Heat pipe based heat exchangers in challenging industrial waste heat recovery applications

Authors:
S. Almahmoud, G. Bianchi, S. A. Tassou, R. Llera, F. Lago, J. J. Arribas Ramirez and H. Jouhara

Researcher:
Sulaiman Almahmoud

Supervised by:
Dr Hussam Jouhara

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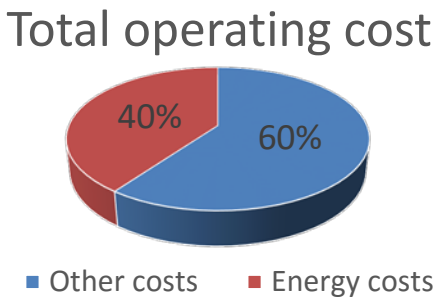
Overview

- The Thermal Design of a Flat Heat Pipe (FHP) for waste heat recovery by radiation high temperature sources
- A theoretical model to predict the thermal performance was built
- The Mechanical Design of the FHP
- The Results obtained from testing the unit in the Laboratory

Aims

- Design a Flat Heat Pipe heat exchanger (FHP) to capture the heat by radiation and convection from High and medium temperature sources

Introduction

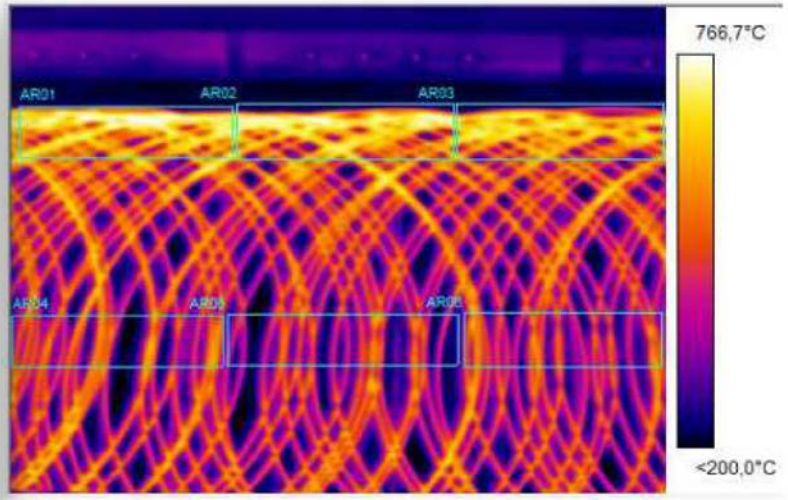


- Energy consumption in steel industry presents 5% world energy consumption
- 40% of total operating cost is for Energy cost
- Challenges:
  - Limited Space, Inaccessibility, Temperature Restrictions
  - Payback periods, Project and investment costs

