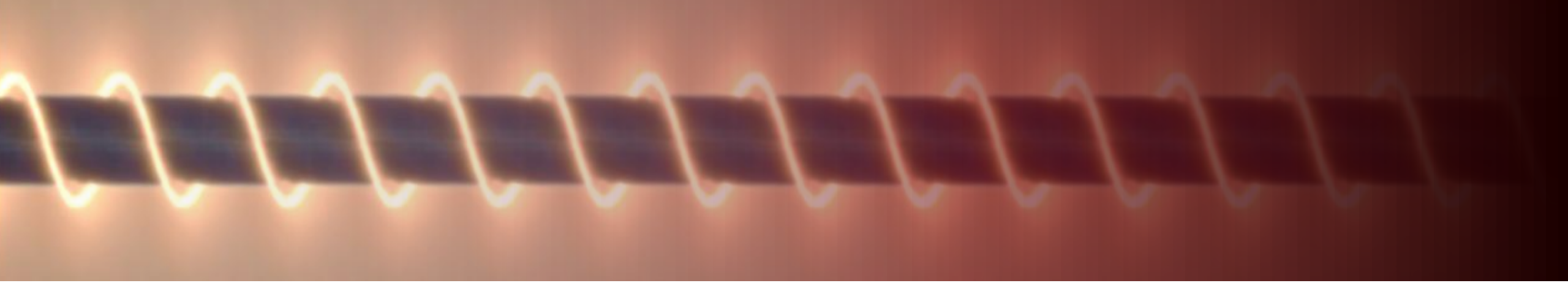

Development of a Test Rig for Investigating the Ageing Behaviour of Electrical Heating Elements in Hybrid Heating Systems

5. AOTK – Aachener Ofenbau und Thermoprozess-Kolloquium
23th September 2025

OWI: F. Kremer, P. Phadnis, D. Kuckelberg, S. Harboe-Minwegen

DLR Projektträger

INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG IGF

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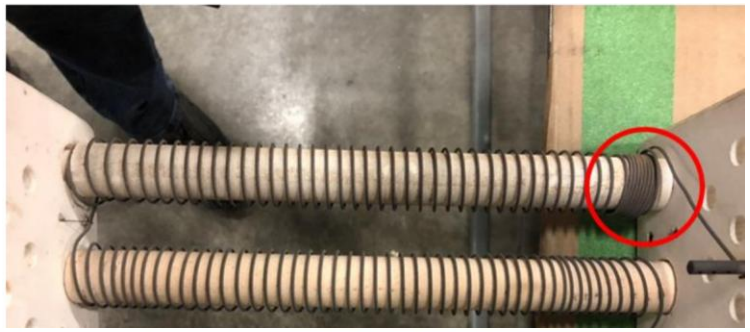
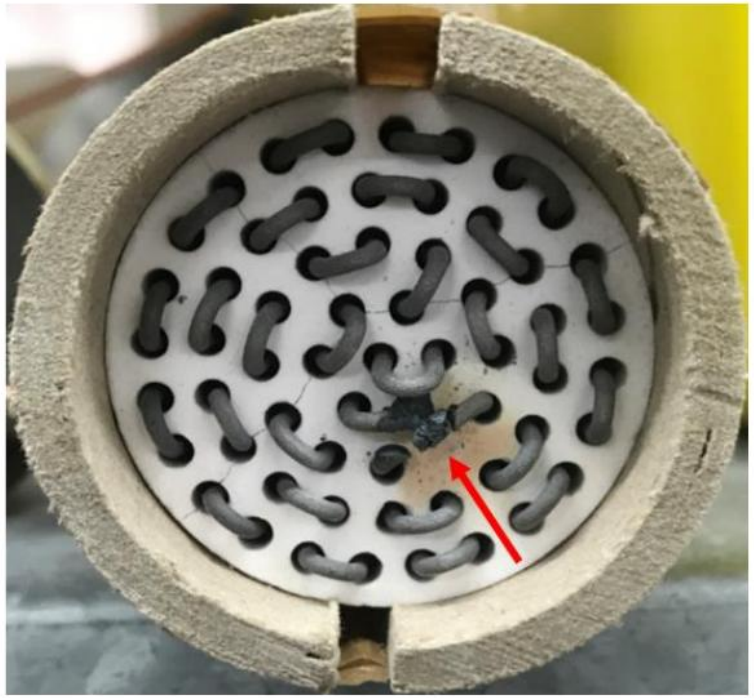
Agenda

- Background
- Test Bench
- Temperature Control
- Emissivity Calibration
- Initial Results
- Conclusions and Outlook

Background





- Energy transition stepping stone: hybrid heating systems
  ➔versatility in fluctuating fuel availability and costs
- Ageing behaviour of heating wires in such atmospheres not well known, but required for reliable lifetime prediction
- Dedicated test bench for temperatures up to 1050 °C

