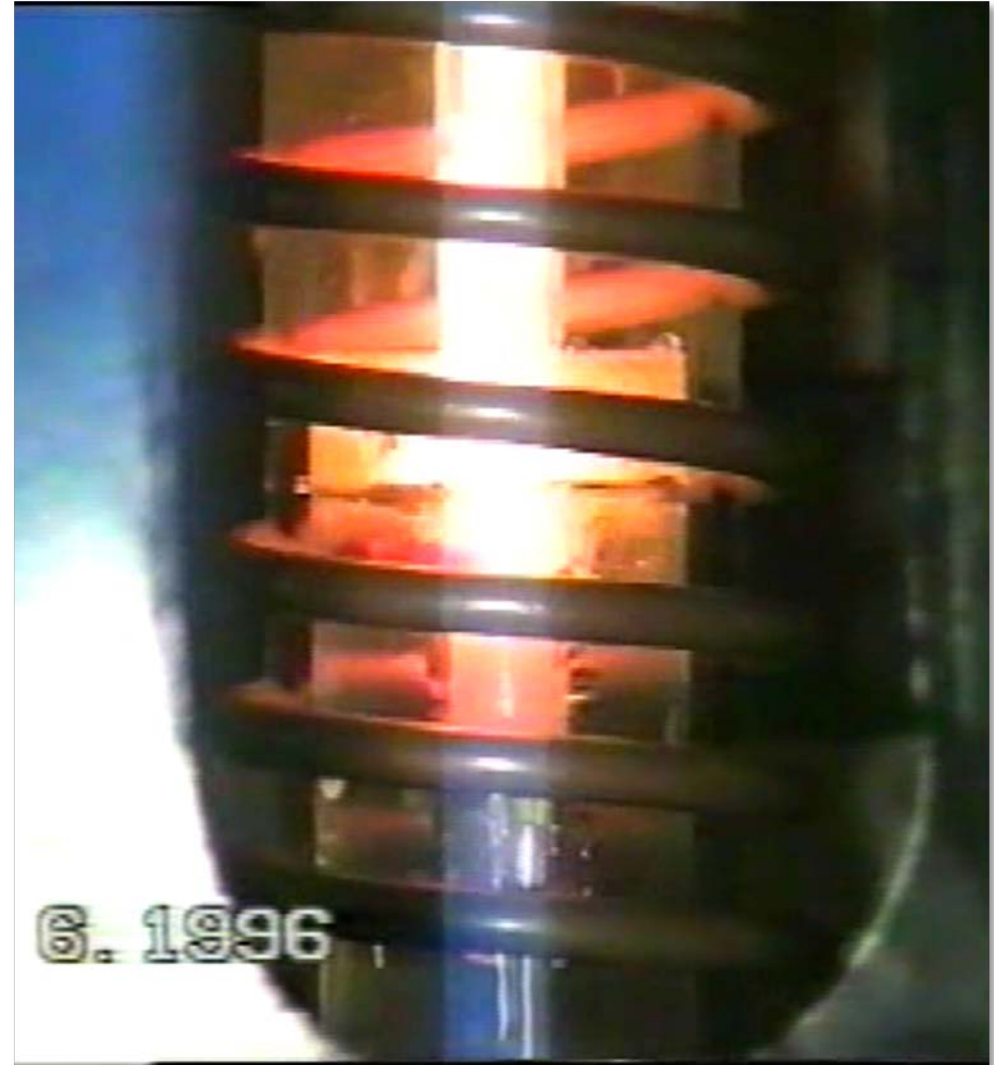
- Hydrogen diffusion into a Zry-4 cylinder
- Surface oxidized except one base
- $\varnothing = 12\text{mm}$, $l = 20\text{ mm}$
- at 1100°C
- time ratio: 1:100

M. Grosse, 16th Intern. Symposium on Zirconium in the Nuclear Industry (ASTM)



Single-rod QUENCH tests

- 15-cm rods filled with ZrO_2 pellets
- Direct inductive heating till melting temperatures
- Video recording
- Mass spectrometer for analysis of hydrogen release



Reflood from 1400°C