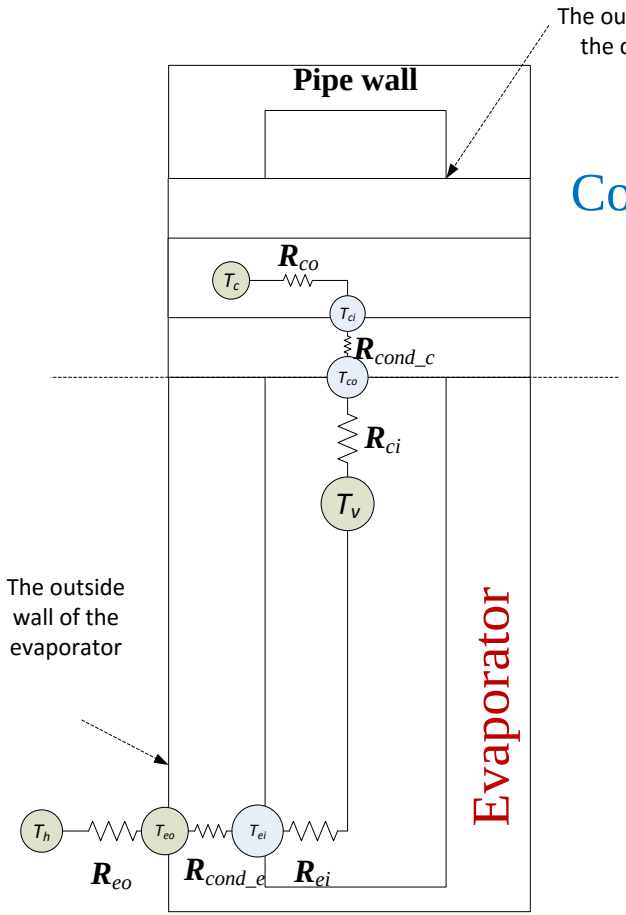
Research Gap

Waste Heat recovery in steel industry

- **Facility: Wire Rod Mill**
- **Product: Wire Rod**
- **Average Temperature: 500 ºC to 600 ºC**