Anticipated hybrid heating scenarios

Combustion Case	Gas atmosphere [vol.%]			
	CO_2	N_2	O_2	H_2O
Dry Air (Reference)	-	78	22	-
Natural Gas/Air	8,5	72	2,5	17
H_2/Air	-	66,5	2,5	31
H_2/O_2	-	-	2,5	97,5

Background

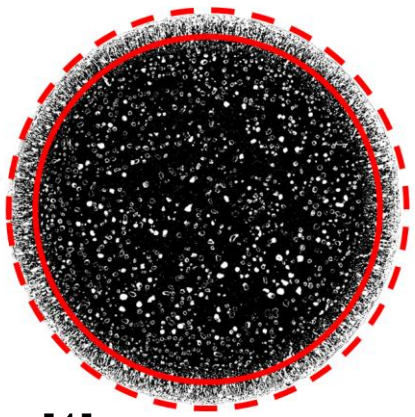
Due to oxidation the effective cross section is reduced over time

Also weight changes

This can be correlated with a change in resistance

} Mechanical failure

Ø 2 mm



[1]

➡ Life time modelling [1], depending on combustion case

$$R = \rho \cdot \frac{l}{A}$$

R: Resistance
ρ: Specific resistance
l : Length of wire
A: Cross section

Materials to be tested:

Austenitic:

- VDM® Alloy HT 60 (2.4867, Ni-22Fe-15Cr)
- VDM® Alloy HT 80 (2.4869, Ni-20Cr)

Ferritic:

