



### TOWARDS THE STANDARDIZATION OF MOLTEN SALT LOOPS' INSTRUMENTATION AND COMPONENTS

#### **FLOW METERS**

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Agenda – Flow Meters

- Test Environment
- Ultrasonic Flow Meters
- Venturi Tube
- Alternative Evaluation Method



# Flow Meter Test Environment @ Fraunhofer ISE

Method implemented:

• A calibration method for flow meters has been developed using a gauging station including a high precision scale



Molten salt loop for gravimetric calibration of flow meters



Flow Meter

#### Compressed air connection

Mechanical decoupling



High precision scale



![](_page_4_Picture_0.jpeg)

# Mechanical decoupling

![](_page_4_Picture_2.jpeg)

# Flow Meter Test Environment @ Fraunhofer ISE

Method implemented:

- A calibration method for flow meters has been developed using a gauging station including a high precision scale
- Pre-tests were run with water at ambient temperature
- Volumetric flow in 1-minute time span indicated by flow meter is compared to weight increase on precision scale

![](_page_5_Picture_5.jpeg)

Molten salt loop for gravimetric calibration of flow meters

![](_page_5_Picture_7.jpeg)

# **Ultrasonic flow meter: Specification**

- Commercial clamp-on sensor using wave guides was used
- Operating temperatures < 550 °C
- Evaluation for periods of constant flow rates (500-5000 kg/h)

#### Conclusion:

 Using a high precision scale in a gauging station was found to be suitable for the calibration of flow meters for molten salt

Remark:

• In the current setup only small tube diameters can be investigated.

![](_page_6_Picture_8.jpeg)

![](_page_6_Figure_9.jpeg)

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## **Ultrasonic flow meter: Specification (DLR)**

• Clamp-on sensor provided by Endress+Hauser Flow

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- First prototype with operating temperatures < 550 °C
- Prototype avoids the use of Waveguides
   → Sensors in direct contact with
   the pipe surface
- Trace heating and insulation can remain on the pipe\*

![](_page_7_Picture_5.jpeg)

![](_page_7_Picture_6.jpeg)

\*Thermal insulation was removed during tests to allow quick changes to the component

### **Ultrasonic flow meter: Test setup (DLR)**

- Inlet length > 50 pipe diameters
- Temperature measurement in the immediate vicinity downstream of the flow meter
  - $\rightarrow$  Density calculation
- Coriolis flow meter functions as the main reference (limited to < 400 °C)</li>

![](_page_8_Figure_5.jpeg)

## **Ultrasonic flow meter: Experiments (DLR)**

- Temperature measurement valid for density calculation (see on the right)
- 2 days of experiments
  - Day 1: 300 °C + mass flow variation
  - Day 2: 400 °C + mass flow variation
- Comparison of the prototype with installed clamp-on ultrasonic flow meters and Coriolis

![](_page_9_Figure_6.jpeg)

![](_page_9_Figure_7.jpeg)

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## **Ultrasonic flow meter: Conclusions (DLR)**

- Full results cannot be published (Confidentiality)
- Molten salts can be measured with ultrasound in the 1 MHz frequency
- Functionality of the prototype at high medium temperatures confirmed
- With optimal design a measurement uncertainty in the ±2% range seems feasible
- 2<sup>nd</sup> round of prototype tests in 2024

![](_page_10_Figure_6.jpeg)

Coriolis measurement for experiment day 1 (300 °C)

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## Venturi tube with Differential Pressure Transmitters (DPT)

![](_page_11_Picture_1.jpeg)

Venturi tube + thermal

insulation

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![](_page_11_Picture_5.jpeg)

- Testing within SFERAIII
  trans national access scheme
- Results still to be processed

#### **Alternative Flow Rate Evaluation - Time of Flight (ToF) Method**

- Method developed to evaluate the flow rate with (existing) temperature sensors in the absence of dedicated flow sensors
- Only 4 flow meters installed in the field but >700 temperature sensors

![](_page_12_Picture_3.jpeg)

Aerial view of CSP plant Andasol III, Granada, Spain including four subfields with 152 loops in total

(Rohani 2015)

![](_page_12_Picture_6.jpeg)

#### **Alternative Flow Rate Evaluation - Time of Flight (ToF) Method**

- 5 Temperature sensors per loop
- Identification of temperature step responses in data from commercial CSP plant

![](_page_13_Figure_3.jpeg)

![](_page_13_Picture_4.jpeg)

#### **Alternative Flow Rate Evaluation - Time of Flight (ToF) Method**

Conclusions:

- Flow rate for each loop can be evaluated
- Paper to be published shortly in Journal of Solar Energy
- Accuracy to be improved in ongoing activities

![](_page_14_Figure_5.jpeg)

## Thank you!

#### Time for your Comments and Questions

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