Flat heat pipe Thermal Design

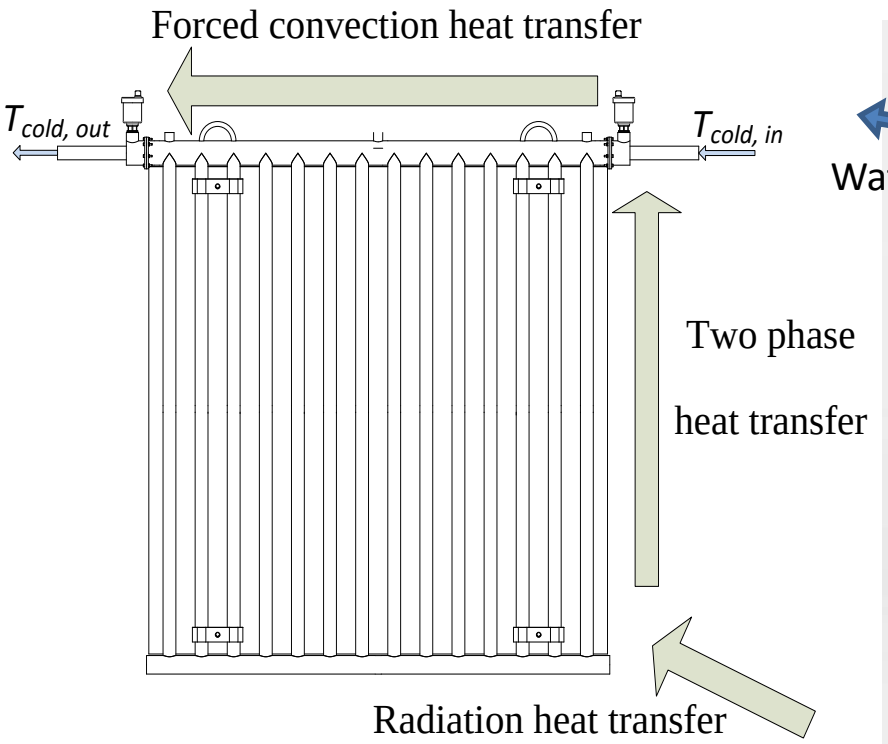


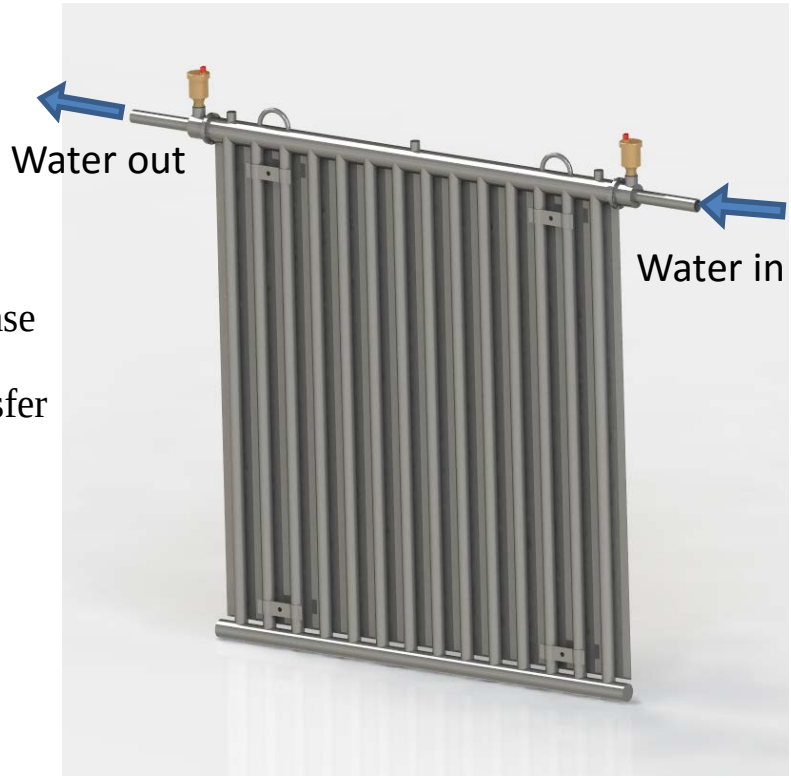
Condenser

$$R_{hp} = R_{cond\_e} + R_{ei} + R_{co} + R_{cond\_c}$$

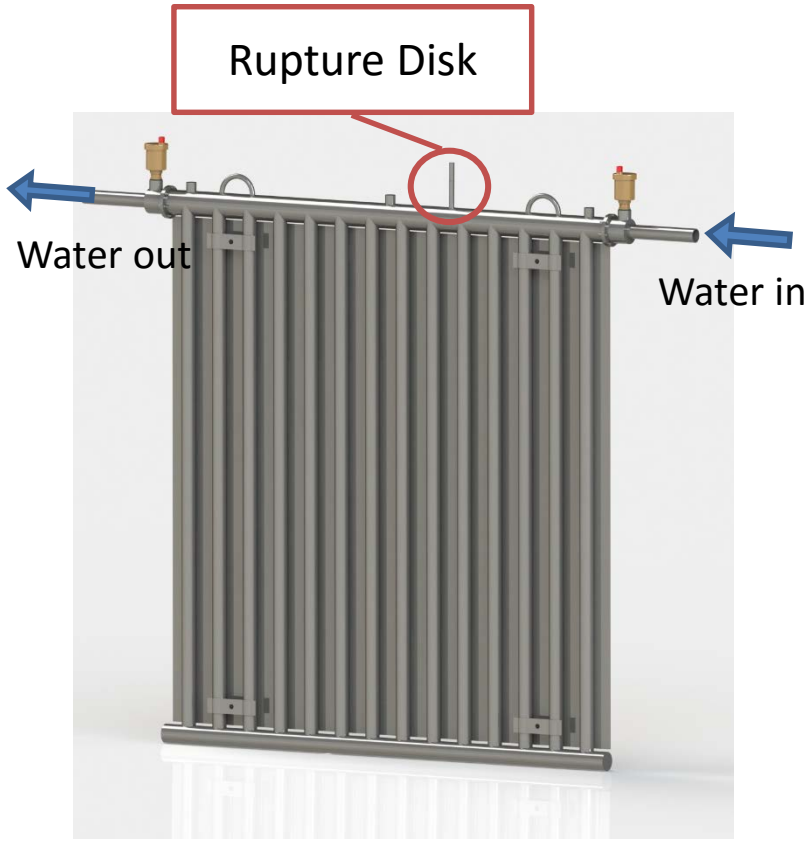
$$Q_{hp} = \frac{T_{eo} - T_{ci}}{R_{hp}}$$