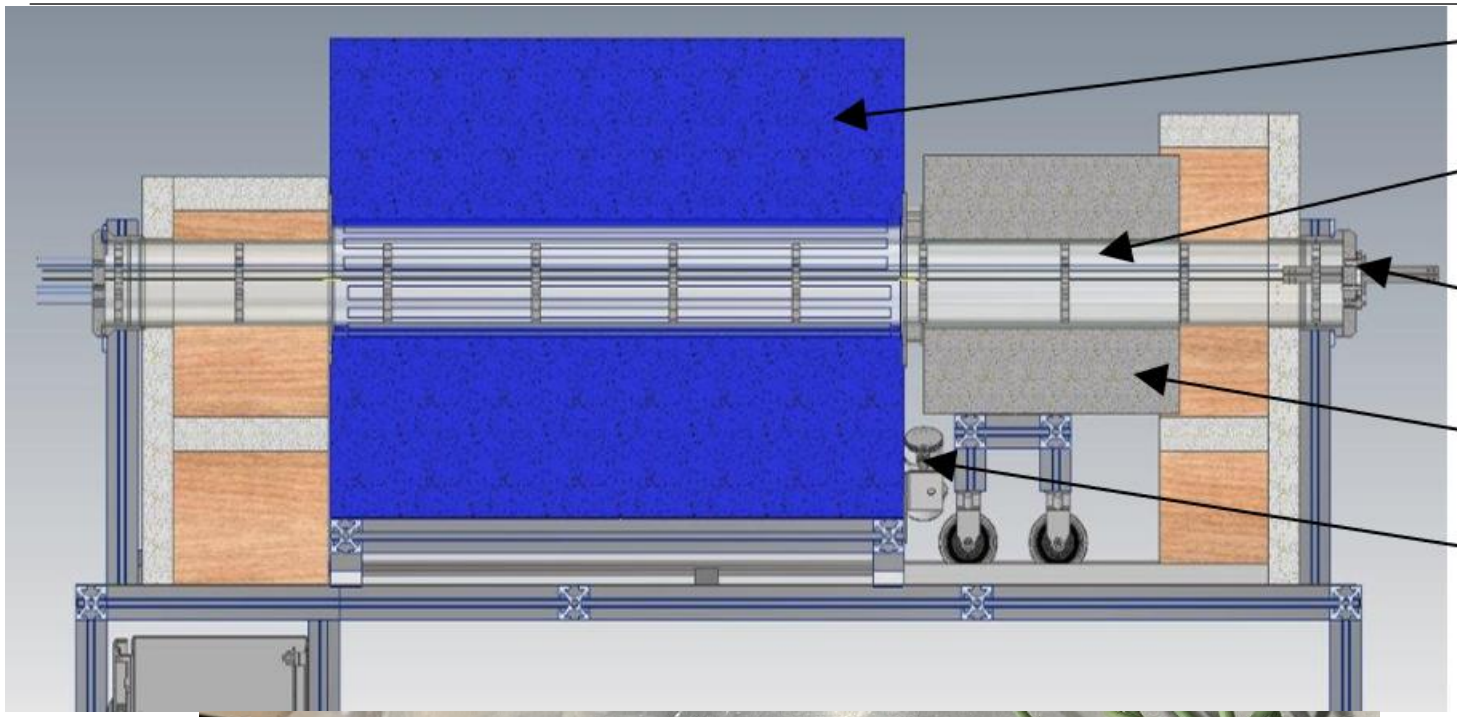
- Kanthal APM

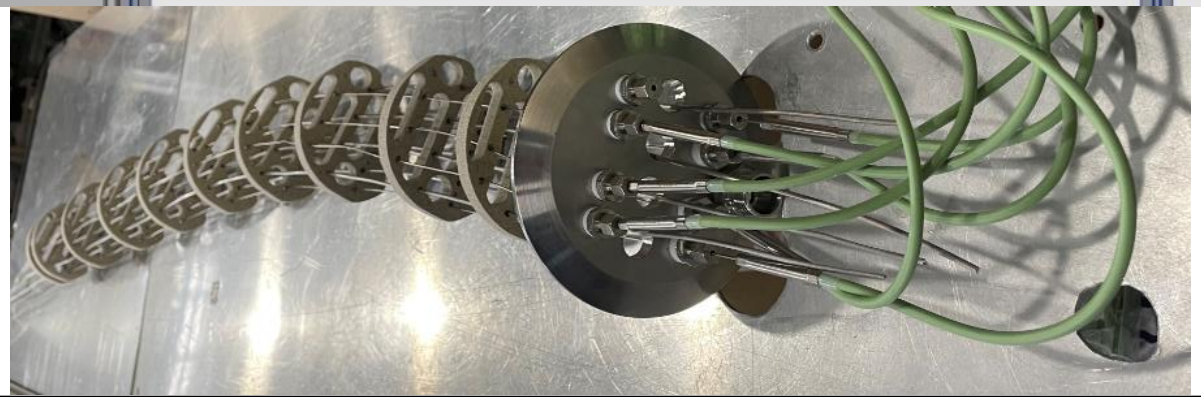
[1] DECHEMA Research Institut, Germany

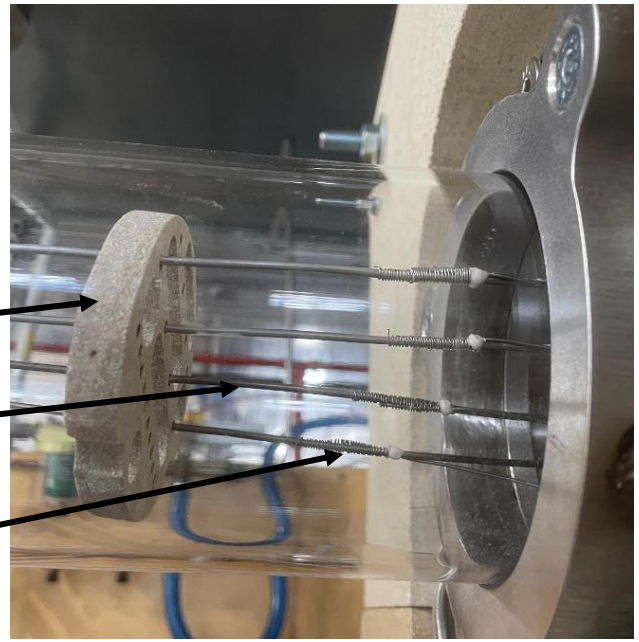
Test Bench Requirements

- Testing up to 1000 h
- Heating wires of about 2 mm cross section
- Keep heating wire at a set temperature, near 1050 ºC
- Simultaneous testing of 3 different materials, each separately temperature controlled
- Measurement of current and voltage for each electrically heated wire for determination of resistance and radiating power
- Inclusion of non-electrically heated wires
- Keep gas/furnace temperature near 900 ºC
- Small gas volume rate around 0,2 slm
- Variation of gas atmosphere, depending on combustion case
- Heating wire surface temperature measurement on the electrically and non-electrically heated wires using thermocouples and infrared camera
- Thermocouple attachment to heat wire without soldering

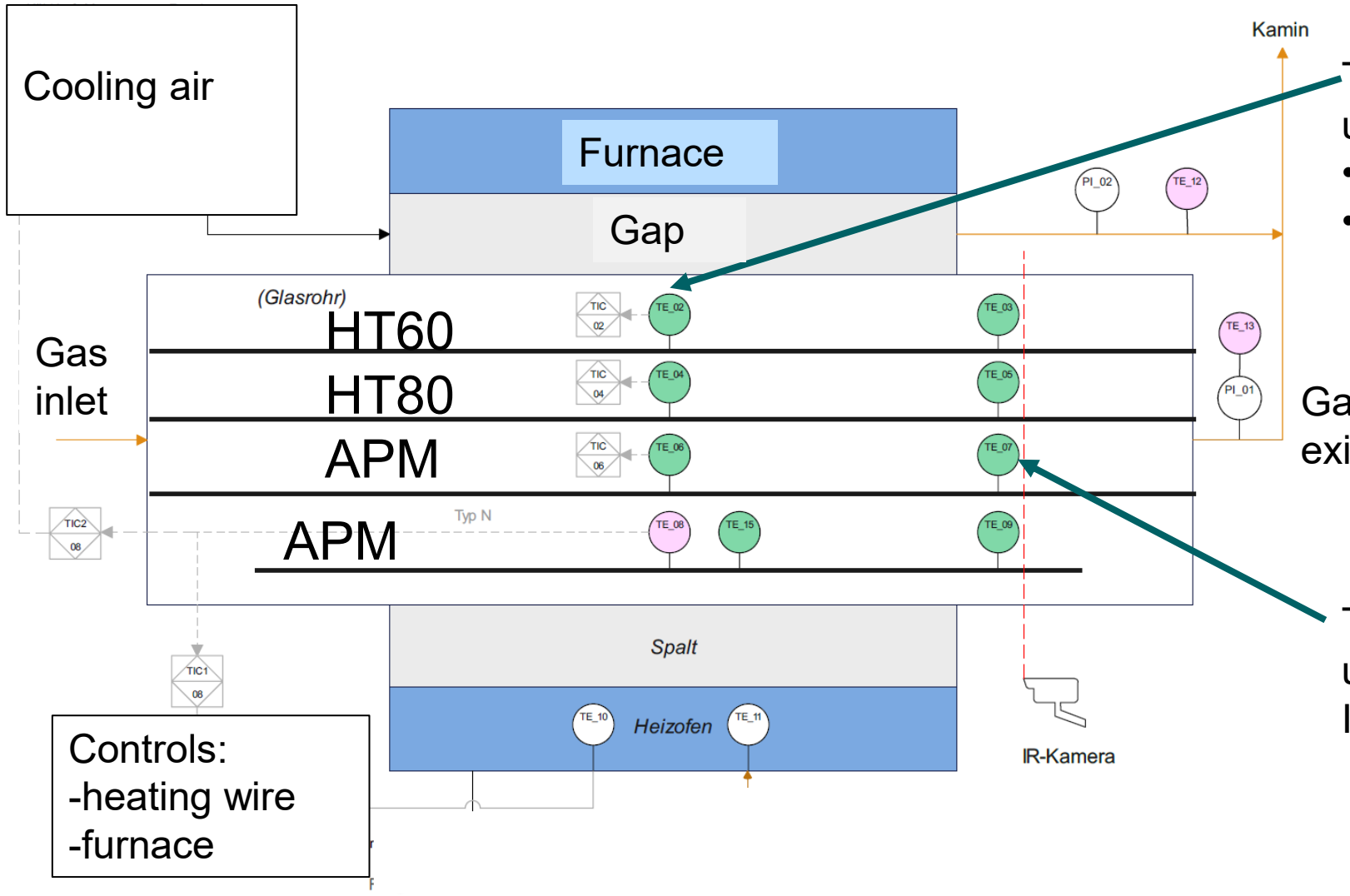
Test Bench Set Up







Process & Instrumentation Diagram

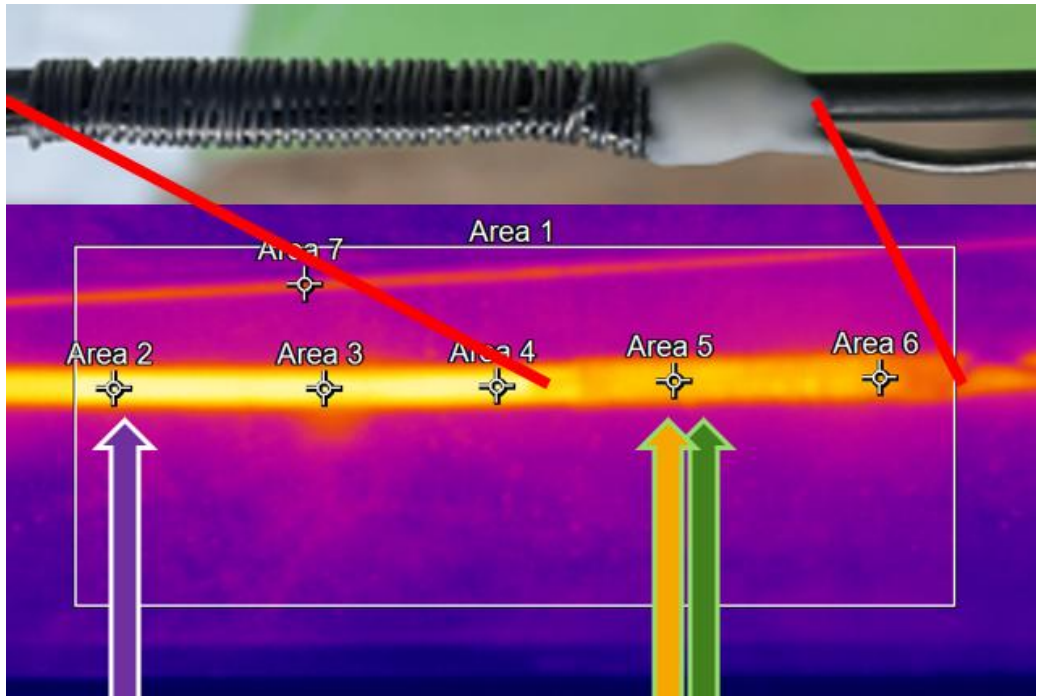


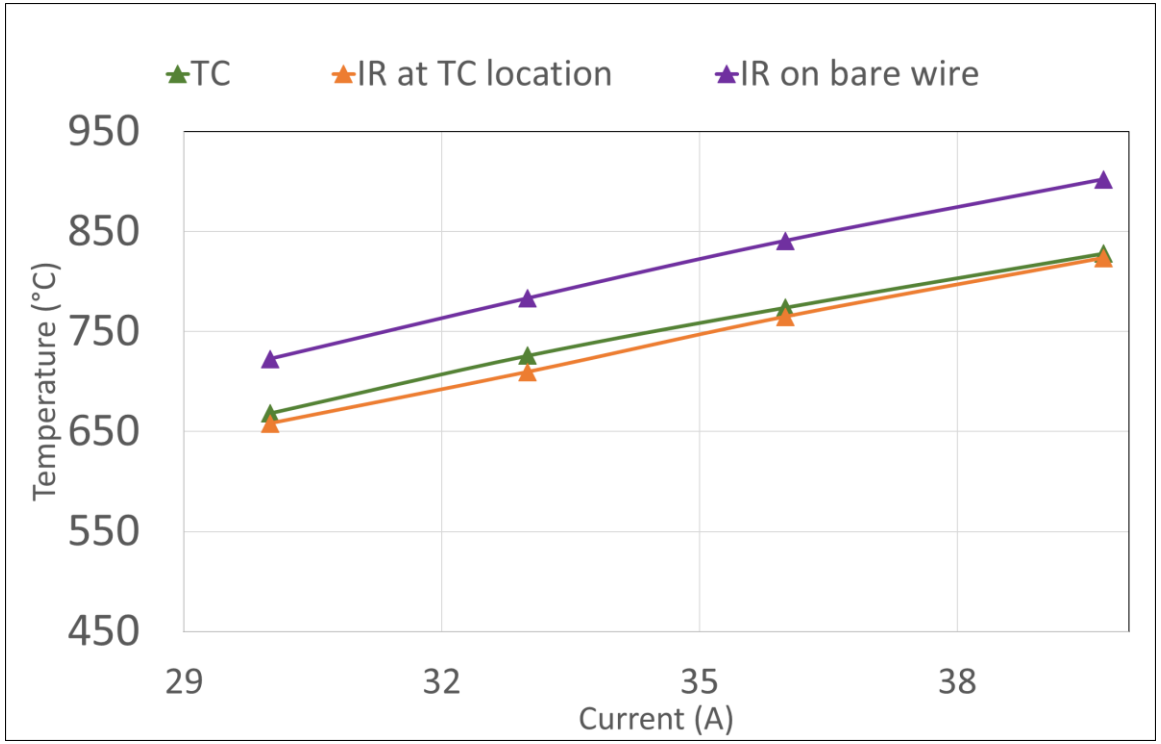
Thermocouples (TC) in middle of furnace used for control of temperature:

- for each electrical heating wires
- for one non-electrical heating wire

Thermocouples (TC) at furnace exit used for comparison with daily Infrared (IR) measurement