Flat Heat Pipe Design



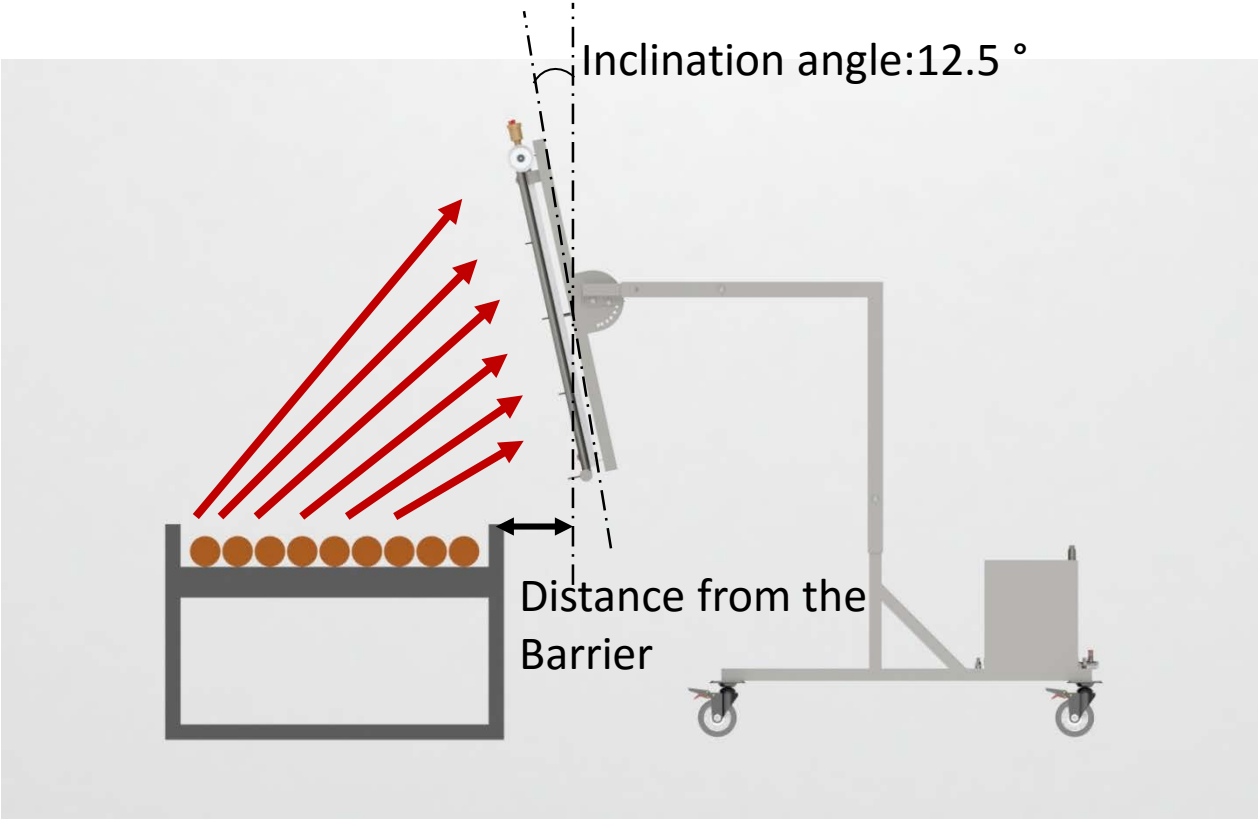


FHP Design

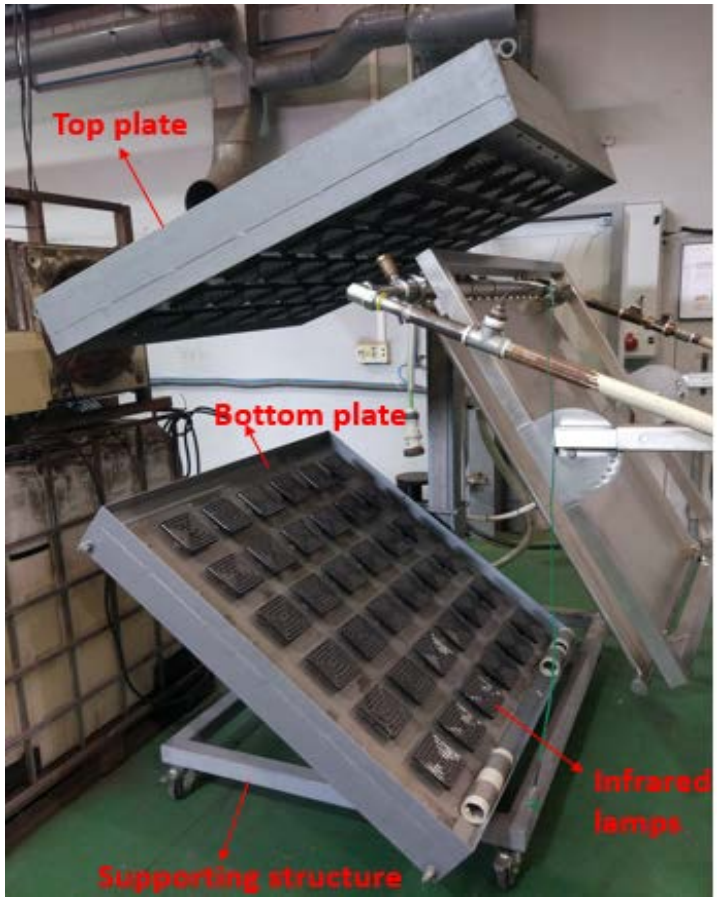


FHP Design

FHP Concept



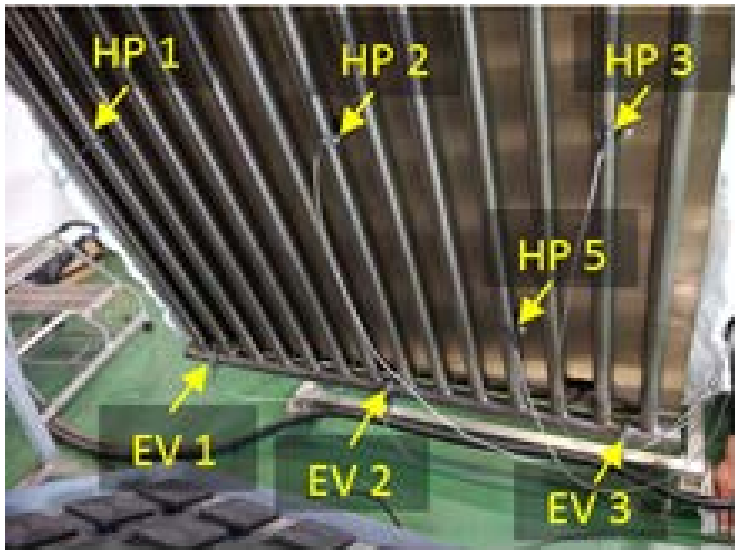
Lab Testing

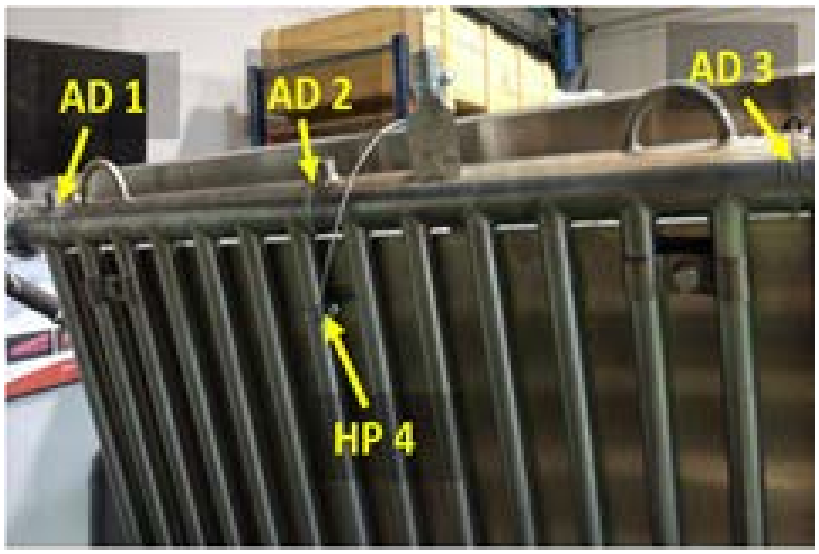

Top plate
Bottom plate
Infrared lamps
Supporting structure

Lab Testing

Thermocouple Positioning:

- 3 Thermocouples on the bottom header
- 5 Thermocouples on the pipes
- 3 Thermocouples on top header
- Thermocouples to measure the water inlet and water outlet