Temperature Control Pretesting



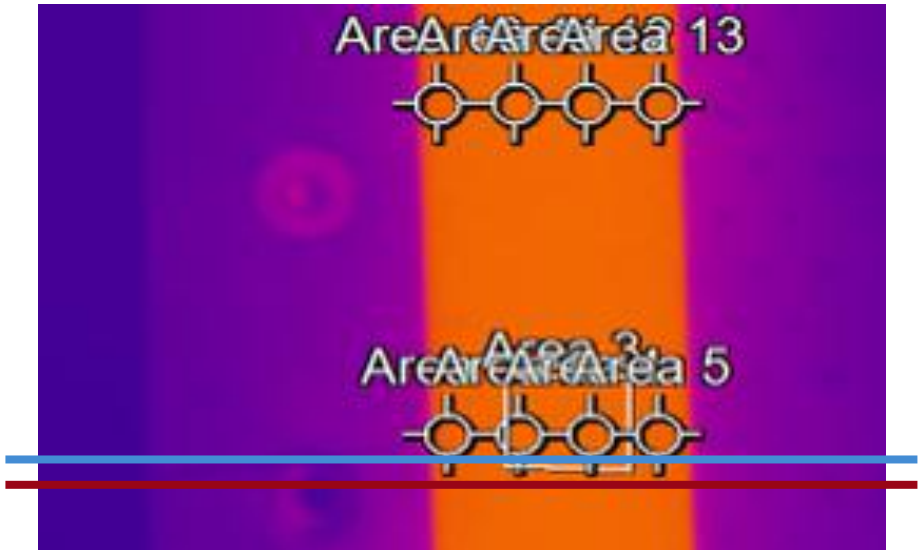


- Thermo couple aligned with heating wire, both wrapped with 0.4 mm wire and bonded to avoid sliding
- Thermo couple measurement possible on electric heating wire employing a galvanical isolation
- Temperature at thermocouple (TC) about 50 ºC lower, but in line with infrared (IR) measurement

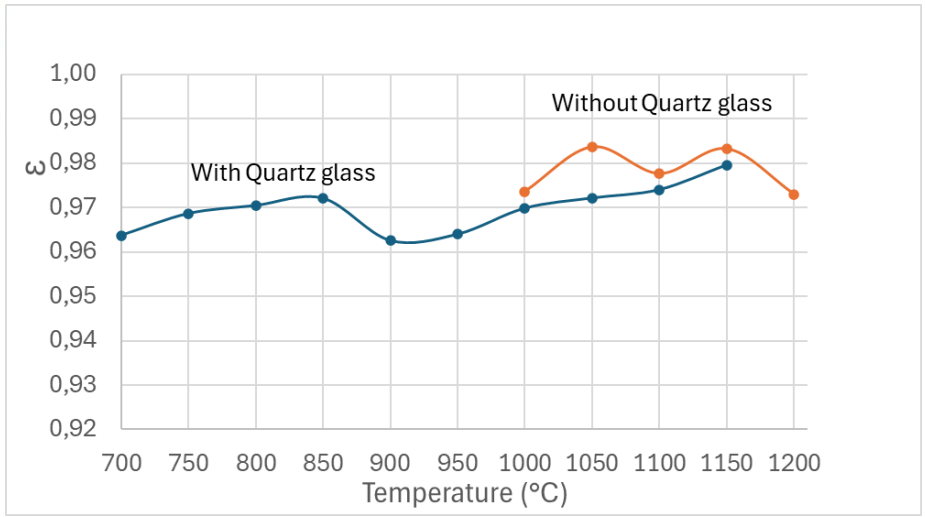
Emissivity Calibration

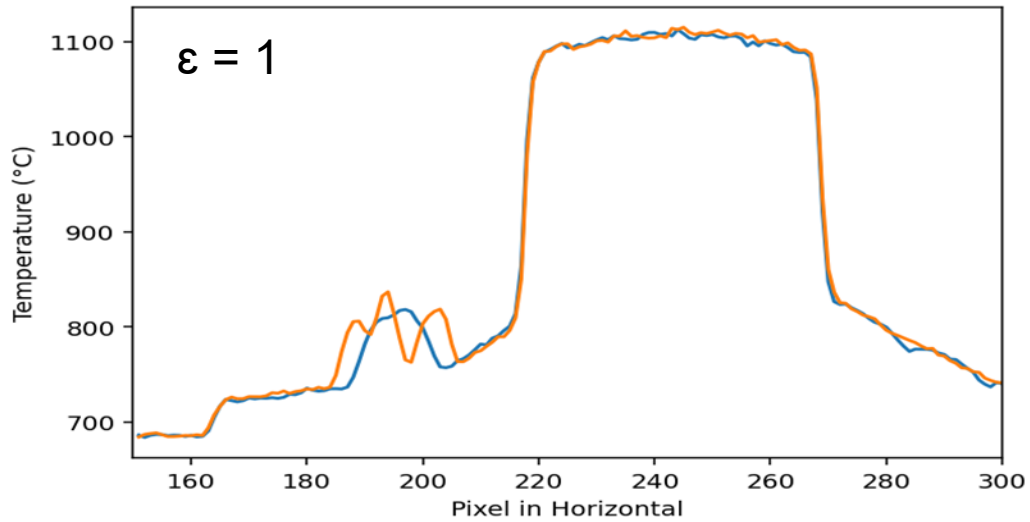
[2]

- Emissivity near 1
- Quartz glass has high transparency
- Temperature gradient influences accuracy