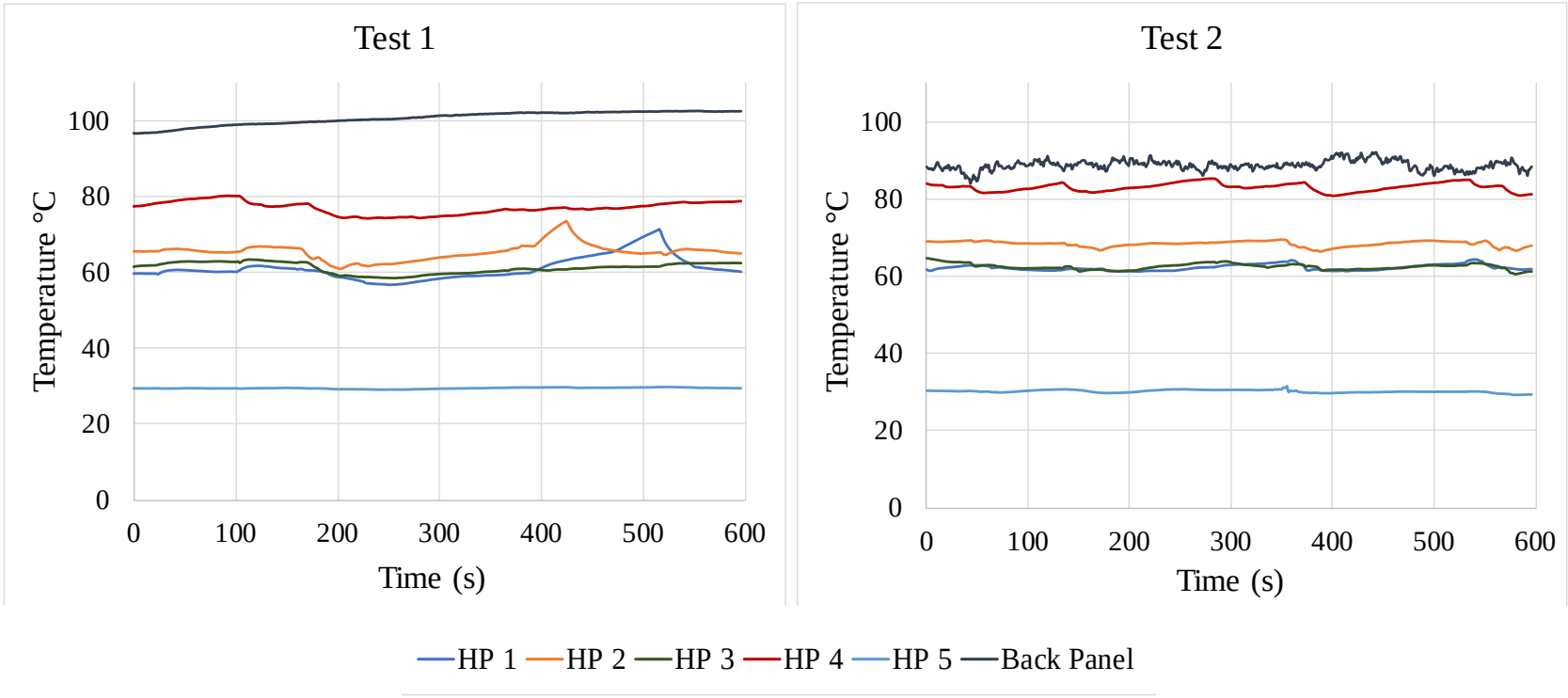
Lab Testing

Experimental Conditions

Test #	**1**	**2**
Heater temperature	500 °C	580 °C
Heater power	25 kW	29 kW
FHP inclination angle from the vertical	12.5°	
Water flow rate	25 L/min = 0.42 kg/s	
Water inlet temperature	10.6 °C	