$$\varepsilon = (T_{IR}/T_{TC})^4$$





[2] IOB, RWTH Aachen University

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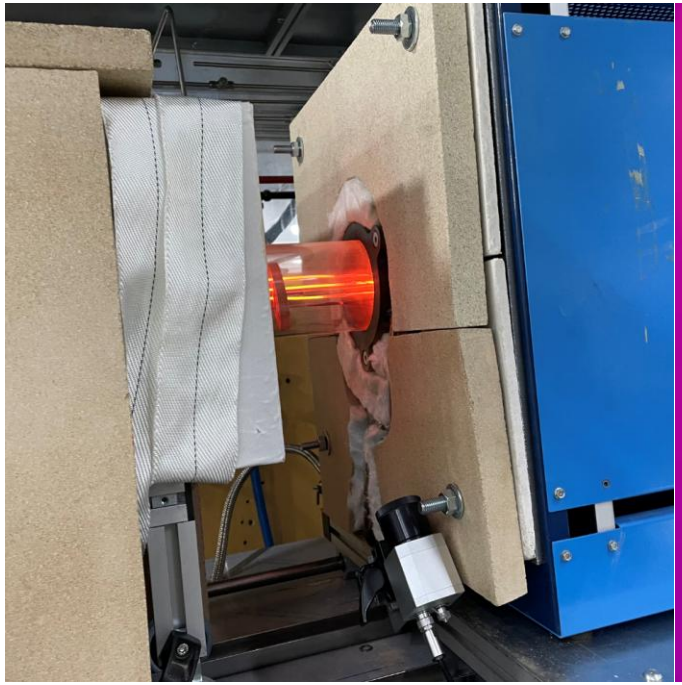
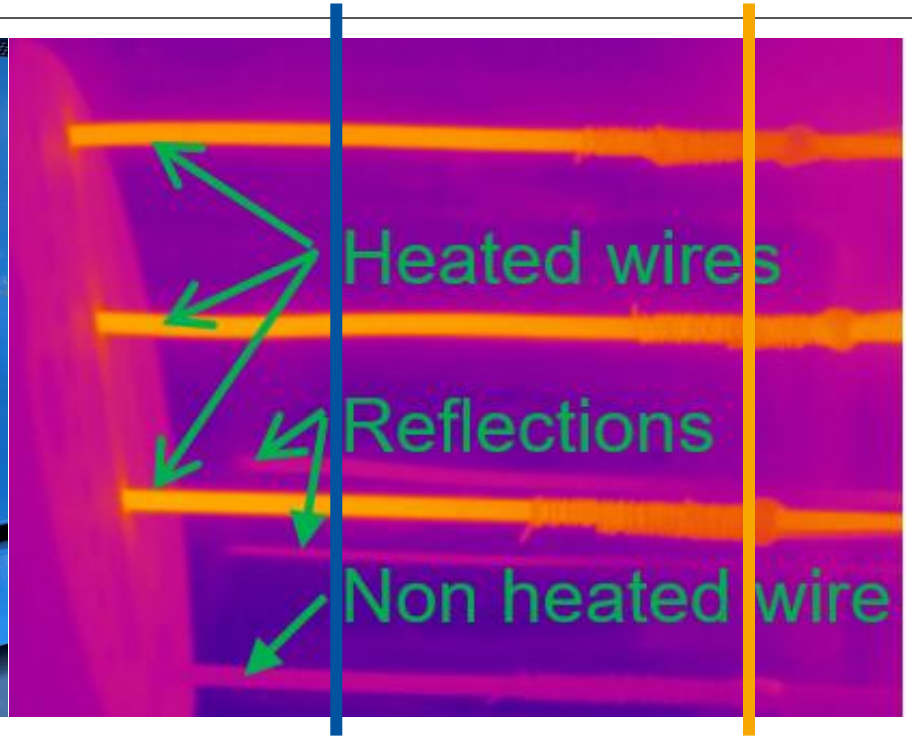
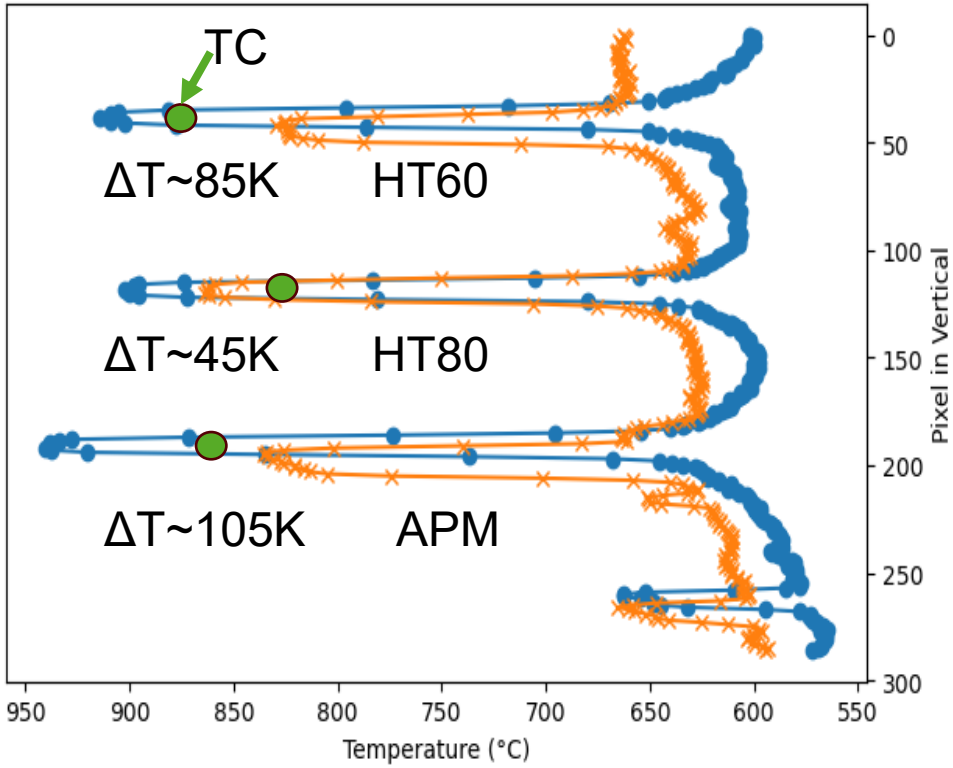
Initial Results