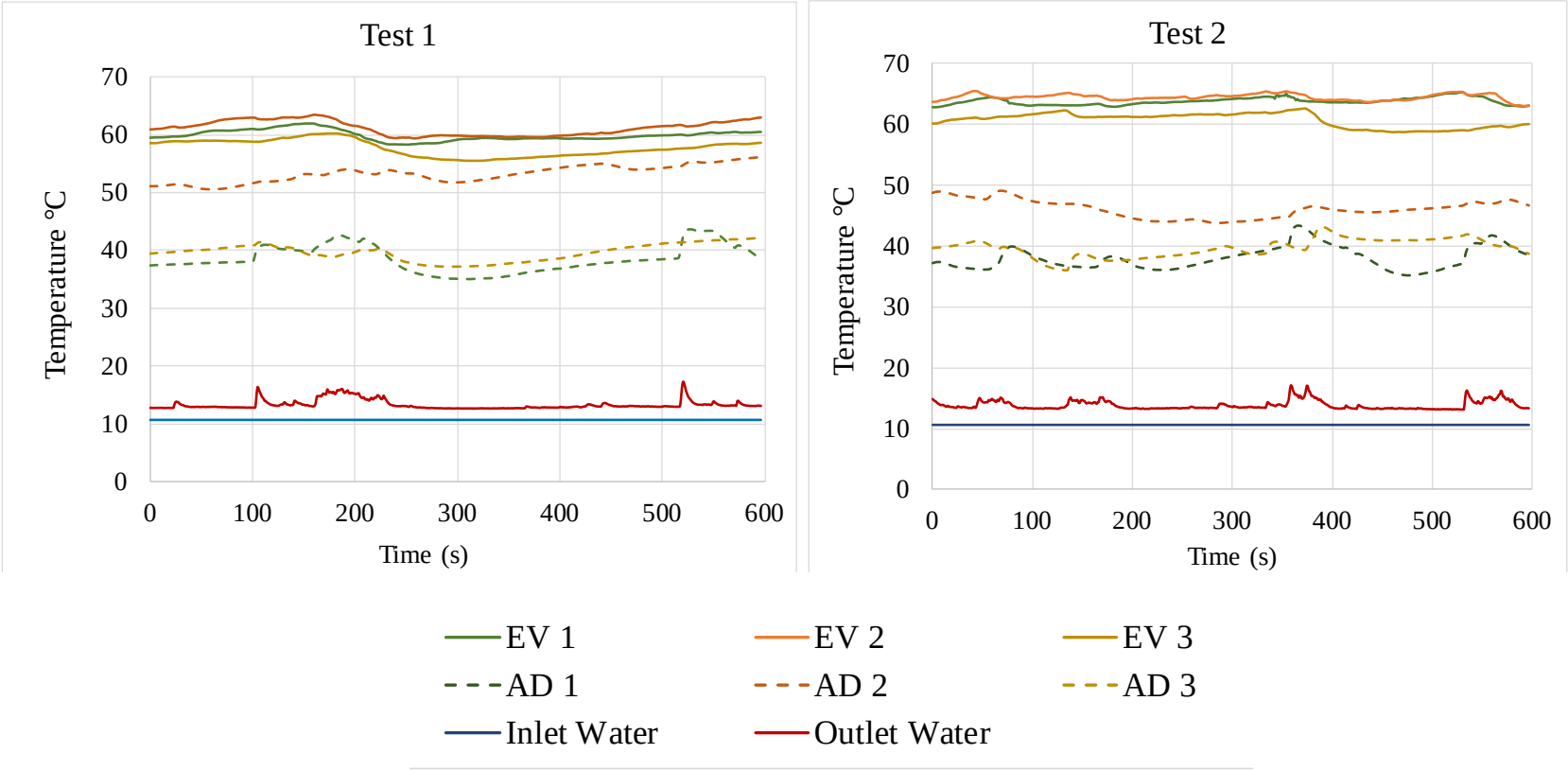
Results

Electrical heaters Power: Test 1: 25 kW, Test 2: 29 kW
Heater temperature: Test 1 :500 °C, Test 2: 580 °C
Water Flow rate 25 L/min = 0.42 kg/s



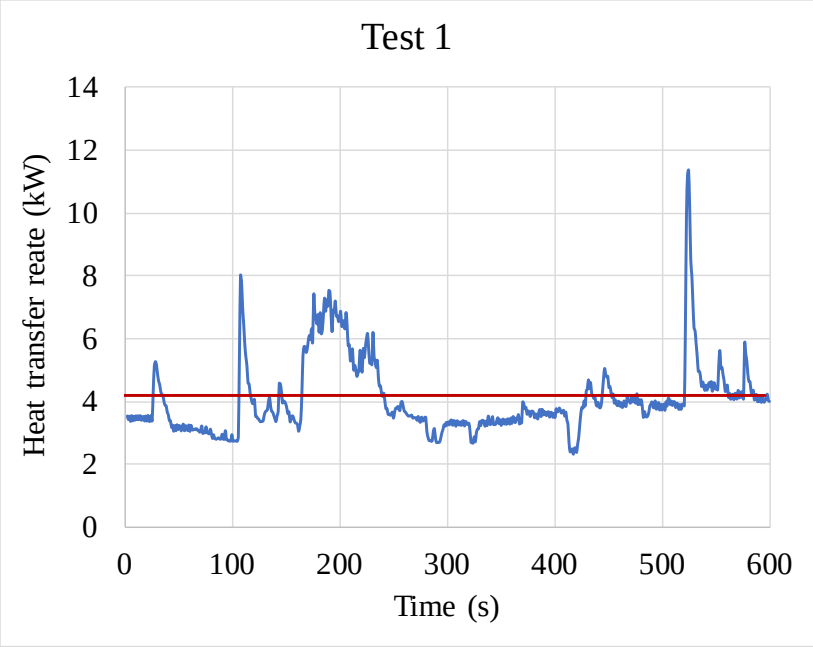
Results

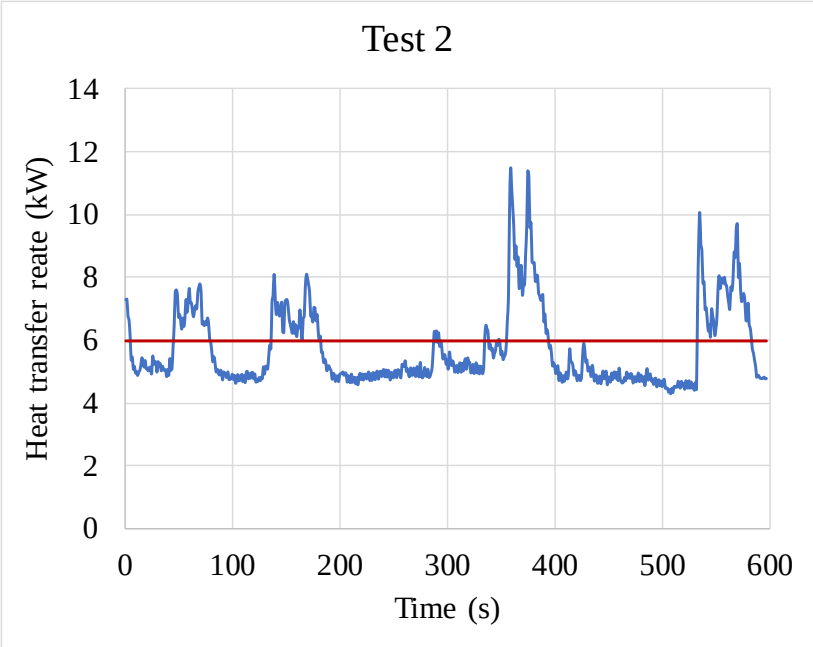
Electrical heaters Power: Test 1: 25 kW, Test 2: 29 kW
Heater temperature: Test 1 :500 °C, Test 2: 580 °C
Water Flow rate 25 L/min = 0.42 kg/s
Max outlet temperature: 17.3 °C & 17.1 °C



Results

Electrical heaters Power: Test 1: 25 kW, Test 2: 29 kW
Heater temperature: Test 1 :500 °C, Test 2: 580 °C
Water Flow rate 25 L/min = 0.42 kg/s
Max heat transfer Experimental: 11.4 & 11.5 kW





Experimental Theoretical

Acknowledgements

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Thank you

Additional Slides

Testing In Factory

Steel temperature 450 °C, Air flow velocity 6.7-12 m/s, Air temperature 136 °C

Testing In Factory

Results

Hot wire temperature 500 °C to 600 °C, Water flow rate 25 L/min
High and low density of steel wires, Distance from the barrier 65 cm and 5 cm