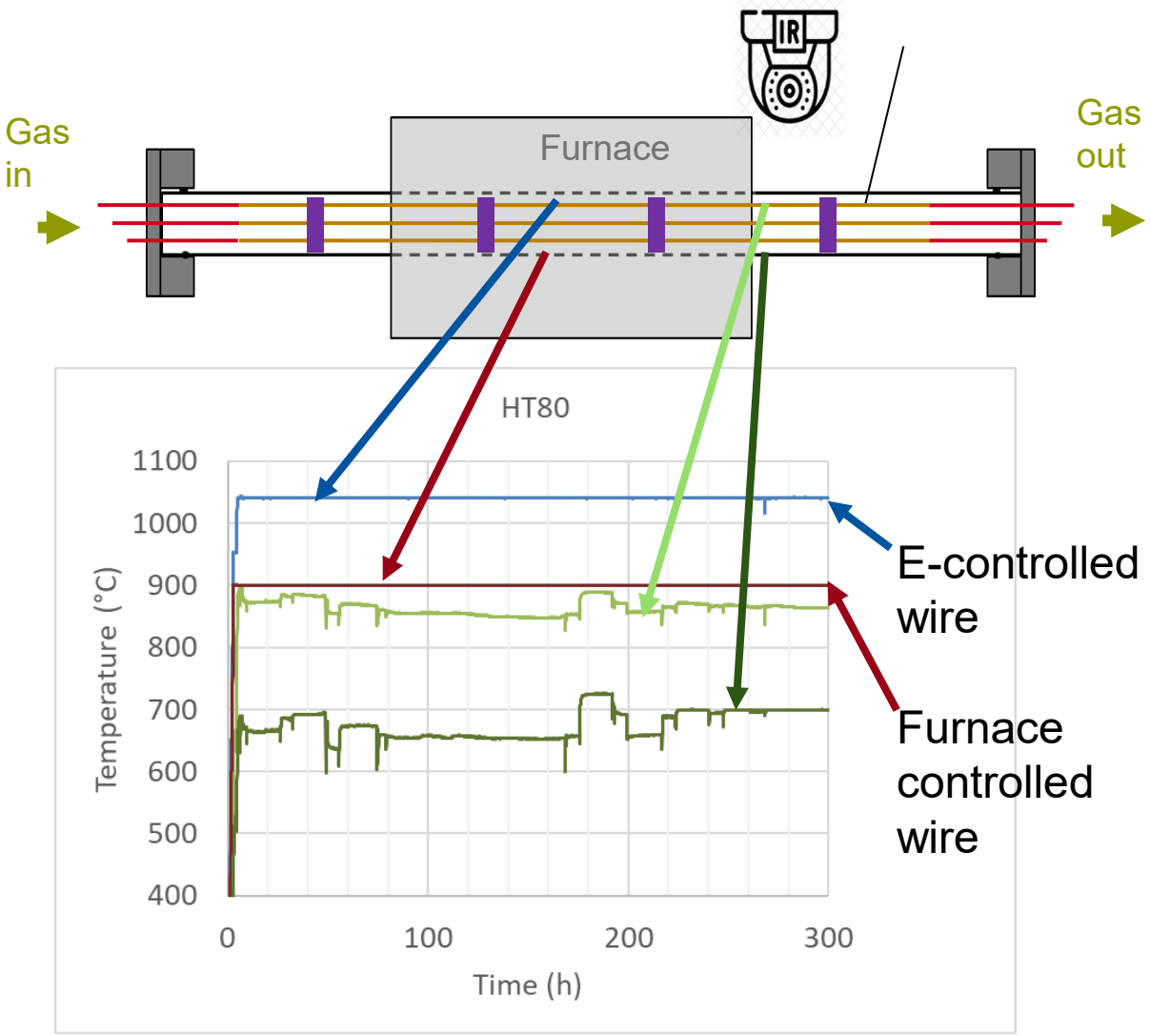






- Reference test with air atmosphere started
- Temperature differences between TC position and blank wire between 45 and 105K, but requires more enhanced approach

Initial Results



- Drop in temperature at furnace exit during IR-measurement
- Closure of movable isolation influences furnace exit temperature

Conclusions and Outlook

- Test bench developed for assessing heating wire lifetime for several exhaust gas compositions
- Pretest shown feasibiliy for temperature control on electrical wire with a TC
- Emissivity coefficient determined for the foreseen materials
- First results available show improvement issues
- AI tool in development for correlation of test results and accuracy analysis

Thank you
for your attention!

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